THE APPLICATION OF THE ENVIRONMENTAL PRODUCT DECLARATION TO WASTE DISPOSAL IN A SANITARY LANDFILL: (TWO CASE STUDIES ON BANGKOK METROPOLITAN ADMINISTRATION IN KAMPANGSAN LANDFILL SITES)

ANURAT SASOMSUB

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ABSTRACT

Municipal solid waste (MSW) management has become a major issue facing developing cities. Bangkok is one of those cities that generates a large amount of MSW per day. After the collection service for all households is completed, the majority of MSW is typically sent to landfills at fully utilized sanitary landfills. The purpose of the present study was to evaluate the potential environmental impact associated with urban waste dumping in a sanitary landfill by using the environmental product declaration (EPD) tool. The study was based on the material from the covered area of Bangkok Municipality. The MSW resource for the investigation originated from Tarang transfer station, located in the northern part of Bangkok; and Nongkam transfer station, located in the southwestern part of Bangkok. Nevertheless, the MSW resource would be hauled over to the site area, which is located in Kampangsan district, Nakornpathom province. Through the application of EPD, this work signifies the importance of the four major phases, which include transportation phase, landfill phase, leachate phase and biogas phase. The results showed that the amount of diesel oil used was the key factor in identifying the emissions produced from the transferring phase. The compositions of the waste influenced the environmental burdens of the landfill and leachate phases. Biogas management was shown to be the best practicable option that benefits the environment.

KEY WORDS: ENVIRONMENTAL PRODUCT DECLARATION/MUNICIPAL SOLID WASTE/KAMPANGSAN LANDFILL SITE/SANITARY LANDFILL

77 pages.

การจัดทำเอกสารฉลากสิ่งแวดล้อมของการกำจัดขยะมูลฝอยอย่างถูกหลักสุขาภิบาล: กรณีศึกษาการจัดการขยะชุมชนกรุงเทพมหานคร; บริเวณฝังกลบขยะกำแพงแสน

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บทคัดย่อ

การพัฒนาอย่างต่อเนื่องของเมืองก่อให้เกิดปัญหาที่สำคัญนั้นก็คือ การจัดการขยะชุมชน (MSW) กรุงเทพมหานครเป็นอีกเมืองหนึ่งที่มีปริมาณขยะชุมชนในแต่ละวันเป็นจำนวนมาก การจัดการขยะชุมชน (MSW) โดยการฝังกลบขยะมูลฝอยเป็นวิธีการที่ถูกหลักสุขาภิบาล ภายหลังจากที่มีการเก็บรวบรวมขยะมาไว้ที่พักขยะเรียบร้อยแล้ว

วัตถุประสงค์ของงานวิจัยเพื่อประเมินผลกระทบต่อสิ่งแวดล้อมที่เกิดจากการจัดการขยะมูลฝอยชุมชน ด้วยวิธีการฝังกลบอย่างถูกหลักสุขาภิบาล โดยการจัดทำเอกสารฉลากสิ่งแวดล้อม (EPD) ที่ได้มาจากการศึกษาวัสดุพื้นฐานของขยะที่ได้มาจากชุมชนเมืองกรุงเทพมหานคร ทำการวิเคราะห์ขยะมูลฝอย โดยเริ่มที่สถานีขยะมูลฝอยท่าแร้ง ซึ่งตั้งอยู่ทางทิศเหนือของกรุงเทพมหานคร และสถานีขยะมูลฝอยหนองแขม ซึ่งตั้งอยู่ทางทิศตะวันตกเฉียงใต้ของกรุงเทพมหานคร อย่างไรก็ตาม วัตถุดิบของขยะมูลฝอยจากทั้งสองสถานีจะถูกขนส่งด้วยรถบรรทุก เพื่อนำไปฝังกลบที่อำเภอกำแพงแสน จังหวัดนครปฐม

การจัดทำเอกสารฉลากสิ่งแวดล้อม (EPD) ของขยะมูลฝอยชุมชนมีส่วนสำคัญ 4 ขั้นตอน คือ การขนส่ง การฝังกลบ การชะล้างขยะ และการเกิดแก๊สชีวภาพ ผลการศึกษาพบว่าปริมาณการใช้น้ำมันดีเซลในการขนส่ง การฝังกลบ และการชะล้างขยะมูลฝอย เป็นขั้นตอนที่ส่งผลกระทบต่อสิ่งแวดล้อม ส่วนแก๊สชีวภาพที่เกิดจากการฝังกลบขยะเป็นขั้นตอนที่ไม่ส่งผลกระทบต่อสิ่งแวดล้อม

77 หน้า

CONTENTS

CONTENTS (cont.)

CONTENTS (cont.)

LIST OF TABLES

LIST OF FIGURES

LIST OF ABBREVIATIONS

MSW	Municipal solid waste
BMA	Bangkok Metropolitan Administration
DOPC	Department of Public Cleansing
EPD	Environmental Product Declaration
HDPE	High density polyethylene
PSR	Pescara transportation
PCD	Pollution Control Department of Thailand
LDPE	Low density polyethylene
PE	Polyethylene
BOD	Biochemical oxygen demand
COD	Chemical Oxygen Demand
TOC	Total organic carbon
EC	European Commission
EMS	environmental management systems
LCA	life cycle assessment
PCRs	Product Category Rules
Ems	effective microorganisms
UNEP	United Nations Environmental Programme
IPCC	Intergovernmental panel on climate change
GJ	gigajoule
CIWMB	California Integrated Waste Management Board
ASTM	American Society for Testing and Materials
UAE	United Analyst and Engineering Consultant
GWP	Global warming potential

CHAPTER I
INTRODUCTION

1.1Background and Rationale

Due to the civilization and population growth of the developed world, the amount of waste is increasing rapidly in every part of the world. Municipal solid waste (MSW) management becomes a major issue facing developing cities. Bangkok is one of those cities who generate a large amount of MSW per day. After the collection service for all households is completed, the majority of MSW is typically sent to landfills at fully utilized sanitary landfills after collection.

Even though many parts of Thailand still openly dump their MSW, in the mean time Bangkok has already minimized its open dumping to almost none. While Bangkok gathers all the waste and delivers its MSW to three different transfer stations. Due to challenging factors such as, funding, political matters or domestic technology, etc, Bangkok Metropolitan Administration (BMA) sees that the suitable method for Bangkok waste management scheme at this stage would be landfilling.

In year 2000 municipal solid waste in Bangkok city generated roughly 9,130 tons per day or 3.33 million tons per year. Bangkok Metropolitan Administration was able to manage 9,040 tons per day or 3.30 millions tons per year, which was 99% of the total waste generated. BMA processes the waste by appointed private sectors to manage the disposal of the waste [1]. The waste from Nongkam and Tarang transfer stations, which is about 5,563 tons/day, is transferred to Amphur Kampangsan, Nakhonpathom Province. The waste from On Nut transfer station is transferred to Amphur Bangplee Samuthprakarn Province at about 3,578 tons daily, but nowadays, the waste has been shifted to the dump site of the landfill site at Chachuengsao.

From the record of BMA, the amount of waste generated has been increasing consistently. Moreover, BMA has a hard time finding the disposal areas or sites. Therefore, BMA set the strategy of reducing, reusing and recycling the waste for the fifth development plan of Bangkok (1997-2001). The target was to recycle at least 20% of the total waste generated within year 2001. The Department of Public Cleansing (DOPC) of BMA set a project for encouraging people to reduce, reuse and recycle. Fifty Bangkok local authorities followed such a project by starting to exercise school, villages, town houses, shopping malls, temples, government offices, etc, to reduce, reuse and recycle their waste. The record was kept since November 1998 where 11,630 tons of waste was able to be reused. Within two years, the number increased to 22,227 tons per year [2]. Even though the strategy of reduce, reuse and recycle is affective in a certain extent, an enormous amount of waste generated still requires a proper management disposal.

Though MSW is not as contagious as hazardous waste, without a proper way of treating the waste, there would be tremendous effects upon the environment. Landfilling has its own impacts onto the environment; depending on the characteristic of the waste and the process of the disposal. Thus, it is important for BMA to acknowledge the impact on the environment and set and meet the standard for landfilling. Bangkok is a big city with numerous amounts of people, therefore, its environment deserves a proper treatment and caring attitude in the way we use resources and deal with unavoidable wastes.

In order to acknowledge the impact on the environment and meet the standard for landfilling, the framework of the Environmental Product Declaration (EPD) needs to be applied. Environmental Product Declaration (EPD) is defined as quantified environmental data for a product, with pre-determined parameters, based on the ISO 14040 series of standards, which mat be supplemented by other qualitative and quantitative information [3]. With respect to this study, the environmental burdens or impacts of the Bangkok Municipal Solid Waste Sanitary Landfill would be reflected and compared through the EPD of 4 different phases, Transfer, landfill, Leachate and Biogas phase.

1.2 Significant of the Study

As the matter of fact, Thailand, including Bangkok, has never derive the base-line information of the potential environmental burdens in the related field of waste management. Precisely speaking, Thailand has never been introduced to the evaluation of the standard of sanitary landfill under the framework of the EPD system. Through the application of the EPD, this piece of work would signifies the importance of the four major phases, which includes Transport phase, Landfill phase, Leachate phase and Biogas phase, under Bangkok Municipal Solid Waste Sanitary Landfills under the identical technology, during a five years campaign from 2000 to 2004. For further development, the collective data would enhance the standard of the waste management sector to presume the finest practice for the waste management scheme all over the country.

1.3 Research question

The questions toward this study are set to be as follow:

1.3.1 Before landfilling process as a raw resource, what are the compositions or characteristic of the MSW generated by Bangkok population.

1.3.2 Within each phases of MSW sanitary landfill, how the Environmental Product Declaration (EPD) could be described and evaluated.

1.3.3 After the application and evaluation of the EPD, what are the results of the pollutants emission or environmental burdens from each phases of sanitary landfill management.

1.4 Objective of the Study

1.4.1 To characterize the MSW compositions generated from Bangkok municipality, which is transferred to the sanitary landfill in Nakhonpathom province.

1.4.2 To determine and study the burdens and impacts regarding the process of sanitary landfill through the EPD system.

1.5 Scope of Study

This piece of study is solely based on the material from the covered area of Bangkok Municipality. The resource of the investigation is originated from Tarang

Transfer Station; locate at the Northern part of Bangkok and Nongkam Transfer Station; locate at South-Western part of Bangkok city. Nevertheless, the resource or the MSW would be hauling over to the site area, which is located in Kampangsan district, Nakhonpathom province. The investigation of this study is set to the scope of the received and transferred waste from the 2 different Transfer Stations, Nongkam and Tarang Transfer Stations, until the material or MSW is being disposed by the 2 different sanitary landfilling at Kampangsan landfill site. Within the phase of transferring, the amount of diesel used would be the key factor to identify the emission produced from this work process. In addition, the disposing and landfilling phase is also a crucial factor. Before landfilling the waste, the composition of the waste must be initiated; hence, the number can be converted back to the environmental burdens. Moreover, the scope of this study would extend further to the phases of leachate and Biogas, which derived from the landfills. The study on leachate and biogas would cover the pollutants or emissions produced from each phases before they are being treated, in this case, we would find the actual and exact environmental burdens that are generated by the raw resources and not yet being treated.

1.6Conceptual framework

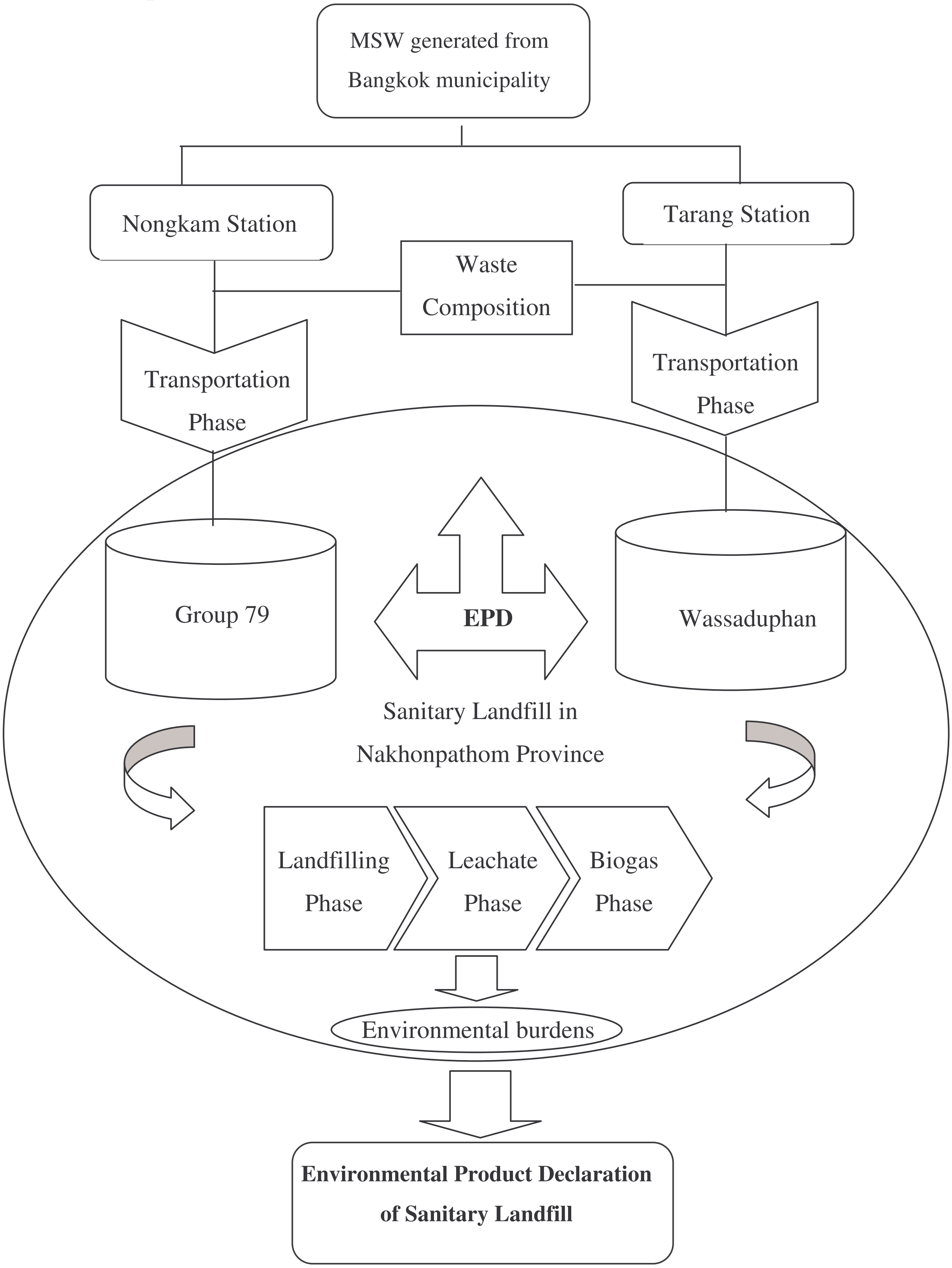

Figure 1.1 Conceptual framework

1.7 Expected Outcomes

1.7.1 The environmental burdens generated from sanitary landfill in Nakornprathom province will be declared, which could be served as a framework for sanitary landfill declaration in Thailand

1.7.2 The results could be used for the assessment of BMA and other public or private sectors on MSW management under the ecological consideration.

CHAPTER II
LITERATURE REVIEW

2.1 Concept of Sanitary Landfill

Sanitary landfill is landfill that has physical barriers such as liners and leachate collection systems, and procedures to protect the public from exposure to the disposed wastes. The term sanitary landfill normally refers to those where municipal solid waste is disposed of, as well as other wastes high in organic material [4].

The process of Sanitary Landfill is the waste management system whereby the waste is placed over the prepared area which has been carefully selected under the consideration of engineering, economical, environmental and the surrounding social acceptances, etc. Additionally, the design and structure must be cautiously proposed whereby the surrounding environment shall not be affected in anyway, for instance, soil quality, air emission, underground water contamination or contamination to population surrounding the area. According to theoretical works, the process of Sanitary Landfill must be practiced in a certain routine and instruction, nevertheless, it is important for BMA to exercise its sub-contractors to follow and perform the best management both practically and theoretically.

2.2 Practical Frame Work of the Companies Sanitary Landfilling Process

With the concern toward environmental suitability of the surrounding condition of the landfills area, G79 and Wasaduphan Co., Ltd. have implemented their frame work regarding theoretical. Before we can start landfill a lot of effort is needed in the preparation phases. The process starts from the daily transportation of the waste from Bangkok Municipality. Next important item is choosing suitable land. Then we need to excavate down to certain levels and compaction for both the landfill and leachate treatment ponds. Then, leachate collection system must be carried out.

