รายงานวิจัยฉบับสมบูรณ์

การวิเคราะห์ปริมาณการปลดปล่อยก๊าซมีเทนจากบ่อฝังกลบขยะในประเทศไทยและกัมพูชา

Methane emission from solid waste disposal sites in Thailand and Cambodia

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โครงการวิจัยประเภทงบประมาณเงินรายได้จากเงินอุดหนุนรัฐบาล

(งบประมาณแผ่นดิน) ประจำปีงบประมาณ พ.ศ. 2561

มหาวิทยาลัยบูรพา

รหัสโครงการ 2561A10802151

สัญญาเลขที่ 50/2561

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กิตติกรรมประกาศ

งานวิจัยนี้ได้รับทุนสนับสนุนการวิจัยจากงบประมาณเงินรายได้จากเงินอุดหนุนรัฐบาล (งบประมาณแผ่นดิน) ประจำปีงบประมาณ พ.ศ. 2561 มหาวิทยาลัยบูรพา ผ่านสำนักงานคณะกรรมการการวิจัยแห่งชาติ เลขที่สัญญา 50/2561 ขอขอบพระคุณ Sothyroth Sam Oeurn ที่ช่วยในการดำเนินงานวิจัยนี้

บทคัดย่อ

งานวิจัยนี้ประมาณปริมาณการปลดปล่อยก๊าซมีเทนของบ่อฝังกลบขยะเทศบาลเมืองแสนสุข จ.ชลบุรี การศึกษาได้สำรวจปริมาณและส่วนประกอบของขยะในบ่อฝังกลบ นอกจากนี้ยังได้มีการทดสอบคุณสมบัติของน้ำชะขยะ จากนั้นทำการประมาณปริมาณขยะและน้ำชะขยะที่จะรองรับโดยบ่อฝังกลบขยะตลอดอายุการใช้งาน การประมาณปริมาณก๊าซมีเทนที่เกิดจากขยะแข็งได้ใช้แบบจำลอง (i) IPCC zero-order mass balance และ (ii) IPCC first-order decay ส่วนการประมาณปริมาณก๊าซมีเทนที่เกิดจากน้ำชะขยะได้ใช้แบบจำลอง IPCC default

ABSTRACT

The purpose of this research is to estimate a quantity of methane emission generated from a solid waste disposal site at Saensook landfill, Chonburi. The composition of a solid waste is characterized. The methane emission from a solid waste is estimated by using IPCC (Intergovernmental Panel on Climate Change) models, i.e. (i) zero-order mass balance model and (ii) first-order decay model. The leachate is tested and its quantity is estimated. The methane emission from leachate is estimated by IPCC default model.

สารบัญ

Chapter 1 Introduction

1.1 Introduction

The rise of economic, livelihood, industrialization, urbanization, population growth, changed consumption and demand, and urbanization affect waste generation many in the Asian countries (Ashok, 2008; Tay, 2007; Uyen & Hans, 2009). Generally, solid waste management in the cities of Asian nations is a linear system, which consists of four steps such as waste generation, collection, transportation, and disposal into landfill without any solution (Kum et al., 2007). Recently, some governments have spent over 25,000 million USD per years for waste management in sub-cities and mega-cities.

Nowadays, climate change is a serious environmental problem. This change impacts the environment through many aspects, which can result in rise of sea level that might flood costal and river delta communities, shrinking of mountain glaciers and reduce snow cover flat that may diminish freshwater resource. Other impacts include increase of infectious diseases and increased heat-related mortality, possible loss in biological diversity and ecosystem impacts, and agricultural shift such as crop yield and productivity (UNEP, 2009; EPA, 2002). Sunil et al. (2004) presented that solid waste disposal in landfill is also one of the main concerns of methane emission into the atmosphere. Methane gas causes increase of global temperature as high as 20 times more than carbon dioxide (CO_2). As a matter of fact, methane emission from landfill contributes 10 to 20% of total amount of methane emission from human activities (Juha-Kalle et al., 2007, IPCC, 2007; UN-HABITAT, 2010).

To reduce GHGs generation level many developing countries are running projects the CH_4 reduction such as decomposition, waste recycling, bio-digestion, and incineration (Mufeed et al., 2007). In 2009, the Cambodia Development Plan for 2009-2013 of Cambodian government showed positive commitment to solid waste control and management of environmental safety. However, formal laws for control and reduction of gas emission from landfill is still in process (Kum at al, 2009). In Thailand, the environmental and “Green growth” sector have important role to prepare eco-friendly measures as drivers for global and national development. The government promotion of “Growth first; clean up later” towards “Low carbon, Green growth” demonstrates a responsible awareness of sustainability in natural resource uses. Long-term environmental preservation on qualities of water and air, GHGs emission, solid waste and unlocking value of natural capital are the environmental policy for Thai government (Thailand competitiveness report, 2012).