Further, HDPE liner must be put down and joined with special machine before checking for leakage on both landfill and leachate treatment ponds. After that we have to put Geo-net and Geo-textile to prevent any sharp object from piercing down the liners at this stage only for the landfill. Also, the HDPE collection pipe for landfill gas is lay out and covered with rock and sand [5]. Finally, before the landfill process can start the site needs to be approved by BMA. Moreover, the site must be inspected by BMA every month making sure the site is running well and according to the project timeline.

2.2.1 Transferring Phase

Both of the case studies required the same procedure of transferring, though, the only different between the 2 is the distance from the transfer station to the landfill site. According to both cases, the semi-trailer, which can haul 34 tons of waste in each trip, is being used as the transportation [5]. Regarding the operators, duties, the significance of the transferring MSW is to manage the waste within the transfer station well enough that the entire waste must be removed and transfer to the site as soon as it comes. Hence, the operators must be well prepare and make sure that the amount of the semi-trailer trucks is enough to manage the daily incoming waste. At the same time with the quantity, the semi-trailer must be well taken care of, in order to maintain the well quality and not releasing any waste, odor, leachate and/or other emissions to the environment.

The collection of waste represents a key factor of waste treatment. There are big variations depending on the type of waste, especially with sorted special waste streams. Key parameters for collection are truck fuel consumption per kilometer, loading capacity distance to waste treatment location and population density. Therefore, the modellisation of waste collection and transfer is influenced by road configuration, by the presence of the integrated waste management system and by data availability. The latter point includes routes of trucks, oil consumption and % used of the maximum capacity of a truck. There data are very difficult to collect, especially when waste collection and transport is performed by different companies from the one managing the landfill. Therefore, a comparison of results should not be representative, due to the diversity of data collection methods. This matter can be solved excluding the transport phase from this PSR. Otherwise, a corrective factor can be defined, obtained and averaged from the distances from municipalities to landfills.

2.2.1.1 The need for transfer operations

Transfer and transport operations become a necessity when hauling distances to the available processing centers or disposal sites increase so that direct hauling is no longer economically feasible. They also become a necessity when processing centers or disposal sites are sites in remote location and cannot be reached directly by highway. Transfer operations are an integral part of all types of MRFs. Transfer stations are also an integral part of large integrated MR/TFs. For reasons of public safety, the use of a small transfer station, for individuals hauling wastes in automobiles and pickups and other noncommercial haulers, at landfills is gaining in popularity.

2.2.1.2 Types of transfer stations.

Transfer stations are used to accomplish transfer of solid wastes from collection and other small vehicles to larger transport equipment. Depending on the method used to load the transport vehicles, transfer stations may be classified into three general types: direct-load, storage-load and combined direct/discharge-load. Transfer station may be classified with respect to throughput capacity as follows: small, less than 100 ton/d; medium, between 100 and 500 ton/d; and large, more than 500 ton/d

At direct-load transfer stations, the wastes in the collection vehicles are emptied directly into the vehicle to be used to transport than to a place of final disposition or into facilities to compact the wastes into transport vehicles or into waste bales that are transported to the disposal site. In some cases, the waste may by emptied onto an unloading platform and then pushed into the transfer vehicles, after recyclable materials have been removed. The volume of waste that can be stored temporarily on the unloading platform is often defined as the surge capacity or the emergency storage capacity of the station.

In the storage-load transfer station, waste is emptied directly into a storage pit from which they are loaded into transport vehicles by various types of auxiliary equipment. The difference between a direct-load and storage-load transfer station is that the latter is designed with a capacity to store waste.

In some transfer station, both direct-load and discharge-load methods are used. Usually these are multipurpose facilities that service a broader range of users than a single-purpose facility. A multipurpose transfer station can also house a materials recovery operation. The layout of multipurpose transfer station, designed for use by the general public and by various waste collection agencies [26].

2.2.2 Disposing/Landfilling Phase

2.2.2.1 Landfill Sitting Consideration

The site consideration for a sanitary landfill is one difficult task for operating a landfill. There are a range of main aspects in evaluating potential sites for long-term disposal of municipal solid waste; (1) haul distance, (2) location restriction, (3) available land area, (4) site access, (5) soil conditions and topography, (6) climatologically condition, (7) surface water hydrology, (8) geologic and hydrogeology conditions, (9) local environmental conditions, and (10) potential ultimate uses for the completed site [6].

According to the Pollution Control Department of Thailand (PCD), the site consideration is suggested to match the condition of the country [2], whereby

1. The area must not be in the level 1 and level 2 river-basin areas following the council of ministers' resolution according to the regulation of River Basin quality on 28th May, 1985.

2. Set aside from boundary line of the archaeological sites according to the act of registration on archaeological sites, archaeological finds, artifact objects, and national museum or locality at least 1 kilometer.

3. Shall be set aside from the community at least 1 kilometer.

4. Shall be set aside from airport at least 1 kilometer.

5. Shall be set aside from the water supplies or sources or factories at least 700 meters.

6. Shall be set aside from the natural or man-made water sources, including wetland at least 300 meters; except the water sources within the site.

7. The land area shall remain a strong geology characteristic, in order to support the weight and the waste.

8. Shall be set in the upland area, to prevent the affect from the rush down of flooding or flash flooding.

9. Shall be set in the low-level underground water area to prevent the leachate to the natural underground water.

10. After consider a few site areas, there shall be a public hearing for the acceptance of the community.

2.2.2.2 Types of Landfill [6]

There are 3 main different types of landfill;

1. Normal Landfill is to dispose the waste by dumping the waste on the prepared ground and use soil or other material, such as LDPE for the covering.

2. Sanitary Landfill is to dispose the waste within the prepared pit with lining, leachate collection and treatment system and use soil or other material, such as LDPE for the covering.

3. Secure Landfill is to dispose mostly hazardous waste within a prepared pit with double lining, leachate collection and treatment system and use soil or other material, such as LDPE for the covering.

2.2.2.3 Landfilling Methodology [6]

1. Area Method is the method without preparing the hollow or pit area. The procedure starts by compacting the waste in horizontal plane and continue to rise upward until reaching the calculated height. On the side of the compacted waste, it needs to install the embankment or berm to act as a barricade of the landfill and to protect the leachate from the fermentation of the compacted waste to escape from the side. The suitable topography for this method is the low basin land which has the level of underground water at around 1 meter.

2. Trench Method is the method that starts from the lower level of land by excavating the land to the engineered level. The level is set by the level of the underground water (during raining season) where it should be at least 1 meter below the excavating level. The excavated soil can be reused again for the covering process.

3. Canyon Method is the method which uses the natural canyon or natural hollow area. The waste is dumped into the open area and covered similarly to the other methods. This method is mostly practiced in certain topographic countries.

2.2.2.4 The machinery used in the landfill [5]

It is also very important to provide a suitable fleet of machineries to perform appropriately with the landfill processes, for instance:

- *Caterpillar tractor*: to push and move the massive amount of waste.
- *Spine-wheel compactor*: to compact the waste in the landfill.
- *Excavating tractor*: to excavate the land and to ladle both soil and waste.
- *Truck*: to transfer both soil and waste.

2.2.2.5 Step by step to sanitary landfill method according to the sub-contractor under contract of Bangkok Municipality Administration. [5]

1. *Find suitable land* - Need to carry out extensive survey such soil boring test, hydrogeology, installing the observation wells.

2. *Excavation and compaction* – Constructing the standard landfill first excavate down to the level and then paving the clay liner at lowest layer. Also the compaction level must be higher than 85% AASHTO standard.

3. Put *HDPE in place*- High density version of PE plastic is installed to prevent contamination to surface or groundwater resources. Liner connections must also be checked to make sure they are 100% leak proof.

4. *Geo-net and Geo-textile* - Geo-net is being place only along the side of the landfill; it is used to increase adhesion. Geo-textile is used to prevent any sharp object from piercing the HDPE. Then leachate sump must also be installed at this staged.

5. *Leachate pipe and Leachate sump*: On top of the three layers, soil and leachate collection pipes and the sumps are installed to collect the waste water and send to the treatment system.

6.*Leachate Treatment ponds*- Leachate will slowly drain through the landfill and into the collection pipe which then will be treated using different methods before entering storage pond.

7. Landfill can finally start, each 2.70 meters layer of waste must be covered with 0.30 meter layer of soil.

2.2.3 Leachate Phase [7]

The process of wastewater treatment can be divided into 3 categories:

1. *Physical treatment*: This process treats physical waste mixture within wastewater, such as big pieces of waste, sand, rock, solid grease, oil, etc. The methods are such; screening, comminuting, grit removal, oil and grease removal, sedimentation, flotation, and filtration

2. *Chemical treatment*: This process treats the chemical matter within the wastewater, such as level of pH, heavy metals, organic substances, etc. The procedures for this treatment are such; coagulation, precipitation, neutralization, ion exchange, oxidation reduction and disinfection, etc.

3. *Biological treatment:* This process treats the biological contamination within the wastewater. It is divided into 2 methods, one on requiring oxygen and one not requiring oxygen, aerobic process and anaerobic process. Aerobic process is basically based on the work of microorganism that uses oxygen to change the organic substances to CO_2 and H_2O. On the other hand, anaerobic process is based on the microorganism that does not need oxygen to transform the organic substances to CO_2, CH_4 and H_2S.

The sub-contractor companies acknowledge that BMA waste contains high moisture and high organic content. In addition, Thailand is an area where there is considerable rainfall. The environmental engineering team has used their experience to designing the most suitable leachate treatment system that has proven to be very effective. It significantly reduces the key factors such as BOD, COD and metal substance.

Each of the companies has 14 HDPE lined linear treatment ponds which provide the company with various jobs of treatments. The leachate will enter first the anaerobic then aerobic treatment. After that the leachate will enter maturation pond then wetland and lastly to the storage pond (for reused inside the site for watering the plants). All the leachate treatment process is being monitored and controlled very closely by the environmental engineering team who takes daily reading of parameters.

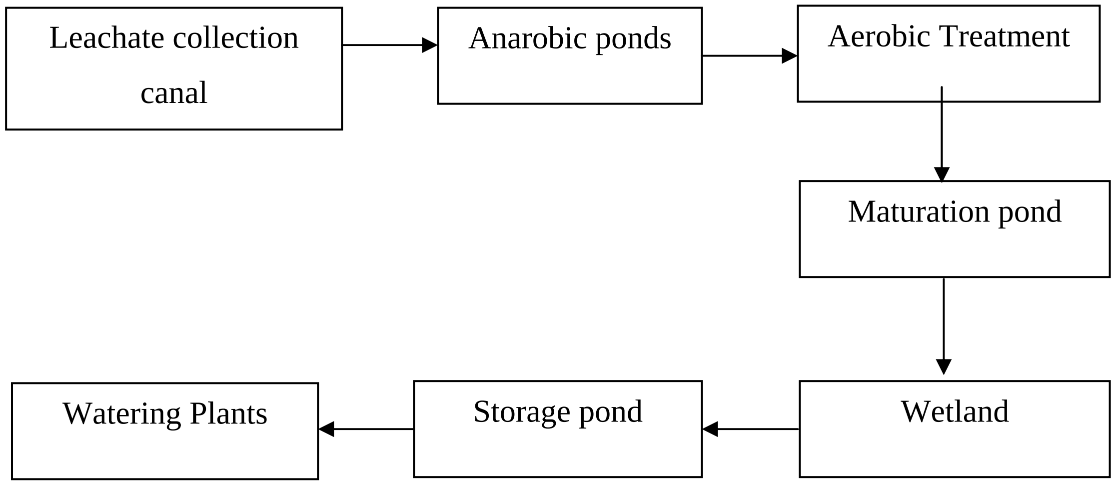

Figure 2.1 Leachate Treatment Diagram [5]

Leachate represents the water which passes through the waste from precipitation, and water generated from the waste within the landfill site, resulting in a liquid containing suspended solids, soluble components of the waste and products from the degradation of the waste by various micro-organisms. The composition of the leachate will depend on the heterogeneity and composition of the waste and, for biodegradable waste, the stage of biodegradation reached by the waste, the moisture content and the operational procedures. The characteristics of the leachate are influenced by the waste material deposited in the site. For example, inert waste will produce a leachate with low concentrations of components, whereas a hazardous waste leachate tends to have a wide range of components with highly variable concentrations. The decomposition rate of the waste also depends on aspects such as pH, temperature, aerobic or anaerobic conditions and the associated types of micro-organism. Associated with leachate is a malodorous smell, due mainly to the presence of organic acids.

The production of leachate from the decomposition of municipal solid waste in non-hazardous waste landfill sites, changes with time as the waste degrades through the various five stages of biodegradation. Table 2.1 compares the typical leachate of the acetogenic Stage III with the methanogenic Stage IV. The table shows that the pH of the early formed leachate is acidic/neutral with a pH range between 5.12

and 7.8, equating with the formation of acetic acid and other organic acids by the acetogenic micro-organisms under anaerobic conditions. The organic material of Stage III is very high, in the range 1010 – 29000 mg/l for the TOC. Ammoniacal nitrogen levels tend to be higher in Stage III, due to the biodegradation of the amino acids of proteins and other nitrogenous compounds in the waste. The presence of organic acids of the acetogenic stage increases the solubility of metal ions into the leachate. BOD and COD levels are high, with high ratios of BOD:COD, indicating that a high proportion of the organic materials in solution are readily biodegradable. Methanogenic leachate has a neutral/alkaline pH reflecting the degradation of the organic acids of Stage III to methane and carbon dioxide by the methanogenic micro-organisms. As a consequence, the TOC in the leachate decrease compared with the acetogenic stage. Metal ions continue to be leachate from the waste but as the pH of the leachate increase, the metal ions become less soluble and decrease in concentration in the leachate. The concentration of ammoniacal nitrogen decreases slightly, but remains high in the leachate. BOD and COD levels decrease compared with acetogenic leachates [8].

Table 2.1 Composition of acetogenic and methanogenic leachate from large landfill sites with waste input rate and relatively dry environments (mg/l) [8]

Parameter	Acetogenic		Methanogenic	
	Range	Mean	Range	Mean
pH value	5.12 – 7.8	6.73	6.8 – 8.2	7.52
COD	2,740 – 152,000	36,817	622 – 8,000	2,307
BOD_{5day}	2,000 – 68,000	18,632	97 – 1,770	374
Ammoniacal-N	194 – 3,610	922	283 – 2,040	889
Chloride	659 – 4,670	1,805	570 – 4,710	2,074
BOD_{20day}	2,000 – 125,000	25,108	110 – 1,900	544
TOC	1,010 – 29,000	12,217	184 – 2,270	733
Fatty acids (as C)	963 – 22,414	8,197	<5 - 146	18
Alkalinity (as $CaCO_3$)	2,720 – 15,870	7,251	3,000 – 9,130	5,376
Conductivity (μS/cm)	5,800 – 52,000	16,921	5,990 – 19,300	11,502
Nitrate-N	<0.2 - 18	1.80	0.2 – 2.1	0.86
Nitrite-N	0.01 – 1.4	0.20	<0.01 – 1.3	0.17
Sulphate (as SO_4)	<5 – 1,560	676	<5 - 322	67
Phosphate (as P)	0.6 – 22.6	5.0	0.3 – 18.4	4.3
Sodium	474 – 2,400	1,371	474 – 3,650	1,480
Magnesium	25 - 820	384	40 – 1,580	250
Potassium	350 – 3,100	1,143	100 – 1,580	854
Calcium	270 – 6,240	2,241	23 - 501	151
Chromium	0.03 – 0.3	0.13	<0.03 – 0.56	0.09
Manganese	1.40 - 164	32.94	0.04 – 3.59	0.46
Iron	48.3 – 2,300	653.8	1.6 - 160	27.4
Nickel	<0.03 – 1.87	0.42	<0.03 – 0.6	0.17
Cadmium	<0.01 – 0.10	0.02	<0.01 – 0.08	0.015
Lead	<0.04 – 0.65	0.28	<0.04 – 1.9	0.20
Arsenic	<0.001 – 0.148	0.024	<0.001 – 0.485	0.034
Mercury	<0.0001 – 0.0015	0.0004	<0.0001 – 0.0008	0.0002

2.2.4 Biogas Phase [9]

Biogas or Landfill gas the product of biodegradation process of the refuse materials in the landfill. Throughout the lifespan of the MSW, the gas generation process has its own characteristic during each stage. The most common containments of the gases are primarily Methane, Carbon Dioxide, Ammonia, Nitrogen, Hydrogen Sulphide and traceable amount of Non-methane organic compounds, etc. After the MSW has been landfilled, the biological reactions slowly begin under the 2 different phases. The first phase takes place in the atmospheric air, which is near by the surface of the landfill whereby the natural organic compounds are oxidized aerobically. The second phase emerges within the landfill anaerobically and can be divided into 3 stages. The first, fermentative bacteria would hydrolyze the organic compound into soluble molecules. Within the second stage, the molecules are converted by bacteria to carbon dioxide, hydrogen and organic acids; the primary acids produced are acetic, propionic, butyric acid and also ethanol. The last stage is basically where the methane is formed by methanogenic bacteria, by breaking down of acids to carbon dioxide and methane or by the reduction of carbon dioxide with hydrogen.

These emerging gases can cause hazards such as, odor, toxicity (carcinogenic, mutagenic, etc), explosion, asphyxiation, global warming, etc. In fact, a proper collection and treatment system must be installed to prevent the following emissions and impacts to the environment.

Gases arising from the biodegradation of biodegradable waste in landfills consist of hydrogen and carbon dioxide in the early stages, followed by mainly methane and carbon dioxide in the later stages. What is known as landfill gas is a product mainly from the methanogenic stage of degradation of biodegradable waste. Landfill gas is produced from municipal solid waste, which contains a significant proportion of biodegradable material. Municipal solid waste is permitted to be deposited into non-hazardous waste landfills under the EC Waste Landfill Directive (1999). In addition, waste permitted to be deposited into hazardous waste landfill may also contain biodegradable components, which will degrade and produce landfill gas. The main gases are methane and carbon dioxide, but a wide range of other gases can potentially be formed. In addition, the gas usually saturated with moisture. Table 2.2 shows the composition of the major constituents of landfill gas.

The main chemical compounds found in landfill gas can be broadly categorized into saturated and unsaturated hydrocarbons, acidic hydrocarbons, organic alcohols, aromatic hydrocarbons, halogenated compounds, sulphur compounds and inorganic compounds. The major constituents of landfill gas, methane and carbon dioxide are odorless; and it is the minor components such as hydrogen sulphide, organic esters and the organosulphur compounds, which give landfill gas a molodorous smell. Landfill gas contains component which are flammable and when mixed with air can reach explosive concentrations in confined spaces. There have been problems associated with uncontrolled leakages of landfill gas into houses, shafts, culverts, pipework, etc., with potentially devastating effects. The lower flammable limit, where ignition of the gas mixture can occur, is 4% for hydrogen and 5% for methane. In addition, the gas can cause asphyxiation where levels accumulate in such areas as manholes and culverts. This is particularly a problem where certain mixtures of landfill gas components result in the gas having a higher or lower density than air thus causing stratification of the air and gas. An asphyxiation hazard can occur in a confined space where the oxygen level has fallen from 21 to 18%. Some of the trace components of landfill gas have a toxic effect and may be hazardous if high enough concentrations are reached, for example, hydrogen sulphide. Aromatic hydrocarbons are in low concentration but may potentially have an adverse effect on the workforce of the landfill site. A wide rang of chlorinated hydrocarbons have been identified in landfill gas. Chlorinated hydrocarbons are important because of their potential harm to the environment, but also when landfill gas is used as a fuel in landfill gas utilization schemes there is the potential to form hydrogen chloride [8].

Table 2.2 Typical landfill gas composition [8]

Component	Typical value (% by volume)	Observed maximum (% by volume)
Methane	63.8	88.0
Carbon dioxide	33.6	89.3
Oxygen	0.16	20.9
Nitrogen	2.4	87.0
Hydrogen	0.05	21.1
Carbon monoxide	0.001	0.09
Ethane	0.005	0.0139
Ethene	0.018	-
Acetaldehyde	0.005	-
Propane	0.002	0.0171
Butanes	0.003	0.023
Helium	0.00005	-
Higher alkanes	<0.05	0.07
Unsaturated hydrocarbon	0.009	0.048
Halogenated compound	0.00002	0.032
Hydrogen sulphide	0.00002	35.0
Organosulphur compounds	0.00001	0.028
Alcohols	0.00001	0.127
Others	0.00005	0.023

2.2.5 Processes Operating in Hazardous Waste Landfills [8]

Hazardous waste is derived from a large number of industrial sources. However, the main sources are from organic and inorganic industrial processes. Other important sources include inorganic wastes from thermal processes, inorganic waste from metal treatment facilities and waste treatment facilities. Since the landfilling of liquid wastes is specifically banned under the EC Waste Landfill Directive, only solid hazardous waste are allowed to be landfilled in hazardous waste landfilled, to reduce the hazardous nature of the waste in terms of impact on human health and the environment.

Once the treated hazardous waste is placed in the landfill, it will be subjected to a range of biological, physical and chemical processes, which will degrade the components of the waste. These processes include biodegradation, filtration, redox reactions, complexation, ion exchange, absorption, precipitation, neutralization, etc. The migration of leachate through the hazardous waste mass in the landfill will disperse and dilute the pollutants. In addition, leachate may be absorbed into or absorbed onto the components of the waste. Chemical reactions of the leachate derived from the hazardous waste will be attenuated or reduced by interaction between the leachate and other components of the surrounding waste and other material, including daily and intermediate cover material to chemically alter or fix the leachate. Such reactions include interaction of cautions and anions via ion-exchange, removal of leachate pollutants by precipitation reaction, or the formation of large ion complexes, which effectively remove pollutants from the environment by fixation in a large complex molecule, and oxidation-reduction reactions. Some of the waste may be biodegradable and undergo the decomposition reactions as well.

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2.2.6 Processes Operating in Non-hazardous Waste Landfills

Municipal solid waste is the most significant category of waste that permitted to be deposited in a non-hazardous waste landfill. Municipal solid waste contains a high proportion of organic material which can be degraded by the range of micro-organisms found in waste landfills including food and garden waste, paper and board, wood and some textiles.

The processes of degradation of oganic bioreactive waste in landfills involve not only biological processes but also inter-related physical and chemical processes. The processes operate on any organic waste, consequently, such biodegradation processes may also occur, not only in non-hazardous waste sites accepting municipal solid waste, but also in hazardous waste landfills where biodegradable hazardous wastes are accepted. The stages involved in the degradation of bioreactive solid wastes may take many decades to complete.

Table 2.3 Leachate composition from hazardous waste only landfill sites [8]

Constituent	Hazardous waste-only leachate (mean concentration μg/l)
Methyl ethyl ketone	19,800
Methyl isobutylketone	19,700
Acetone	17,400
Phthalic acid	19,300
Phenol	21,700
Arsenic	17,000
Nickel	2,160
Zinc	950

2.2.7 Decomposition Processes of Bioreactive Waste in Landfills

The organic components of the waste are degraded by micro-organisms in the landfill. The organic materials occurring in waste can be classified into broad biological groups represented by proteins, carbohydrates and lipids or fats. Carbohydrates are by far the major component of biodegradable waste and include cellulose, starch and sugars. Proteins are large complex organic materials composed of hundreds or thousands of amino acids groups. Lipids or fats are materials containing fatty acids. Figure 2.2 shows the decomposition pathways of the major organic and inorganic components of biodegradable waste.

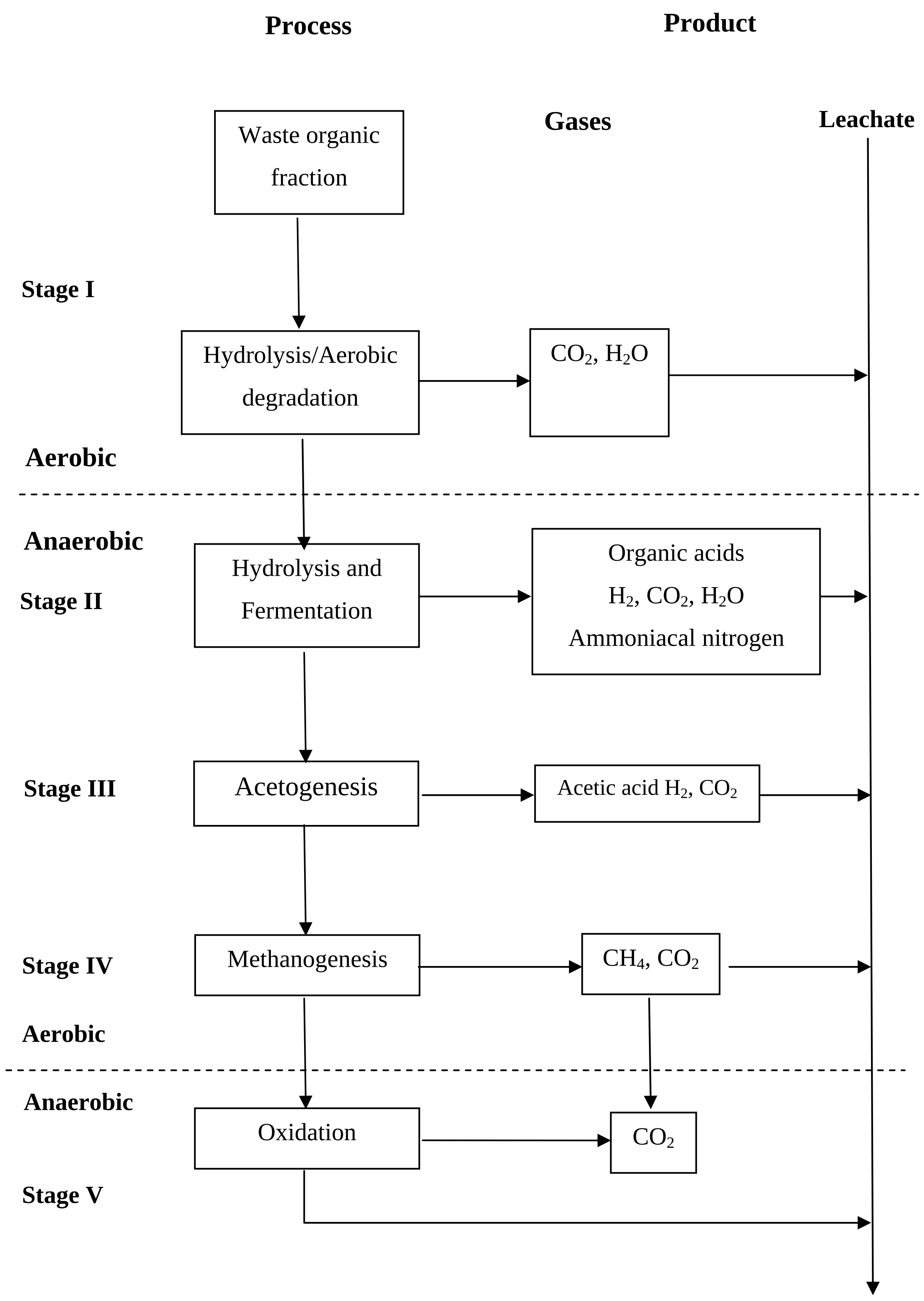

Figure 2.2 Major stages of waste degeadation in landfill

2.3 Environmental Product Declaration (EPD)

Today, product-related environmental issues are playing an important role within the strategic planned out for business sectors. Such developments required business sectors, companies or organizations to recruit all vital information about environmental aspects of products and services, which in return would provide such sectors to be able to place the information in the context and make their own decision. Under the sense of sustainable development, the goal of EPD is to provide relevant, verified and comparable information to meet the various needs within an organization including within environmental management systems (EMS), for Eco-design, and in green procurement, etc.

An environmental product declaration (EPD) is defined as quantified environmental data for a product with pre-set categories of parameters based on the ISO 1404 series of standards, but not excluding additional environmental information. [3]

2.3.1 Key Characteristics of EPDs [3]

The key characteristics of EPDs in the international EPD system can be described as being:

Objective - The international EPD system is based on a requirement to use internationally accepted and valid methods for life cycle assessment (LCA). This requirement makes it possible to identify and focus on the most significant environmental aspects in a holistic perspective which leads towards continuous improvement.

Credible - Another requirement of the international EPD system regards the aspect of critical review, approval and follow-up by an independent verifier.

Neutral - There are no claims of environmental preferability, valuations and predetermined environmental performance levels that must be met within the international EPD system.

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Comparable - The international EPD system makes comparisons possible through the establishing of so-called Product Category Rules (PCRs) for selected product groups and services. PCRs describe the harmonized LCA-rules for data collection, methodology, calculations and presentation of the results.

Open to all products and services – The international EPD system practices the principle of non-selectivity which makes the system applicable to all products and services.

Open to all interested parties - Most aspects of the international EPD system are handled and marketed mainly through easy-accessible information on the Internet.

Environmental impact-oriented - The international EPD system provides the possibility to include assessments of potential environmental impacts.

Instructive - The international EPD system has the ambition to help to interpret the information given in EPDs by making it possible to provide explanations of terms, definitions and concepts, as well as general information on relevant environment issues.

2.3.2 Guiding principles of the EPD system [3]

The guiding principles of the international EPD system following the international EPD standard ISO 14025 are:

Voluntaries - to be non-mandatory in nature.

Transparency - through all stages of development and operation of the program.

Accessibility to all interested parties - open to all potential applicants fulfilling program requirements.

Open stakeholder dialogue and consultation about PCR - to carry out a formal and open stakeholder consultation process to receive input and comments on suggested PCR documents from all interested parties.

Product functionality - to ensure that the product functionality, i.e. the intended use of the product and related levels of performance, is taken into account.

Scientifically-based - building on a methodology to develop EPDs based on scientific accepted approaches for LCA which reflects and communicates the significant environmental aspects relevant to the product.

Confidentiality - to guarantee full confidentiality of specific information which has been identified as such by an organizations.

Cost-effectiveness - to be based on open, well-established, market-oriented and internationally recognized systems for verification and registration.

2.3.3 Advantages when creating and using EPDs [3]

The international EPD system is applicable for all types of products and services within clearly defined product categories. EPDs are designed to meet various information needs within the supply-chain and for end-products both in the private and public sector, as well as for more general purposes in information activities and marketing. The main advantages of EPDs are:

For those creating EPDs and providing information on the market

EPDs provide opportunities for giving quantitative and verified information about the environmental performance of products, viewed from a comprehensive life cycle perspective. The following advantages can specifically be outlined:

Objective - through the use of scientifically accepted and valid methods based on international standards for life cycle assessment (LCA).

Non-selective and neutral - because no claims of valuations or predetermined environmental performance levels must be met.

Flexible - through enabling any change or improvement of the EPD as required by the company/organization after due external review and verification.

For those using EPD information for various purposes

Since EPDs contain factual-based and verified information about the environmental performance of products and services they can be used as source information for various purposes. The following advantages can specifically be outlined:

Comparable - because the information in EPDs are being collected and calculated based on international accepted and harmonized calculation rules.

Credible - through the requirements for routine inspections, review, approval and follow-up by an independent verifier.

Accurate - because the information has to be continuously-updated based on in-company routines for documentation and follow-up procedures.

EPDs are based on principles inherent in the ISO standard for Type III environmental declarations (ISO 14025) [10] giving them a wide-spread international acceptance. The overall goal of an EPD is to provide relevant and verified information to meet the various communication needs. An important aspect of EPD is to provide the basis of a fair comparison of products and services by its environmental performance. EPDs can reflect the continuous environmental improvement of products and services over time and are able to communicate and add up relevant environmental information along a product's supply chain. [3]

2.4 The Application of EPD to Waste Disposal in Sanitary Landfill

Certified environmental product declarations (EPDs) are beginning to be used as a tool for communicating LCA-based information. EPDs are based on ISO/TR14025 [10] and have been made operative in countries including Finland, Italy, Japan, Norway, Poland and Sweden [11].

According to the study of the development of interpretation keys for environmental product declarations [10], to date, user experience indicates that the EPD results are difficult for professional purchasers and salespeople to understand. In order to improve understanding, three interpretation keys have been developed. They recalculate the EPD results to other numbers, which are easier to value. One key calculates the degree of satisfaction of environmental goals, another calculates the damage cost and yet another compares with what is normal in economic activity. The three interpretation keys represent different ethical views of the environment. Intended users, people having some knowledge of environmental issues without being specialists, have tested the keys on several occasions after which the keys were redesigned. The study concluded that the interpretation keys offer increased understanding. With regards to the above fact, the statement of the EPD shall be exercise more in rather every field of working process, which in return would summarize the big picture into a smaller and more understandable explanation format.

Precisely speaking, Environmental Product Declaration represents a verifiable and accurate way to show the environmental aspects of products or services, view from a comprehensive life cycle perspective ‘from cradle-to-grave’. It is defined as ‘quantified environmental data for a product, with pre-determined parameters, based on the ISO 14040 [12] series of standards, which may be supplemented by other qualitative and quantitative information [13]. The information contained in the EPD, developed using Life Cycle Assessment (LCA), are exclusively informational in nature, and the declaration contains no criteria for assessment, preferability or minimum levels to be met.

The declaration of the EPD has been exercising among developed countries for the purpose of declaring the best and most suitable method for the work operation, whilst the environment is also being added into an account. As the matter of fact, the study of the application of the environmental product declaration to waste disposal in a sanitary landfill [14] for the 4 case studies landfills in Italy has carried out the useful information for the possible sustainable develop for the waste management scheme. With regard to the study [14], the aim is to evaluate, through LCA, the potential environmental impacts associated to urban waste dumping in s sanitary landfill for four case studies and to compare different technologies for waste treatment and leachate or biogas management in the framework of the EPD system. Specific data were collected on the four Italian Landfills during a five-year campaign from 2000 to 2004, whereby those landfills are managed with different technologies as concerns waste pretreatment and leachate or biogas treatment. For each landfills, a life cycle assessment study shall be performed. This work also analyses the comparability of EPD results for different products in the same product category. The comparison of the LCA result is performed separately for the following phases: transport, landfill, leachate and biogas. With regards to this study of EPD to waste disposal in Italian sanitary landfills, the analysis of four case studies showed that, through the EPD tool, it is possible to make a comparison among different declarations for the same product category only with some modification and integration to existent PSR 2003:3 [15]. Furthermore, the study also stated that it is not possible to identify the ‘best product’ from an environmental point of view, but it is possible to identify the product (or service) with the lowest impact on the environment for each impact category and resource use.

In fact, in the waste management field, there is an increasing demand of LCA-based, so called Type III environmental declarations from policy makers and citizens. As concerns EPDs applied to waste treatment services, they should be used as a source of information by citizens, municipalities, local corporations and industrial consumers enabling one to add up and accumulate LCA-based data in the supply chain and to provide easily accessible, quality-assured and comparable information regarding environmental performance of these kind of services. [16, 17] Indeed, Life-cycle approach applied to the major companies performing waste treatment, such as the four Italian landfills case studies above and as well as the case studies of the two Thai Landfill sites under this study, shall represents an environmental management tool which able both to communicate environmental information by the Type III environmental label EPD, and to look for different scenarios that can improve the environmental performance of the 'Collection, transfer and disposal service for urban waste in sanitary landfill'.

2.5 Literature Reviews

Pondhe and Meshram [18] had studied the Characterization and composition of Municipal Solid Waste (MSW) generated in Sangamner City, District Ahmednagar, Maharashtra, India. The composition of solid waste was studied by segregating it into different components, i.e., kitchen waste, paper, earth and fine material, slaughter house waste, leaves, metals, etc. These components were categorized into organic waste and inorganic waste. It was observed that Sangamner city produces around 61% organic waste, and the rest is inorganic waste. The characteristics of organic solid waste, i.e., pH, electrical conductivity, moisture content, organic carbon, nitrogen, phosphorus and potassium were evaluated. The analysis of organic content of MSW indicates that it is good source of nutrients for the agriculture sector whereas inorganic material can be used for landfill.

Aizhong et al [19] had a further study on the Biological control of leachate from municipal landfills. Since landfilling is still a popular way for municipal solid waste (MSW) treatment, leachate generated from landfills is becoming a great threat to the surrounding as it contains high concentrations of toxic substances. How to control leachate migration and to protect environmental polution is now a concern for many environmentalists. In this work, eight effective microorganisms (EMs) were isolated from wastewater, sludge and soil samples by enrichment culturing techniques and used for lechate migration control in columns and pilot experiments. The preliminary experiments reveal that the EMs could remove 25% and 40% of chemical oxygen demand from leachate in fine sand and sabulous clay columns, respectively. An aquifer system was designed to simulate in-situ control for leachate migration with EMs. The EMs was injected into the simulated aquifer and formed a permeable biological barrier. The experimental results show that the barrier removes 95% of COD and approximately 100% inorganic nitrogen, that is, nitrate-N plus nitrite-N, from the migrating leachate. CO_2 production, redox potential and microbial number were monitored simultaneously in the aquifer during the experiment to assess the EMs activities and the effect of the bio-barrier. The data indicate that the EMs isolate in this work had high activities and were effective for organic and nitrogenous contaminant removal throughout the experiment.

Ishigaki et al [20] had come up with the Estimation and field measurement of methane emission from waste landfills in Hanoi, Vietnam. A methodology for estimating the methane emission from waste landfills in Hanoi, Vietnam, as part of a case study on Asian cities, was derived based on a survey of documents and statistics related to waste management, interviews with persons in charge, and field investigations at landfill sites. The waste management system in Hanoi was analyzed to evaluate the methane emissions from waste landfill sites. The quantity of waste deposited into the landfill was evaluated from an investigation of the waste stream. The composition of municipal solid waste was surveyed in several districts in the Hanoi city area, and the quantities of degradable organic waste that had been deposited into landfill for the part 15 years were estimated. Field surveys on methane emissions from landfill of different ages (0.5, 2, and 8 year) were conducted and their methane emissions were estimated to be 120, 22.5 and 4.38 ml/min/m^2, respectively. The first-order reaction rate of methane generation was obtained as 0.51/year. Methane emissions from waste landfills were calculated by a first-order decay model using this emission factor and the amount of landfilled degradable waste. The estimates of methane emissions using the model accorded well with the estimates of the field survey. These results revealed that methane emissions from waste landfills estimated by regional-specific and precise information on the waste stream are essential for accurately determining the behavior of methane emissions from waste landfills in the past, present, and future.

Seadon, [21] derived the Integrated waste management-Looking beyond the solid waste horizon. Waste as a management issue has been evident for over four millennia. Disposal of waste to the biosphere has given way to think about, and try to implement an integrated waste management approach. In 1996 the United Nations Environmental Programme (UNEP) defined “integrated waste management” as “a framework of reference for designing and implementing new waste management systems and for analyzing and optimizing existing system”. In this paper the concept of the integrated waste management as defined by UNEP is considered along with the parameters that constitute integrated waste management. The examples used are put into four categories (1) integration within a single medium (solid, aqueous or atmospheric wastes) by considering alternative waste management options, (2) multi-media integration (solid, aqueous, atmospheric and energy wastes) by considering waste management options that can be applied to more than one medium, (3) tools (regulatory, economic, voluntary and informational) and (4) agents (governmental bodies (local and national), businesses and the community). This evaluation allows guidelines for enhancing success: (1) as experience increase, it is possible to deal with a greater complexity; and (2) integrated waste management requires a holistic approach, which encompasses a life cycle understanding of products and services. This, in turn, requires different specialism to be involved in the instigation and analysis of an integrated waste management system. Taken together these advance the path to sustainability.

Keith et al [22] obtained the study on Life Cycle Management of Municipal Solid Waste. Life-cycle assessment concepts and methods are currently being applied to evaluate integrated municipal solid waste management strategies throughout the world. The Research Triangle Institute and the U.S. Environmental Protection Agency are working to develop a computer-based decision support tool to evaluate integrated municipal solid waste management strategies in the United States. The waste management unit processes included in this tool are waste collection, transfer stations, recovery, compost, combustion, and landfill. Additional unit processes included are electrical energy production, transportation, and remanufacturing. The process models include methodologies for environmental and cost analysis. The environmental methodology calculates life cycle inventory type data for the different unit processes. The cost methodology calculates annualized construction and equipment capital costs and operating costs per ton processed at the facility. The resulting environmental and cost parameters are allocated to individual components of the waste stream by process specific allocation methodologies. All of this information is implemented into the decision support tool to provide a life-cycle management evaluation of integrated municipal solid waste management strategies.

Nickolas et al [9] had developed the study of Methane generation in landfills. Methane gas is a by-product of landfilling municipal solid waste (MSW). Most of the global MSW is dumped in non-regulated landfills and the generated methane is emitted to the atmosphere. Some of the modern regulated landfills attempt to capture and utilize the landfill biogas as a renewable energy source, to generate electricity or heat. As of 2001, there were about one thousand landfills collecting landfill biogas worldwide. The landfills that capture biogas in the US collect about 2.6 million tones of methane annually, 70% of which is used to generate heat and/or electricity. The landfill gas situation in the US was used to estimate the potential for additional collection and utilization of landfill gas in the US and worldwide. Theoretical and experimental studies indicate that complete anaerobic biodegradation of MSW generates about 200 Nm^3 of methane per dry tonne of contained biomass. However, the reported rate of generation of methane in industrial anaerobic digestion reactors ranges from 40 to 80 Nm^3 per tonne of organic wastes. Several US landfills report capturing as much as 100 Nm^3 of methane per ton of MSW landfilled in given year. These findings led to a conservative estimate of methane generation of about 50 Nm^3 of methane per ton of MSW landfilled. Therefore, for the estimated global landfilling of 1.5 billion tones annually, the corresponding rate of methane generation at landfills is 75 billion Nm^3. Less than 10% of this potential is captured and utilized at this time.

Arvind et al [23] studied on the Greenhouse gas emissions from municipal solid waste management in Indian mega-cities: A case study of Chennai landfill sites. Municipal solid waste generation rate is over-riding the population growth rate in all mega-cities in India. Greenhouse gas emission inventory from landfills of Chennai has been generated by measuring the site specific emission factors in conjunction with the relevant activity data as well as using the IPCC methodologies for CH_4 inventory preparation. In Chennai, emission flux ranged from 1.0 to 23.5 mg CH_4 m^{-2} h^{-1}, 6 to 460lg N_2O m^{-2} $h^{-1}$and 39 to 906 mg CO_2 m^{-2} h^{-1} at Kodungaiyur and 0.9 to 433 mg CH_4 m^{-2} h^{-1}, 2.7 to 1200.lg N_2O m^{-2} h^{-1} and 12.3 to 964.4 mg CO_2 m^{-2} h^{-1} at Perungudi. CH_4 emission estimates were found to be about 0.12 Gg in Chennai from municipal solid waste management for the year 2000 which is lower than the value computed using IPCC, 1996.

Oyeshola and Shabbir [24] had derived the Estimation of construction waste generation and management in Thailand. This study examines construction waste generation and management in Thailand. It is estimated that between 2002 and 2005, an average of 1.1 million tons of construction waste was generated per year in Thailand. This constitutes about 7.7% of the total amount of waste disposed in both landfills and open dumpsites annually during the same period. Although construction waste constitutes a major source of waste in terms of volume and weight, its management and recycling are yet to be effectively practiced in Thailand. Recently, the management of construction waste is being given attention due to its rapidly increasing unregulated dumping in undesignated areas, and recycling is being promoted as a method of managing this waste. If effectively implemented, its potential economic and social benefits are immense. It was estimated that between 70 and 4,000 jobs would have been created between 2002 and 2005, if all construction wastes in Thailand had been recycled. Additionally it would have contributed an average savings of about 3.0 - 105 GJ per year in the final energy consumed by the construction sector of the nation within the same period based on the recycling scenario analyzed. The current national integrated waste management plan could enhance the effective recycling of construction and demolition waste in Thailand when enforced. It is recommended that an inventory of all construction waste generated in the country be carried out in order to assess the feasibility of large scale recycling of construction and demolition waste.

CHAPTER III
METHODOLOGY

The theoretical framework derives from the studies and understanding from the texts is set to be the standard of proper landfilling process. On the other hand, the solid waste management of BMA case study: Sub-contractors (Group 79 Co, Ltd. and Wassaduphan Co, Ltd.) landfills, Kampangsan District, Nakhonpathom Province is an On Site Research for practical framework. Beside, by adopting PSR 2003:3 [15], which defines the requirements, based on environmental parameters should also be considered within the LCA study of MSW Sanitary Landfill Management under the scope of transferring, disposing and treating leachate and biogas.

3.1 Research Implementation

In order to study the EPD of the sanitary landfill in Nakhonpathom province, it needs to plan and design a research in step by step. The location of the sanitary landfill sites and system boundary for collecting data need to be established. Surveying and gathering data then will be done at the visiting site in terms of inputs and output data; however, some data might be obtained from the monitoring report. All inventory data will be analyzed and interpreted that shows the environmental performance of each phases. The results of this research need to be discussed and recommended in the final step.

3.2 Location of the Sanitary Landfill and System Boundary

The Group 79 Co., Ltd. Landfill site is located at 39 Moo.8, Tumbol Tungbua, Kampangsan District, Nakhon Pathom Province, 73000 and Wassaduphan Co., Ltd. site is located at 49 Moo.8, Tumbol Tungbua, Kampangsan District, Nakhon

Pathom Province, 73000. The surrounding environment of the area is quiet suitable for landfilling process. The area is located in a non or less community zone, high ground above the sea-level, deep underground water table, dry and unfertile soil, etc. As a matter of fact, with regard to the distance of rough figure, 80 and 90 kilometers from Bangkok Municipality, the landfill area is considered a proper area for the operation

The system boundary of the landfilling process and this study starts from the transportation of the municipal solid waste from Nongkam District and Tarang District in Bangkok and haul to Kampangsan landfill sites. The following step is the disposal of waste into the landfill and daily covering by compacted soil; within this stage, the composition of waste must be taken in order to examine the environmental product declaration of waste disposal in a sanitary landfill. The further boundaries are the leachate and biogas that emerge from the sanitary landfill, whereby the study needs to be prepared for the usage of EPD.

3.3 Site Information [5]

The sites are located within the same area of Kampangsan district, Nakhon Pathom province. The 2 different sites are managed by Thai operator, Group 79 Co, Ltd. (Case Study 1) and Wassaduphan Co, Ltd (Case Study 2) and are considered to be the biggest 2 landfill site operating within the country. Group 79 and Wassaduphan Co, Ltd. have been providing reliable landfill for BMA for more than 20 years in Kampangsan, Nakornpathom province. Recently both of the companies have won the fourth consecutive contract from BMA to manage municipal waste from both Nongkam and Tarang transfer stations which receive 2/3 of the total waste generated in Bangkok city. The contract term will last for the next 10 years. Each site is set within the boundary of 500 rais, whereby both of the sites has the identical operation and management. Within the 500 rais area, the landfill area is set to utilize 200 rais just for waste dumping area, another 200 rais is for leachate treatment system and the rest shall be for other purposes.

The daily incoming waste for Group 79 site is at the average of 2700 tons per day, and Wassaduphan site is at around 2600 tons per day. Both of the site have started their operation on the fairly similar date since 20^{th} March 2005, thus far, the sites have been in activation for 3 years and both of them contain the rough number of 3 millions ton of waste each.

According to BMA and sub-contractors (Group 79 Co, Ltd. and Wassaduphan Co, Ltd.), sanitary landfill is the most reliable, minimal environmental impact and cost effective mean of dealing with BMA municipal waste. Under the consideration of BMA, the future trend for waste management scheme of Bangkok city for the next 10 years has already been under the contract for landfilling all of the receiving waste from BMA.

3.4 Data Collection

Data collection would be coming up with mainly field survey and companies' monitoring report. The field survey would starts from the process of transferring The amount of MSW generated from Bangkok municipality in tons, which is transferred to Nakhonpathom's landfill sites, will be gathered and the compositions of the MSW will be classified and analyzed. At the stage of waste composition characterization, the method would be adopted from California Integrated Waste Management Board (CIWMB), which stated that; for landfill studies, samples shall be chosen randomly. Vehicles from which samples are taken shall be chosen randomly, and the sampled portion of the vehicle load shall also be chosen randomly by the grid method or by the cone and quarter method as described in the ASTM "Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste." The minimum sample weight shall be 200 lb. (91 kilograms) for each sample, and only one sample will be taken from each truck. [25] With regard to the above standard of ASTM, the test sample shall be collected separately from two different case studies, however, during the same time period and exact same amount of raw material. Hopefully, the results shall return the closest and most accurate waste composition for the study.

Apart from the field survey, the companies' monitoring report on diesel usage during the transportation phase, 24 parameters of leachate and 4 parameters of biogas characterization monitoring must also be collected in order to find out the actual environmental burdens. Since the distance between the transfer stations and the site is fairy constant, the number of the diesel consumption is also steady as well, therefore, the data collection of 3-4 trips per each site shall be enough for the transferring phase. In addition to the data collection factors, the companies have to report the monitoring results on both leachate and biogas generated from the landfilling process to the government sector or BMA every other 3 month, hence, the data collection of this study would be derived from the average number of the past 3 years monitoring results.

The inputs and outputs data from the sanitary landfill's case studies, materials in tonnage, energy consumption in joule, water consumption in cubic meter, by product gas in cubic meter, and pollution emissions in kiligram, covering all 4 phases, transportation phase, landfilling phase, leachate phase, and biogas phase, will be gathered on the basis of actuality and certainty. Table with regarding to the gathering inputs and outputs data of each phase would be designed properly before collecting data (see 3.6 Annex).

3.5 Inventory Data Analysis

After the data has been collected, the accuracy data must be verified through the confirmation of the operator themselves and also through the report of the governmental sector or BMA, which has been implemented by the third party. All outcomes of the inventory data is a list containing the quantities of the amount of materials, water and energy consumed, by product generated, and pollution released to the environment that described by unit phases. The environmental loading from each phase will be evaluated following the IPCC instruction. The results then perform each unit phase releasing the environmental impacts in single score. Finally, the analyzed data will be summarized. The EPD of the sanitary landfill's case studies will be discussed and used for further development.

3.6 Annexes

The data collection of the various information of the landfill is consider to be the main methodology for specifying the study of the existing and future trend of the waste management schemes under the contract of 10 years landfilling of Bangkok municipal solid waste.

3.6.1 Waste Composition

In Table 3.1 the waste compositions for both cases are presented in the identical format. The average composition of Bangkok Municipality waste happen to be quite similar, hence, both case studies would perform and result in similar values. Case Study 1 and 2 compositions obtain from municipal solid waste characteristic of the waste conducted at the respective landfill sites. The detail and characteristic of the waste occur to be comparable under the sense of collection, transportation, timing, processing; however, the only differ among both case studies is the location of the originated MSW. The parameters within the table of waste composition would manipulate the pattern of burdens and impacts, which would strongly reflect the fact of the LCA and also resulting in the EPD of waste management scheme.

Table 3.1: Composition of Bangkok Municipality MSW at the disposal landfill site (1 ton sample)

Waste Composition	Case Study 1	Case Study 2	Average Amount
Organic matter	-	-	-
Plastic material	-	-	-
Iron/Metal	-	-	-
Glass	-	-	-
Paper	-	-	-
Wood	-	-	-
Textiles	-	-	-
Inert material	-	-	-

3.6.2 Transferring

Case Study 1. The receiving waste from Nongkam station is roughly at 3,000 tons per/day, where the distance is about 86 kilometers. The route starts from Nongkam station out to Petchakasem Road; turn right toward Nakhon Pathom province; turn right onto Malaiman or highway 321 up until km 29th; turn left toward Chanthrubeka about 6 km and turn right onto the landfill site. According to this case study, the trailers required to perform the task are 48 trucks. As the matter of fact, the emission and diesel usage would be identified within the table 3.2 below.

Case Study 2. The incoming daily waste for Tarang station is roughly at 2,000 tons per/day, whereby the distance is at around 135 kilometers. The route of the transferring starts from Ramintra Road; pass through Laksee intersection straight toward west direction; turn right onto Rangsit and turn left toward Pratumtanee bridge; turn left onto highway 346 pass LardlumKaew, Banglean district; turn to highway 321 followed by 3040 for 6 km.; turn right toward the public road for another 5 km. and would reach the landfill site. In relevant between the number of 2,000 tons of waste per day and the distance of the 135 kilometers, the amount of semi-trailers needed are 39 trucks, whereby each of the trailers would consume the diesel and also produce emission as stated in table 2.

Table 3.2: Emission produced from Transfer phase

Case Study	Distance (Round Trip)	Diesel consumption	Emission (CO_2) produced
Case 1	**172 kilometers**	**0.58 liter/kilometer**	**-**
Case 2	**270 kilometers**	**0.58 liter/kilometer**	**-**

3.6.3 Leachate

Case Study 1. The leachate produced from the landfill is pumped from the bottom of the landfill and hurl to the leachate collection canal. Within the leachate collection canal the sludge would get settle to the bottom of the pond and the leachate would be over-flowed toward systematic Stabilization Pond, which start from Facultative Ponds, follow by Aerobic Ponds, which are all lined-up in linear sequence. Last treatment pond to arrive is the Constructed Wetland, which is the quality alteration process by biological treatment. After all kinds of treatment ponds, the treated leachate would be discharged to the gigantic storage pond and use for other purposes. During this period of time, leachate only circulates within the first stage of the treatment system, which is Stabilization pond. In fact, the measurement under table 3.3 shows the present condition of leachate, which is not yet completely treated

Case Study 2. The leachate treatment system is exactly identical with the earlier case study 1. The only differ among the two is the composition of MSW, which came from different area, which consequence in the diverse results of the measurement in each parameters.

Table 3.3 Leachate Measurement (24 Parameters)

Parameters	Units	Case Study 1	Case Study 2
pH	-	-	-
EC	µmho/cm	-	-
Color	Color unit	-	-
Temperature	^{o}C	-	-
TSS	mg/L	-	-
TDS	mg/L	-	-
Chloride	mg/L	-	-
Sulphate	mg/L	-	-
BOD	mg/L	-	-
COD	mg/L	-	-
Nitrate	mg/L	-	-
Ammonia	mg/L	-	-
Total Phosphate	mg/L	-	-
Alkalinity	mg/L	-	-
Arsenic	mg/L	-	-
Cyanide	mg/L	-	-
Phenols	mg/L	-	-
Chromium Hexavalent	mg/L	-	-
Nickel	mg/L	-	-
Zinc	mg/L	-	-
Cadmium	mg/L	-	-
Copper	mg/L	-	-
Lead	mg/L	-	-
Manganese	mg/L	-	-
Mercury	mg/L	-	-
Sodium	mg/L Na	-	-

To keep a close look at the environmental impact, around the landfill the companies have numerous monitoring wells to watch for any over limit indication of underground water. This process is done by United Analyst and Engineering

Consultant (UAE) the third party environment inspection firm and the result is being given to the companies every month and BMA every three other months.

3.6.4 Biogases

Case Study 1. According to the study of Group 79 Co., Ltd., the generation of the gases would firmly initiate within the 3^{rd}-4^{th} year and tend to increase as time comes. The collection system would be built in the horizontal plan on every 3 layers or 9 meters of the landfill. The first installation system starts in the 5^{th} layer of the landfill with 8 inches diameter main pipeline and 6 inches diameter collection pipelines. The collected gas, if enough, would be utilized for the electricity generation, if not, would be burnt by flaring system. As the matter of fact, the important gases that need to be measure and report to the authority or the BMA are Ammonia, Hydrogen Sulphide, Methane and Carbon Dioxide, which are stated as the following Table 3.4.

Case Study 2. The work procedure of the Wassaduphan Co.,Ltd. is again exactly identical with the first Case Study, however, the amount and the composition of the gases might be dissimilar due to the variation in the amount and composition of the MSW.

Table 3.4: Biogas measurement (4 parameters)

Case Study	Ammonia	Hydrogen Sulphide	Methane	Carbon Dioxide
Case Study 1	-	-	-	-
Case Study 2	-	-	-	-

3.6.5 Resource use

Table 3.5: Resource usage

Phase	Resource use	Case Study 1	Case Study 2
Landfill	Non-Renewable Resource	-	-
	Renewable Resource	-	-
	Water	-	-
Leachate	Non-Renewable Resource	-	-
	Renewable Resource	-	-
	Water	-	-
Biogas	Non-Renewable Resource	-	-
	Renewable Resource	-	-
	Water	-	-

3.6.6 Environmental Impacts

Table 3.6: Environmental Impacts: Transferring phase

Phase	Resource use	Case Study 1	Case Study 2
Landfill	GWP	-	-
	Land use	-	-
	Hazardous Waste	-	-
Leachate	GWP	-	-
	Land use	-	-
	Hazardous Waste	-	-
Biogas	GWP	-	-
	Land use	-	-
	Hazardous Waste	-	-

CHAPTER IV
RESULTS AND DISCUSSIONS

4.1 Site description

The sites are located within the same area of Kampangsan district, Nakhon Pathom province. The 2 different sites are managed by Thai operator, Group 79 Co, Ltd. (Case Study I) and Wassaduphan Co, Ltd (Case Study II) The area is located in a less to non community zone, high ground above the sea-level, deep underground water table, dry and unfertile soil, etc.

Case Study I. The Group 79, Co., Ltd. Landfill site is located at 39 Moo.8, Tumbol Tungbua, Kampangsan District, Nakhon Pathom Province, 73000**.** The daily incoming waste for Group 79 site is at the average of 2700 tons per day; starting from March 2005.

Case Study II. Wassaduphan Co., Ltd. site is located at 49 Moo.8, Tumbol Tungbua, Kampangsan District, Nakhon Pathom Province, 73000**.** The Wassaduphan site started operated since March 2004 and is receiving waste at around 2000 tons per day.

4.1.1 Practical Landfilling Method:

Step by step to sanitary landfill method according to case study of Group 79 Co, Ltd., and Wassaduphan Turakit Co, Ltd., Kampangsan Landfill Sites, under the contract of Bangkok Metropolitan Administration.

1. *Find suitable land* - Need to carry out extensive survey such soil boring test, hydrogeology, installing the observation well.

2. *Excavation and Compaction* – Constructing the standard landfill first excavate down to the level and then paving the clay liner at lowest layer. Also the compaction level must be higher than 85%AASHTO standard.

3. *HDPE is being place*- High density version of PE plastic is installed to preventing contamination to surface or groundwater resources. Liner connections must also be checked until sure that it is 100% leak proof.

4. *Geo-net and Geo-textile* - Geo-net is being place only along the side of the landfill; it is used to increase adhesion. Geo-textile is used to prevent any sharp object from piercing the HDPE is placed. Then leachate sump must also be installed at this staged.

5. *Leachate pipe and Leachate sump*: On top of the three layers, soil and leachate collection pipe, the sumps are installed to collect the waste water and send to the treatment system.

6.*Leachate Treatment ponds*- Leachate will slowly drain through the landfill and into the collection pipe which then will be treated using different method before entering storage pond.

7. *Landfill can finally start:* each 2.70 meters layer of waste must be covered with 0.30 meter layer of soil.

The major description of each site can be determined through the characteristic of the waste contained or the waste composition. In Table 4.1, Figure 4.1 and 4.2 the waste compositions of the two case studies, Group 79 Landfill as Case I and Wassaduphan as case II, are shown, whereby the values are slightly different from each other, due to the fact that the sources of waste are from different area. Both samples were taken at the delivery of waste on site; hence, the quick decomposition of putrescible materials has no effect with the result.

The waste is characterized by direct sampling during the field site investigation at the final disposal site area, before landfilling. Both case studies samples were collected from monthly data for the past three consecutive years (2006, 2007, and 2008). The result shows that the compositions of waste in 2 different areas of Bangkok Municipality are very much alike. The only two major different would be Organic matter and Wood, which might be because of the number of fresh market and national park within the area

Table 4.1 Composition of waste disposed in Landfills

Waste Composition (%)	Case study	
	Case I	Case II
Organic matter	43.99	38.19
Plastic material	20.92	20.96
Iron/metal	0	0
Glass	1.34	1.20
Paper	10.06	14.6
Wood	8.26	18.23
Textile	14.13	5.86
Inert material	1.27	0.94

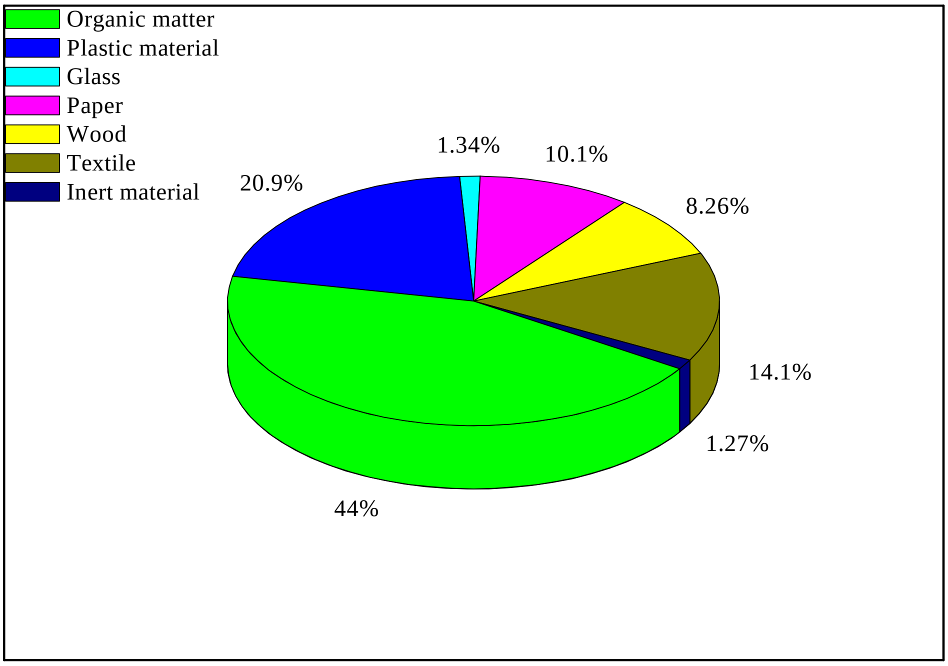

Figure 4.1 Composition of waste disposed in Landfills Case I

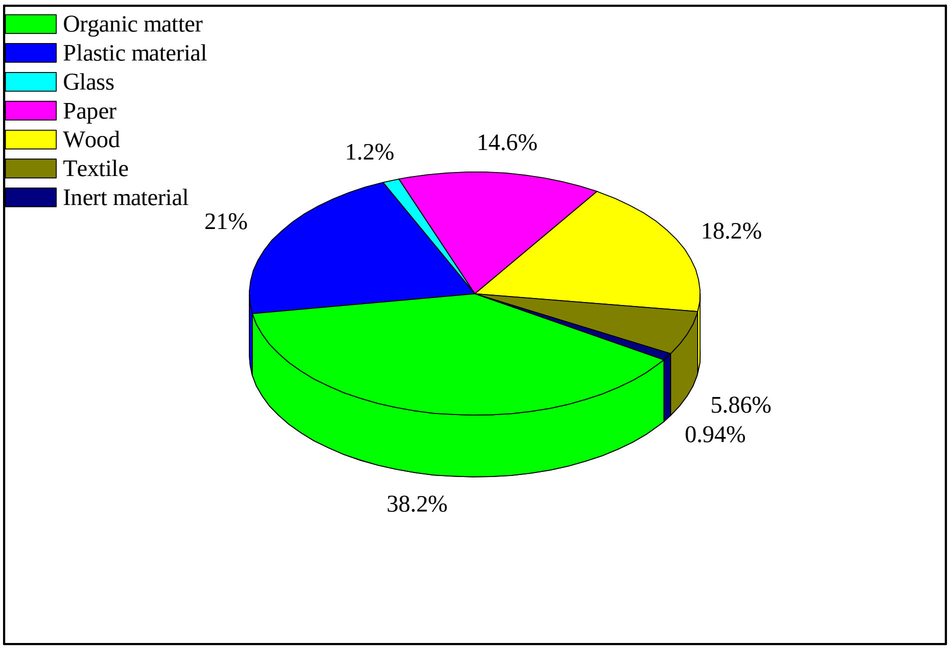

Figure 4.2 Composition of waste disposed in Landfills Case II

4.2 Transport phase

Case Study I. The receiving waste from Nongkam station is roughly at 3,000 tons per day, where the distance is about 86 kilometers. According to this case study, the trailers required to perform the task are 48 trucks.

Case Study II. The incoming daily waste for Tarang station is roughly at 2,000 tons per day, where by the distance is at around 135 kilometers, whereby, the amount of semi-trailers needed are 39 trucks.

As the matter of fact, the impact from transferring phase shall be calculated by diesel consumed by the hauling trucks as shown in Table 4.2 and Figure 4.3 below.

The important cause of variation for the Carbondioxide produced is based on fuel consumption. The distance of the route back and forth parallel with the weight that need to be carried are different for both case studies. Case I required lesser hauling distance, but more trip for the truck to carry 2,700 tons of waste, which in fact produce slightly more CO_2 emission rather than the 2,000 tons flat for Case II.

Table 4.2 CO_2 produced from diesel consumption during transferring phase

Case Study	Yearly average CO_2 produced (Ton CO_2)		
	2006	**2007**	**2008**
Case I	18,510,724	18,372,120	17,565,753
Case II	17,281,346	17,604,326	17,305,521

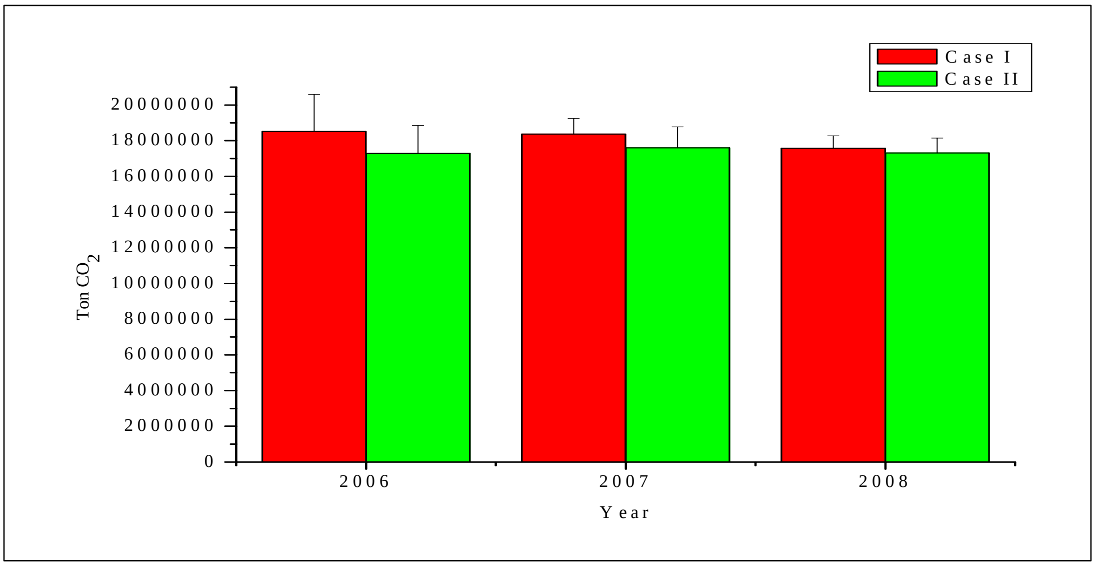

Figure 4.3 CO_2 produced from diesel consumption during transferring phase

4.3 Landfill phase

Sanitary landfill is landfill that has physical barriers such as liners and leachate collection systems, and procedures to protect the public from exposure to the disposed wastes. The term sanitary landfill normally refers to those where municipal solid waste is disposed of, as well as other wastes high in organic material [12].

With the concern toward environmental suitability of the surrounding condition of the landfills area, group 79 and Wasaduphan Co., L.td. have implemented their frame work regarding theoretical. Before the landfill can start the operation, a lot of effort is needed in the preparation phases. The process starts from the daily transportation of the waste from Bangkok Municipality. Next important item is choosing suitable land. Then we need to excavate down to certain levels and compaction for both the landfill and leachate treatment ponds. Then, leachate collection system must be carried out. Further, HDPE liner must be put down and joined with special machine before checking for leakage on both landfill and leachate treatment ponds. After that we have to put Geo-net and Geo-textile to prevent any sharp object from piercing down the liners at this stage only for the landfill. Also, the HDPE collection pipe for landfill gas is lay out and covered with rock and sand [11].

4.4 Water Consumption and Electricity Usage

After landfill has been conducted and ready to be operated, as any other activities, during the process of landfill the 2 resources used would be electricity and water. The main water and electric usage would be based on office work rather than on-site activities. The Table 4.3 and Figure 4.4 show the Water consumption in term of cubic meter. Thus far, the electricity usage can be converting back to CO_2 emission as shown in Table 4.4 and Figure 4.5 below.

Due to the fact that the amount of waste at Group 79 site or case I is greater than the other site, the consumption of water for dusting, planting and general usage would be greater respectively.

Table 4.3 Yearly water consumption rate in Cubic meter

Case Study	Average Water Consumption (Cubic meter)		
	2006	**2007**	**2008**
Case I	5,331	4,863	5,448
Case II	2,997	2,965	3,230

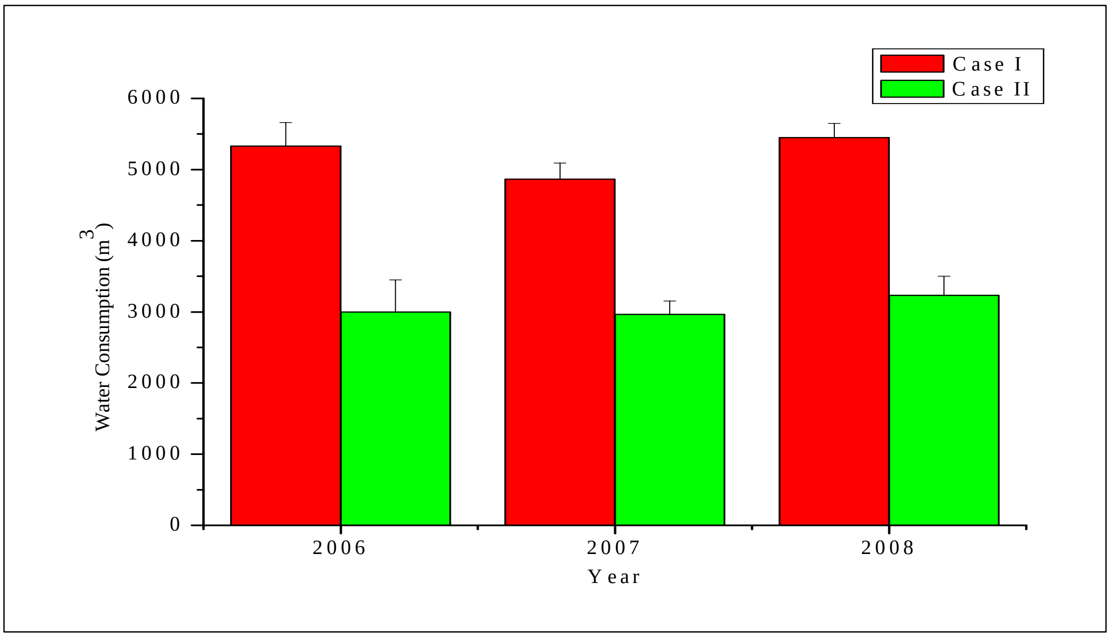

Figure 4.4 water consumption rates

Even though the amount of waste is lesser in Case study II site, but the number of electricity usage appear to be greater; the reason behind this is because both landfill operations share a single operator's team and field office, which located at Wassaduphan or Case II site. Therefore, the number of electricity usage or the number of the CO_2 produced from electricity usage would be much more significant on the Case study II site.

Table 4.4 Yearly CO_2 produced from electricity usage

Case Study	Yearly average CO_2 produce from Electricity usage (Ton CO_2)		
	2006	2007	2008
Case I	1,152,499	2,887,611	3,563,495
Case II	2,779,553	3,113,274	2,720,723

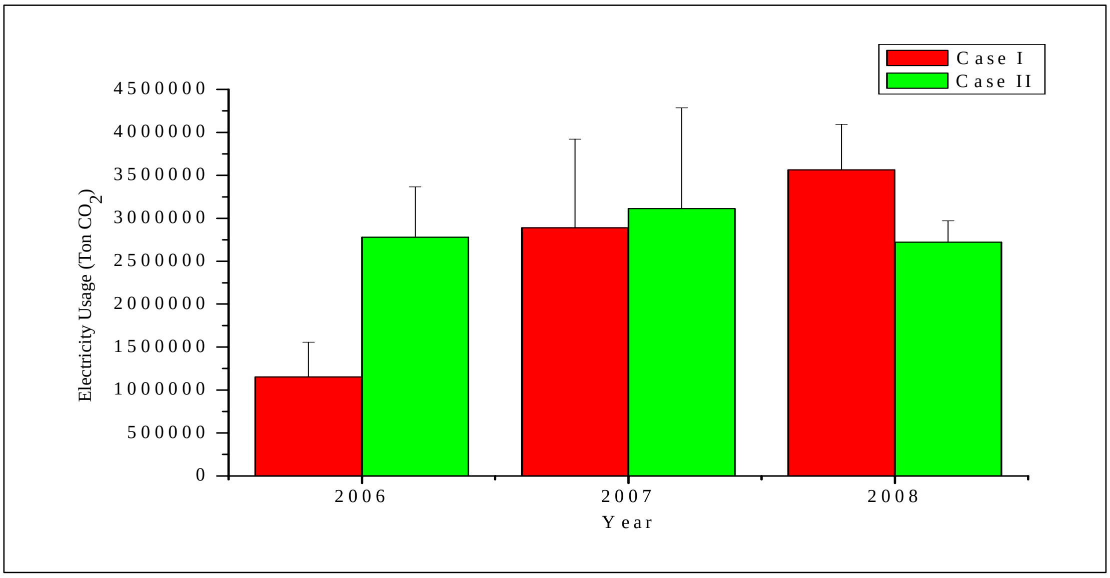

Figure 4.5 CO_2 produced from electricity usage

Even though the amount of waste is lesser in Case study II site, but the number of electricity usage appear to be greater; the reason behind this is because both landfill operations share a single operator's team and field office, which located at Wassaduphan or Case II site. Therefore, the number of electricity usage or the number of the CO_2 produced from electricity usage would be much more significant on the Case study II site.

4.5 Leachate phase

The leachate treatment system contains 14 HDPE lined linear treatment ponds which provide the company with various jobs of treatments. The leachate treatment capacity of each case study is at 2000 cubic meter per day of leachate. The leachate will enter first the anaerobic then aerobic treatment. After that the leachate will enter maturation pond then wetland and lastly to the storage pond.

Case Study I, The leachate produced from the landfill is pumped from the bottom of the landfill and hurl to the leachate collection canal. Within the leachate collection canal the sludge would get settle to the bottom of the pond and the leachate would be over-flowed toward systematic Stabilization Pond, which start from Facultative Ponds, follow by Aerobic Ponds, which are all lined-up in linear sequence. Last treatment pond to arrive is the Constructed Wetland, which is the quality alteration process by biological treatment. After all kinds of treatment ponds, the treated leachate would be discharged to the gigantic storage pond and use for other purposes. During this period of time, leachate only circulates within the first stage of the treatment system, which is Stabilization pond. In fact, the measurement under table 4.3 and Figure 4.4 shows the present condition of leachate, which is not yet completely treated

Case Study II. The leachate treatment system is exactly identical with the earlier case study 1. The only differ among the two is the composition of MSW, which came from different area, which consequence in the diverse results of the measurement in each parameters.

The Table 4.5 below shows the laboratory test results of incoming or untreated leachate collected at the initial pond before entering the treatment system. It is obvious that the results are very much vary in term of numbers; the reasons or factors behind this clause is that the compositions of waste coming into landfill, surrounding condition of the landfill such as amount of oxygen, temperature, moisture content, etc, are different from time to time and also different in each part of the landfill. Hence, it is reasonable enough to claims that the leachate test results would always be varied from each case study and also from each different year.

Table 4.5 Leachate laboratory test results on 26 different parameters

Parameter	Unit	Average 2006		Average 2007		Average 2007	
		Case I	Case II	Case I	Case II	Case I	Case II
pH		8.03	8.17	8.16	8.10	8.03	8.20
EC	μmho/cm	20,861	24,316	14,133	13,965	24,183	23,753
Color	Color unit	-	-	-	-	-	-
Temperature	°C	32.93	31.83	29.63	32.13	30.97	30.20
TSS	mg/L	403.33	246.00	673.33	231.33	387.65	176.67
TDS	mg/L	14,788	13,993	14,736	9,650	14,080	13,569
Chloride	mg/L	4,255	4,366	4,041	5,139	3,967	4,315
Sulphate	mg/L	3.97	14.92	5.53	30.83	3.83	25.33
BOD	mg/L	1,242	210	1,296	119	2,056	113
COD	mg/L	4,202	1,612	3,771	1,639	4,235	1,517
Nitrate	mg/L	36.47	23.37	32.85	11.07	27.01	16.69
Ammonia	mg/L	1,628	909	3,881	555	1,887	895
Total Phosphate	mg/L	39.07	33.40	36.3	32.03	32.77	32.73
Alkalinity	mg/L	8,028	5,981	12,309	5,505	8,747	6,447
Arsenic	mg/L	0.25	0.39	0.57	0.44	0.24	0.18
Cyanide	mg/L	-	-	-	-	-	-
Phenols	mg/L	3.23	1.19	3.86	1.16	2.33	0.90
Chromium Hexavalent	mg/L	-	-	-	-	-	-
Nickel	mg/L	0.39	0.57	0.42	0.30	0.32	0.25
Zinc	mg/L	1.19	0.40	1.45	0.13	0.63	0.17
Cadmium	mg/L	-	-	-	-	-	-
Copper	mg/L	-	-	-	-	-	-
Lead	mg/L	-	-	-	-	-	-
Manganese	mg/L	3.63	0.49	1.07	0.31	1.67	0.17
Mercury	mg/L	0.04	0.063	0.02	0.046	0.0096	0.018
Sodium	mg/L	6,569	3,948	5,468	3,212	5,302	2,900

4.6 Biogas phase

Throughout the lifespan of the MSW, the gas generation process has its own characteristic during each stage. The most common containments of the gases are primarily Methane, Carbon Dioxide, Ammonia, Nitrogen, Hydrogen Sulphide and traceable amount of Non-methane organic compounds, etc. After the MSW has been landfilled, the biological reactions slowly begin under the 2 different phases. The first phase takes place in the atmospheric air, which is near by the surface of the landfill whereby the natural organic compounds are oxidized aerobically. The biodegradable portion of the organic fraction of MSW can be converted biologically under anaerobic conditions to gas containing carbon dioxide and methane [26]. The second phase emerges within the landfill anaerobically and can be divided into 3 stages. The first, fermentative bacteria would hydrolyze the organic compound into soluble molecules. Within the second stage, the molecules are converted by bacteria to carbon dioxide, hydrogen and organic acids; the primary acids produced are acetic, propionic, butyric acid and also ethanol. The last stage is basically where the methane is formed by methanogenic bacteria, by breaking down of acids to carbon dioxide and methane or by the reduction of carbon dioxide with hydrogen.

Case Study I, According to the study of Group 79 Co., Ltd., the generation of the gases would firmly initiate within the first year and tend to increase as time comes. The collection system would be built in the horizontal plan on every 3 layers or 9 meters of the landfill. The first installation system starts in the 5th layer of the landfill with 8 inches diameter main pipeline and 6 inches diameter collection pipelines. The collected gas, if enough would be utilized for the electricity generation, if not, would be burnt by flaring system. The measured gas parameters are Ammonia, Hydrogen Sulphide, Methane and Carbon Dioxide, which are stated as the following Table 4.6, Figure 4.6, 4.7 and 4.8.

Case Study II. The work procedure of the Wassaduphan Co., Ltd. is again exactly identical with the first Case Study, however, the amount and the composition of the gases might be dissimilar due to the variation in the amount and composition of the MSW.

Table 4.6: Biogas laboratory test result on 3 different parameters

Parameter	Unit	Average 2006		Average 2007		Average 2008	
		Case I	Case II	Case I	Case II	Case I	Case II
Ammonia	mg/m^3	0.18	0.27	0.31	0.24	0.28	0.29
Hydrogen Sulphide	mg/m^3	0.001	0.008	0.002	0.007	0.001	0.001
Methane	ppm	15.83	13.70	18.04	16.54	28.80	25.65

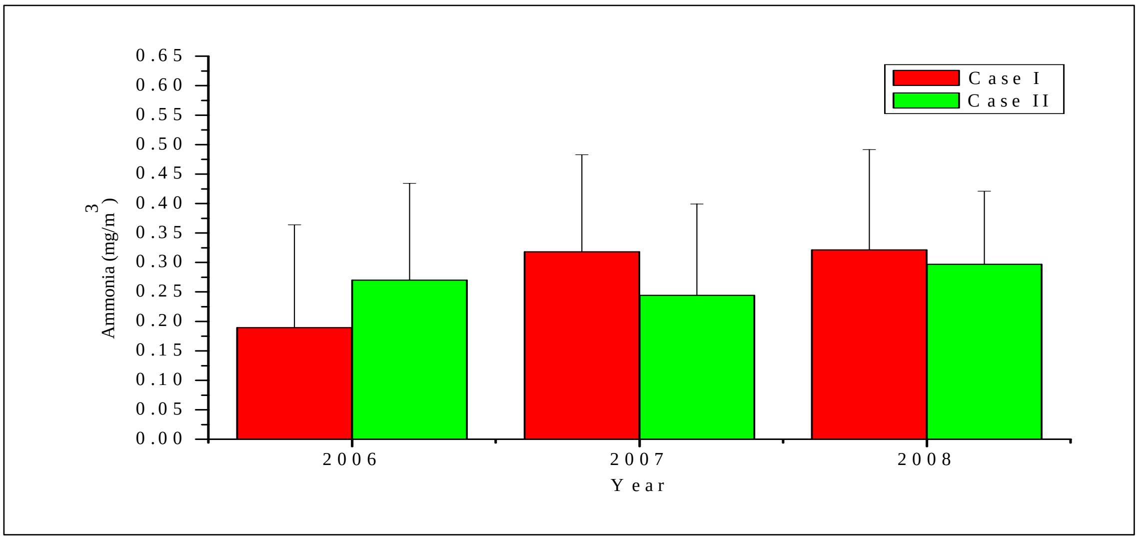

Figure 4.6 Biogas laboratory test result on ammonia

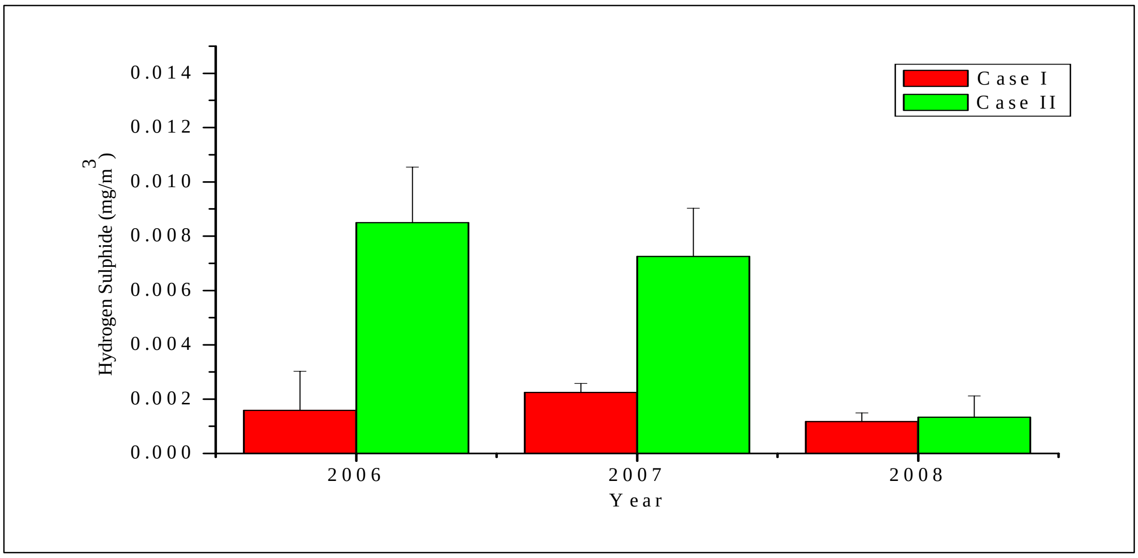

Figure 4.7 Biogas laboratory test result on hydrogen sulphide

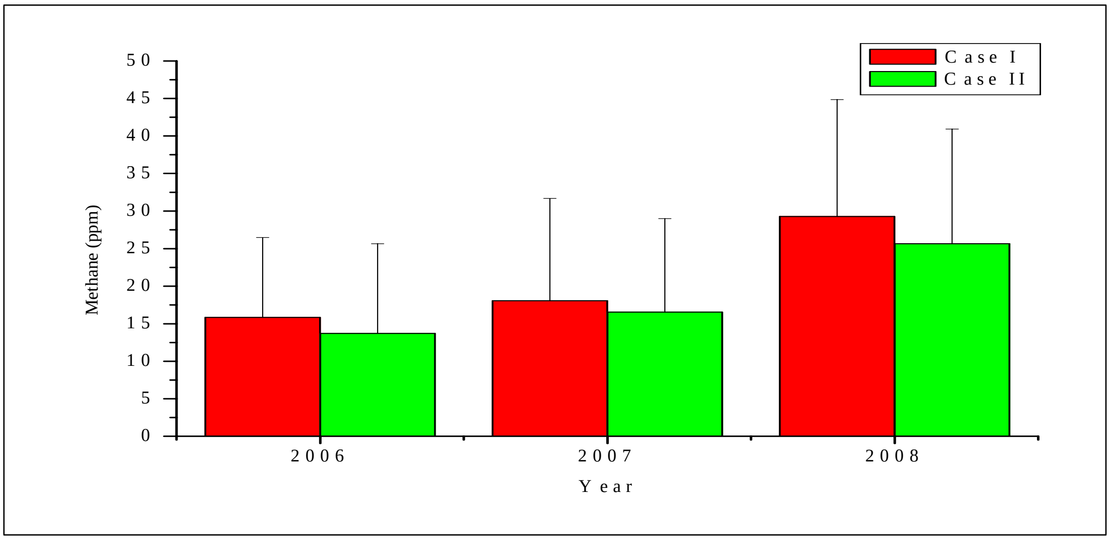

Figure 4.8 Biogas laboratory test result on methane

Within the Biogas phase, the numbers of test results in both case studies are again differ from each other. The non-complex and straight forward reasons is because the diversities in the waste composition, which make the concentration of each parameters higher or lower in numbers. Moreover, the aspects of variation in enclosed area condition, such as temperature, moisture content, amount of oxygen, etc, are also major factors. Above all, the determination of each gases lifespan in controversy with the timing is also crucial. For instance, the test results of methane in figure 4.8 shows that the lifespan of Methane gas tends to increase from time to time, however, the other type of gases such as Ammonia and Hydrogen Sulphide in figure 4.6 and 4.7 do not applied.

CHAPTER V
CONCLUSION AND RECOMMENDATION

5.1 Conclusion

Today, product-related environmental issues are playing an important role within the strategic planned out for business sectors. Such developments required business sectors, companies or organizations to recruit all vital information about environmental aspects of products and services, which in return would provide such sectors to be able to place the information in the context and make their own decision. Under the sense of sustainable development, the goal of EPD is to provide relevant, verified and comparable information to meet the various needs within an organization including within environmental management systems (EMS), for Eco-design, and in green procurement, etc.

Precisely speaking, Environmental Product Declaration represents a verifiable and accurate way to show the environmental aspects of products or services, view from a comprehensive life cycle perspective ‘from cradle-to-grave’. It is defined as ‘quantified environmental data for a product, with pre-determined parameters, based on the ISO 14040 [12] series of standards, which may be supplemented by other qualitative and quantitative information [13]. The information contained in the EPD, developed using Life Cycle Assessment (LCA), are exclusively informational in nature, and the declaration contains no criteria for assessment, preferability or minimum levels to be met. In fact, it is not possible to rely on the studied result to determine the ‘best product’ or ‘best method’ for waste treatment, but it is possible to identify the lowest impact product or service for each resource usage and impact category.

5.2 Recommendation

The theme of this research is based on the declaration of Environmental Product, in this case, sanitary landfill for Bangkok waste by the sub contractors of BMA. Given the fact that stepwise EPD are useful for both business and environmental sectors; the production of EPD or rather exercising the underlying Life Cycle Assessment can be performed as a basis to identify eco-design options for the landfilling managements. The research can more or less assure that Bangkok, as a developing city, has met its standard of landfilling.

Toward the sustainable development of MSW management, the afterlife of the landfill shall be studied through the EPDs data based for the possibility of the renewable products and energies. The common and well know processes for renewable product and energy are Landfill Methane Gas – to – Electricity, Recovery of none-decompose materials, composting and Refuse Derive Fuel (RDF). Moreover, the new thermal process, such as “Thermal Depolymerization”, is far more advance and new for the renewable energy technology.

Landfill Methane Gas – to – energy has been studied and practices in many landfills already. Methane is a byproduct from the landfills. While the decomposition of the organic materials takes place within the landfill, there would be methane generated. The amount of methane generation is varying according to the amount of organic materials. The more organic matters, the more methane produced. The life expectancy of the methane generated again is also varying according to the waste compositions. The extracted methane can be utilized for direct heating application, electricity generation application, feedstock in chemical manufacturing processes, purification to pipeline quality gas, etc. Moreover, the extraction of the landfill gas can also reduce the amount of gases releasing into the air, which is very environmental friendly.

Composting is the “biological degradation of biodegradable organic waste such as garden and food waste.” There are 2 processes of composting, aerobic and anaerobic. Aerobic requires more oxygen for the decomposition while anaerobic does not require as much. Aerobic digestion consumes roughly about 4-6 weeks to reach the stabilized product; however, landfills do not provide enough oxygen for the process, which would required a much long time for the degradation. According to the earlier process, after the extraction of the landfill gases, the extraction of the composting can come afterward. The process for extorted the compost is to segregate the compost out from the non-degraded material, such as plastics, metals, glasses, etc.

After the extracted the compost out from the closed landfill for agricultural benefit, the remaining material would be mainly plastic, this takes ages to degrade. The byproduct from the refinery of crude oil through the polymerization process is the “plastics”. Thermal depolymerization Technology claims that while polymerization of crude oil can produce the plastic, hence depolymerization shall also be able to return the state of plastic such as LLDPE, LDPE, HDPE, PP, etc back to crude oil as well. While the molecules of plastic are bonding tightly, the process of depolymerization would shorten down its bonds and return it in the state of crude oil. “Global Finest” claim that “a new recycling formulation was necessary that would convert existing hydrocarbons not into methane, CH_4, and coke crystals, C, but into CH_2 and only then in molecule lengths that reduce and bind in a manner that separates unusable pollutants. In essence, the new formulation returns to the natural processes used for hundreds of millions of years where fossilized by-products from the seas settled into suspended clay minerals and ultimately formed fossil fuels, such as oil hydrocarbons.” (Global Finest) According to Global Finest, the heating temperature required for this procedure would be approximately 450-500 C. Furthermore, the crude oil would go through the process of refinery which claims to be 50% diesel, 20% benzyl and 30% furnace oil. The main functional components are the “temperature control” and “catalytic”. Beside, these plastics waste could be turn into Refused Derived Fuel for the process of incineration as the fuel for producing electricity due to its high calorific value. Apart from the plastic waste, the material such as glass and metal, which contains as the composition within the landfill can be extracted and being sale in the market. There is certain market which accepts the unusable glass and metal waste for the recycling process.

The outcome of this research will likely recommend comprehensibly base-line data of the MSW management on each of the processes. Landfilling is more or less impossible to be eliminated, which in fact through this study of the EPD, the environmental burdens would be reflected and set the proper standard for the MSW management scheme for all sectors. Throughout the declaration of this study, the application of EPD shall enhance, accumulate and provide the LCA based data for easy access, quality assurance and comparable information regarding environmental performance. At the same time new technologies, such as incineration, gasification, recycling, or composting, etc. must be in use in order to compensate for the burdened and impacted environment. Along with the knowledge of past experiences, there are many other factors which can determine the most environmentally friendly and economically friendly methods for MSW management that would be the best fit for Bangkok. As a matter of fact the study of EPD illustrates ideas of how landfills are operating and at the same time, its effects toward environment and the sustainable trend of Waste Management scheme.

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APPENDIX

Table 1 Composition of waste disposed in Landfills (Case Study I, 2006)

Waste composition	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
Organic matter	40,325	32,154	51,239	32,458	51,324	70,851	51,358	52,165	51,324	62,354	32,458	33,247	561,260	46,771
Plastic material	32,145	13,285	27,541	13,157	27,648	28,654	27,457	27,327	24,534	25,241	13,157	16,547	276,698	23,058
Iron/ Metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	1,352	625	1,324	735	2,004	1,435	1,567	1,534	2,004	1,385	735	3,214	17,915	1,492
Paper	1,321	16,547	10,027	16,487	9,935	7,542	5,247	4,247	9,935	8,354	16,487	1,423	107,553	8,962
Wood	1,532	6,254	6,587	6,271	6,512	12,124	13,642	12,872	6,512	7,234	6,271	8,632	94,447	7,870
Textiles	12,654	24,325	15,472	23,547	10,005	10,024	7,214	7,438	9,218	951	26,324	29,364	176,539	14,711
Inert material	7,521	258	2,465	524	1,541	2,004	1,024	1,085	1,541	241	524	2,014	20,743	1,728

Table 2 Composition of waste disposed in Landfills (Case Study I, 2007)

Waste composition	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
Organic matter	59,321	42,587	51,358	34,458	51,324	50,025	51,324	52,165	49,254	50,027	31,547	35,471	558,866	46,572
Plastic material	23,654	15,632	23,541	13,157	27,648	23,541	24,534	27,327	25,648	27,327	13,157	13,157	258,327	21,527
Iron/ Metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	1,385	735	1,567	735	2,004	1,567	2,004	2,142	2,004	1,534	735	735	17,149	1,429
Paper	8,354	16,487	5,247	16,487	9,935	5,247	9,935	4,247	9,935	4,247	16,487	16,487	123,097	10,258
Wood	7,234	12,871	13,642	6,271	6,512	13,642	6,512	12,872	6,512	11,584	6,271	6,271	110,199	9,183
Textiles	951	3,541	7,214	26,324	10,005	7,214	8,541	7,438	10,005	7,438	26,324	23,694	138,692	11,557
Inert material	241	524	1,024	524	2,574	954	1,541	1,085	1,541	1,085	1,574	684	13,353	1,112

Table 3 Composition of waste disposed in Landfills (Case Study I, 2008)

Waste composition	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
Organic matter	33,241	32,154	51,358	34,458	51,324	49,254	50,025	49,841	34,458	47,365	31,852	31,852	497,185	41,432
Plastic material	13,157	19,874	23,541	13,157	27,648	25,648	23,541	25,418	13,157	25,418	12,157	11,452	234,174	19,514
Iron/ Metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	735	625	1,567	735	2,004	2,004	1,567	1,534	524	1,534	735	735	14,300	1,191
Paper	16,487	18,475	5,247	16,001	9,935	9,935	5,247	4,247	16,487	4,247	16,487	16,487	139,285	11,607
Wood	6,271	5,241	13,642	6,271	6,512	5,547	13,642	11,584	6,271	11,584	6,271	6271	99,113	8,259
Textiles	26,324	24,325	7,214	26,324	10,005	10,005	7,214	7,438	26,324	8,438	26,324	24,321	204,259	17,021
Inert material	856	258	1,024	524	2,574	1,541	1,041	1,085	524	1,085	1,142	1,142	12,800	1,066

Table 4 Composition of waste disposed in Landfills (Case Study II, 2006)

Waste composition	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
Organic matter	24,574	24,710	20,472	19,852	28,361	22,457	27,485	20,472	20,472	22,587	19,852	19,852	271,151	22,595
Plastic material	12,417	12,005	14,254	12,547	13,584	14,254	12,457	14,254	14,254	12,484	12,147	12,547	157,209	13,100
Iron/ Metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	552	552	987	918	552	665	664	987	665	741	874	918	9,075	75
Paper	8,574	8,574	10,254	10,254	10,254	10,254	10,254	10,254	10,254	11,254	10,254	10,254	120,690	10,057
Wood	9,842	9,842	12,584	12,584	12,584	12,584	11,233	12,584	12,584	12,584	12,584	12,584	144,184	12,015
Textiles	3,541	3,541	3,741	3,741	3,541	3,541	3,541	3,741	3,741	3,857	3,741	3,741	44,010	3,667
Inert material	358	228	987	938	847	524	847	987	725	895	741	938	9,015	751

Table 5 Composition of waste disposed in Landfills (Case Study II, 2007)

Waste composition	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
Organic matter	18,713	21,047	24,574	23,854	28,361	21,473	22,584	27,485	20,472	21,451	22,471	23,854	276,346	23028
Plastic material	11,543	11,746	12,417	11,235	13,584	14,254	14,254	12,457	14,254	12,484	11,235	11,235	150,704	12558
Iron/ Metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	735	848	552	514	552	552	632	664	665	665	641	514	7,534	627
Paper	8,574	6,254	8,574	8,574	10,254	10,254	10,254	10,254	10,254	11,254	8,574	8,574	111,651	9304
Wood	8,854	9,842	9,842	10,285	12,584	12,584	12,584	11,233	12,584	12,584	10,285	10,285	133,556	11129
Textiles	3,541	2,754	3,541	3,541	3,541	3,541	3,541	3,541	3,741	3,741	3,412	3,541	41,980	3498
Inert material	224	685	358	225	847	847	985	847	725	725	225	225	6,918	576

Table 6 Composition of waste disposed in Landfills (Case Study II, 2008)

Waste composition	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
Organic matter	24,574	24,710	20,472	19,852	28,361	22,457	27,485	20,472	20,472	22,587	19,852	19,852	271,151	22,595
Plastic material	12,417	12,005	14,254	12,547	13,584	14,254	12,457	14,254	14,254	12,484	12,147	12,547	157,209	13,100
Iron/ Metal	0	0	0	0	0	0	0	0	0	0	0	0	0	0
Glass	552	552	987	918	552	665	664	987	665	741	874	918	9,075	756
Paper	8,574	8,574	10,254	10,254	10,254	10,254	10,254	10,254	10,254	11,254	10,254	10,254	120,690	10,057
Wood	9,842	9,842	12,584	12,584	12,584	12,584	11,233	12,584	12,584	12,584	12,584	12,584	144,184	12,015
Textiles	3,541	3,541	3,741	3,741	3,541	3,541	3,541	3,741	3,741	3,857	3,741	3,741	44,010	3,667
Inert material	358	228	987	938	847	524	847	987	725	895	741	938	9,015	751

Table 7 CO_2 produced from diesel consumption during transferring phase (Case Study I)

Month	2006		2007		2008	
	time	Emission CO_2 (T/TJ)	time	Emission CO_2 (T/TJ)	time	Emission CO_2 (T/TJ)
January	2,291	16,935,566	2,559	18,916,680	2,424	17,918,731
February	2,132	15,760,204	2,308	17,061,234	2,287	16,905,997
March	2,284	16,883,821	2,511	18,561,854	2,416	17,859,593
April	2,097	15,501,476	2,413	17,837,417	2,281	16,861,644
May	2,426	17,933,516	2,743	20,276,848	2,609	19,286,291
June	3,074	22,723,671	2,488	18,391,833	2,450	18,110,929
July	2,779	20,542,968	2,532	18,717,090	2,432	17,977,869
August	2,738	20,239,887	2,594	19,175,408	2,349	17,364,315
September	2,585	19,108,878	2,450	18,110,929	2,309	17,068,626
October	2,605	19,256,722	2,500	18,480,540	2,363	17,467,806
November	2,547	18,827,974	2,378	17,578,689	2,290	16,928,174
December	2,491	18,414,010	2,348	17,356,923	2,305	17,039,057
Total	30,049	222,128,698	29,824	220,465,449	28,515	210,789,039

Table 8 CO_2 produced from diesel consumption during transferring phase (Case Study II)

Month	2006		2007		2008	
	time	Emission CO_2 (T/TJ)	time	Emission CO_2 (T/TJ)	time	Emission CO_2 (T/TJ)
January	1,468	17,034,760	1,486	17,243,633	1,426	16,547,389
February	1,313	15,236,130	1,415	16,419,744	1,419	16,466,161
March	1,390	16,129,643	1,529	17,742,607	1,494	17,336,465
April	1,285	14,911,217	1,469	17,046,364	1,442	16,733,054
May	1,770	20,539,186	1,728	20,051,815	1,656	19,216,323
June	1,658	19,239,531	1,562	18,125,541	1,525	17,696,191
July	1,567	18,183,562	1,594	18,496,871	1,560	18,102,333
August	1,510	17,522,130	1,625	18,856,597	1,530	17,754,211
September	1,463	16,976,739	1,511	17,533,734	1,483	17,208,820
October	1,427	16,558,993	1,512	17,545,338	1,525	17,696,191
November	1,501	17,417,694	1,374	15,943,978	1,416	16,431,348
December	1,519	17,626,567	1,400	16,245,684	1,420	16,477,765
Total	17,871	207,376,156	18,205	211,251,912	17,896	207,666,257

Table 9 Leachate laboratory test results on 26 different parameters (Case Study I)

Parameter	Unit	2006			Average	2007			Average	2008			Average
pH		8.3	8.2	7.6	8.03	8.3	8.3	7.9	8.16	8.3	7.9	7.9	8.03
EC	µmho/cm	17,860	24,871	19,854	20,861	14,526	1,532	26,341	14,133	17,860	25,430	29,260	24,183
Color	Colour unit	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	oC	26.9	35.4	36.5	32.93	30.9	25.6	32.4	29.63	24.8	31.6	36.5	30.97
TSS	mg/L	158	698	354	403	214	854	952	673	177	698	287	387
TDS	mg/L	11,854	19,857	12,654	14,788	14,526	15,474	14,210	14,736	11,174	15,656	15,12	14,080
Chloride	mg/L	4,257	4,185	4,325	4,255	3,873	2,541	5,710	4,041	3,218	4,501	4,182	3,967
Sulphate	mg/L	5.6	2.9	3.4	3.97	4.5	6.5	5.6	5.53	5.8	3.3	2.4	3.83
BOD	mg/L	852	1,547	1,328	1,242	606	742	2,541	1,296	209	4,890	1,071	2,056
COD	mg/L	1,425	9,527	1,654	4,202	2,753	2,041	6,521	3,771	1,064	8,939	2,703	4,235
Nitrate	mg/L	42.5	54.3	12.6	36.47	0.41	32.95	65.2	32.85	29.5	50.7	0.84	27.01
Ammonia	mg/L	1,485	2,041	1,358	1,628	1,918	2,741	6,985	3,881	1,732	2,635	1,294	1,887
Total Phosphate	mg/L	26.9	48.2	42.1	39.07	48.6	23.5	36.8	36.3	22.4	28.7	47.2	32.77
Alkalinity	mg/L	6,324	9,241	8,521	8,028	8,960	14,147	13,820	12,309	7,354	11,333	7,556	8,747
Arsenic	mg/L	0.136	0.241	0.385	0.254	0.373	0.714	0.632	0.573	0.131	0.0725	0.514	0.24
Cyanide	mg/L	ND	ND	ND		ND	ND	ND		ND	ND	ND	ND
Phenols	mg/L	1.85	6.24	1.59	3.23	1.3	2.62	7.65	3.86	0.872	4.53	1.59	2.33
Chromium Hexavalent	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/L	0.32	0.24	0.63	0.39	0.46	0.52	0.28	0.42	0.22	0.38	0.34	0.32
Zinc	mg/L	0.51	2.61	0.42	1.19	0.21	0.54	3.61	1.45	0.30	1.18	0.39	0.63
Cadmium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	mg/L	ND	0.061	ND	ND	0.041	ND	0.061	0.051	ND	0.061	ND	ND
Lead	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	mg/L	4.56	1.38	4.96	3.63	0.19	2.61	0.41	1.07	3.79	0.82	0.40	1.67
Mercury	mg/L	0.0052	0.1248	0.0021	0.04	0.0391	0.0062	0.0007	0.02	0.0062	0.0007	0.0219	0.0096
Sodium	mg/L	6,321	4,854	8,532	6,569	3,874	2,847	9,684	5,468	2,475	11,262	2,170	5,302

Table 10 Leachate laboratory test results on 26 different parameters (Case Study II)

Parameter	Unit	2006			Average	2007			Average	2008			Average
pH		8.2	8.4	7.9	8.17	8.3	8.2	7.8	8.1	8.4	8.2	8	8.2
EC	µmho/cm	23,514	25,471	23,964	24,316	14,160	25,321	2,415	13,965	20,030	26,520	24,710	23,753
Color	Colour unit	-	-	-	-	-	-	-	-	-	-	-	-
Temperature	oC	29	30.3	36.2	31.83	30.8	30.2	35.4	32.13	25	30.2	35.4	30.2
TSS	mg/L	214	328	196	246	270	285	139	231	127	209	194	176
TDS	mg/L	13,254	15,471	13,254	13,993	6,053	12,547	10,352	9,650	12,312	14,168	14,228	13,569
Chloride	mg/L	3,241	5,231	4,628	4,366	4,213	4,852	6,352	5,139	4,140	4,550	4,255	4,315
Sulphate	mg/L	12.65	25.6	6.5	14.92	20.2	65.2	7.1	30.83	9.1	63.8	3.1	25.33
BOD	mg/L	125	321	185	210	119	101	139	119	101	101	139	113
COD	mg/L	1,854	1,324	1,659	1,612	1,619	1,547	1,751	1,639	903	1,899	1,751	1,517
Nitrate	mg/L	26.8	32	11.3	23.37	0.35	32	0.87	11.07	25.1	24	0.97	16.69
Ammonia	mg/L	1,241	963	524	909	306	1,147	214	555	1,098	1,173	416	895
Total Phosphate	mg/L	35.9	31.2	33.1	33.40	29.4	36.5	30.2	32.03	31.6	34.2	32.4	32.73
Alkalinity	mg/L	7,425	6,395	4,125	5,981	4,182	5,621	6,714	5,505	6,447	7,606	5,289	6,447
Arsenic	mg/L	0.32	0.621	0.23	0.39	0.101	0.254	0.951	0.44	0.1	0.0883	0.34	0.18
Cyanide	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Phenols	mg/L	0.321	0.85	2.41	1.19	0.5	0.65	2.34	1.16	0.662	0.922	1.12	0.90
Chromium Hexavalent	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Nickel	mg/L	0.35	0.95	0.42	0.57	0.332	0.254	0.323	0.30	0.226	0.275	0.251	0.25
Zinc	mg/L	0.748	0.125	0.324	0.40	0.074	0.154	0.154	0.13	0.196	0.174	0.154	0.17
Cadmium	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Copper	mg/L	ND	0.025	ND	ND	ND	0.025	ND	ND	ND	0.025	ND	ND
Lead	mg/L	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND	ND
Manganese	mg/L	0.54	0.6	0.32	0.49	0.12	0.5	0.31	0.31	0.19	0.2	0.12	0.17
Mercury	mg/L	0.047	0.053	0.0891	0.063	0.0246	0.065	0.0471	0.046	0.0078	0.0294	0.0174	0.018
Sodium	mg/L	2,684	3,841	5,321	3,948	3,499	3,654	2,485	3,212	2,688	3,554	2,459	2,900

Table 11 Water consumption rate in Cubic meter (Case Study I)

Year	Unit	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
2006	m^3	5,241	5,321	5,874	4,862	5,341	5,298	5,291	5,324	4,981	5,432	5,986	5,021	63,972	5,331
2007	m^3	4,921	4,851	4,921	4,621	5,014	5,174	4,932	4,851	4,861	4,958	4,271	4,982	58,357	4,863
2008	m^3	5,641	5,209	5,074	5,621	5,341	5,437	5,479	5,284	5,684	5,341	5,627	5,642	65,380	5,448

Table 12 Water consumption rate in Cubic meter (Case Study II)

Year	Unit	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
2006	m^3	3,214	3,651	2,135	3,141	2,247	2,741	2,864	3,514	3,124	2,941	3,154	3,241	35,967	2,997
2007	m^3	3,124	2,941	3,014	3,065	2,845	2,951	3,412	3,021	2,765	2,743	2,941	2,754	35,576	2,965
2008	m^3	3,241	3,412	3,051	2,854	3,015	2,913	3,508	3,248	2,964	3,672	3,541	3,345	38,764	3,230

Table 13 CO_2 produced from electricity usage (Case Study I)

Month	2006		2007		2008	
	Unit	Emission CO_2 (T/TJ)	Unit	Emission CO_2 (T/TJ)	Unit	Emission CO_2 (T/TJ)
January	20,138	1,129,741	43,755	2,454,655	67,496	3,786,525
February	21,922	1,229,824	41,274	2,315,471	58,071	3,257,783
March	21,813	1,223,709	42,657	2,393,057	63,912	3,585,463
April	15,835	888,343	45,387	2,546,210	59,852	3,357,697
May	18,465	1,035,886	40,605	2,277,940	61,630	3,457,443
June	15,347	860,966	38,685	2,170,228	62,101	3,483,866
July	15,756	883,911	40,601	2,277,716	74,194	4,162,283
August	18,519	1,038,915	43,690	2,451,009	80,190	4,498,659
September	16,353	917,403	39,430	2,212,023	75,214	4,219,505
October	18,135	1,017,373	66,042	3,704,956	48,984	2,748,002
November	22,218	1,246,429	85,815	4,814,221	60,036	3,368,019
December	42,023	2,357,490	89,730	5,033,853	50,565	2,836,696
Total	246,524	13,829,996	617,671	34,651,343	762,245	42,761,944

Table 13 CO_2 produced from electricity usage (Case Study II)

Month	2006		2007		2008	
	Unit	Emission CO_2 (T/TJ)	Unit	Emission CO_2 (T/TJ)	Unit	Emission CO_2 (T/TJ)
January	46,829	2,627,106	57,765	3,786,525	48,349	2,712,378
February	45,814	2,570,165	49,518	3,257,783	43,253	2,426,493
March	55,273	3,100,815	54,704	3,585,463	49,486	2,776,164
April	45,875	2,573,587	53,547	3,357,697	46,857	2,628,677
May	43,169	2,421,780	54,052	3,457,443	46,286	2,596,644
June	42,806	2,401,416	50,808	3,483,866	48,577	2,725,169
July	42,997	2,412,131	56,805	4,162,283	55,489	3,112,932
August	38,156	2,140,551	58,451	4,498,659	56,969	3,195,960
September	40,059	2,247,309	55,034	4,219,505	46,251	2,594,681
October	57,956	3,251,331	55,482	2,748,002	43,011	2,412,917
November	72,594	4,072,523	60,742	3,368,019	45,127	2,531,624
December	63,029	3,535,926	59,033	2,836,696	52,318	2,935,039
Total	594,557	33,354,647	665,941	37,359,290	581,973	32,648,685

Table 14 Biogas laboratory test results on 3 different parameters (Case Study I)

Year	Substance	Unit	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
2006	Ammonia	mg/m^3	0.006	0.013	0.06	0.077	0.115	0.051	0.248	0.125	0.377	0.537	0.411	0.251	2.271	0.18
	Hydrogen sulphide	mg/m^3	0.002	0.001	0.006	0.001	0.001	0.002	0.001	0.001	0.001	0.001	0.001	0.001	0.019	0.001
	Methane	ppm	6.28	2.88	50.9	1.77	2.35	2.15	7.28	6.02	13	36.3	58.8	2.3	190	15.83
2007	Ammonia	mg/m^3	0.25	0.216	0.279	0.374	0.157	0.541	0.886	0.149	0.254	0.684	0.021	0.003	3.81	0.31
	Hydrogen sulphide	mg/m^3	0.001	0.012	0.001	0.005	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.027	0.002
	Methane	ppm	45	8.15	1.54	1.5	78.1	2.38	6.3	11.7	2.06	2.55	32.1	25.2	161.89	18.04
2008	Ammonia	mg/m^3	0.364	0.254	0.869	0.507	0.092	0.445	0.533	0.533	0.005	0.006	0.007	0.241	3.451	0.28
	Hydrogen sulphide	mg/m^3	0.001	0.001	0.001	0.003	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.001	0.014	0.001
	Methane	ppm	160	35.4	35.1	67.8	1.74	9.14	9.14	1.92	7.2	14.1	3.45	6.28	345.7	28.80

Table 15 Biogas laboratory test results on 3 different parameters (Case Study II)

Year	Substance	Unit	Jan.	Feb.	Mar.	April	May	June	July	Aug.	Sep.	Oct.	Nov.	Dec.	SUM	Average
2006	Ammonia	mg/m^3	0.125	0.248	0.377	0.537	0.411	0.198	0.073	0.131	0.439	0.019	0.406	0.276	3.24	0.27
	Hydrogen sulphide	mg/m^3	0.001	0.002	0.005	0.003	0.001	0.001	0.001	0.01	0.001	0.001	0.003	0.073	0.012	0.008
	Methane	ppm	2.48	4.69	2.63	2.1	2.52	2.91	1.96	3.52	12.8	8.82	55	65	164.43	13.70
2007	Ammonia	mg/m^3	0.093	1.32	0.058	0.211	0.161	0.141	0.151	0.132	0.432	0.031	0.024	0.174	2.928	0.244
	Hydrogen sulphide	mg/m^3	0.063	0.001	0.001	0.001	0.001	0.001	0.001	0.006	0.009	0.001	0.001	0.001	0.087	0.007
	Methane	ppm	13	6.72	2.49	1.68	60.8	2.65	1.93	5.75	3.12	8.28	62.6	29.5	198.52	16.54
2008	Ammonia	mg/m^3	0.15	0.194	0.26	0.197	0.109	0.376	0.706	0.616	0.327	0.023	0.549	0.054	3.56	0.29
	Hydrogen sulphide	mg/m^3	0.001	0.001	0.001	0.001	0.001	0.003	0.003	0.001	0.001	0.001	0.001	0.001	0.016	0.001
	Methane	ppm	42.9	30.4	164	18.4	4.58	8.08	1.9	9.15	6.02	13.54	2.05	6.84	307.86	25.65

BIOGRAPHY

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