1.2 Research Problem

Generally, waste generation is also the one of indicator to show the economic development. The development had more effect to the livelihood standard to change product consumption from basic consumption to no basic consumption have been impact to solid waste generation and management in the future. While there are significant economic advantages to the operation of landfills as bioreactor, our understanding of the mechanics governing accelerated waste degradation in landfill and its impact on waste geotechnical properties in limited. As such, there is need to explain and measurement of gas emission from landfill such as impact to impacts on the quality of environmental and people near the landfill sites. Unfortunately, there are different of model to estimate the greenhouse gas as methane emission from landfill under anaerobic conditions of organic waste are produced higher of GHGs emission by carbon content and water content. So, in this paper will be a range the gas emission model to find the better option to estimated greenhouse gas in landfill.

1.3 Objective

The main objective of this study is to estimate the potentiality of methane emission from waste management facilities at landfill by different models. Based on the characteristic of waste composition, experiment of organic waste and leachate and calculation of methane emission. The two specific objectives of the research are:

- To analysis of the solid waste characteristics.
- To estimate the methane emission and prediction by different models.

1.4 Scope and Limitations of the study

- Two selected landfills are Dang Kor Sanitary Landfill, located in Phnom Penh City, Cambodia and Saensook Sanitary Landfill, located in Chonburi province, Thailand.
- All the data of the research are technical and laboratory only. The cost analysis does not include social and financial agents.
- Only municipal solid waste is sample in this study.
- In leachate quality, we observed only BOD_5, which relates to methane generation.
- Only zero and first order decay (FOD) have been selected for calculation methane emission from landfill

Chapter 2 Literature review

2.1 Definition and types of landfill

Landfill is an engineered facility with specific pollution control technology against waste disposal in the form of space down into the ground where deposited a waste (Moreno B., 2011). Piping system is used to pump out any presence of liquid at the bottom of the site four types of landfill are

- Sanitary landfill, the trash is completed degraded biologically, chemically and physically. Sanitary landfill use technology to contain the waste and prevent the leakage of potentially hazardous substances. Two main methods used in sanitary landfill are the trench method and the area method.
- Construction and demolition waste landfills consist of the debris generated during the construction, renovation, and demolition of buildings, roads, and bridges. Different types of debris include: concrete, wood, asphalt, gypsum (the main component of drywall), metals, brick, glass, plastics, trees, stumps, earth, rock, and furniture (doors, windows, plumbing fixtures, etc.)
- Industrial waste landfills, are nonhazardous solid waste, consisting of nonhazardous waste associated with manufacturing and other industrial activities.

Municipal solid waste (MSW) landfills use a synthetic (plastic) liner to isolate the trash from the environment. The Environmental Protection Agency (EPA) has established minimum criteria that some material may be banned from disposal. Some material such as paints, cleaners, chemicals, motor oil, batteries, and pesticides.

2.2 Solid waste

Definitions of “waste” invariably refer to lack of use or value, or “useless remains” (Concise Oxford Dictionary). Waste is a by-product of human activity. Physically, it contains the same materials as found in useful products; it only differs from useful production by the lack of value. Solid waste is integrated in industrial waste, household waste, commercial waste, hospital waste, and organic waste from household (Olar, 2003). Tsai (2007) defined general types of waste such as garbage, excrement and urine, animal corpses in solid or liquid generated by households or other non-industries, which are capable of polluting the environment. The types of solid waste are considered in the term of waste are all inclusive and encompasses all sources, types of classifications, composition, and properties. As a basis for subsequent discussions, it will be helpful to define various types of solid waste. There are common types of waste:

- Municipal wastes are non-hazardous industrial, commercial and domestic refuse such as household organic trash, street sweepings, hospital and institutional garbage, and construction waste
- Industrial wastes are rise from industrial activities and typically includes rubbish, ashes, demolition, and construction waste, special waste, and hazardous wastes
- Hazardous waste is poses a substantial danger immediately or over a period of time to human, plant and animal life. Hazardous waste is grouped into following: radioactive substances, chemical, biological wastes, flammable waste and explosives. The chemical categories are corrosive, reactive or toxic substances. The principal sources of hazardous biological waste are hospitals and biological research facilities (Olar, 2003).

Municipal solid waste definitions follow the objective of waste component, countries indicator and author to represent a valuable resource. However, municipal solid waste must have a strict legal definition to comply with the meaning of each countries. Municipal waste is defined as any material arises from human and animal activities, which normally are discarded as useless or unwanted (Tchobanoglous et al, 1993); the common term used for waste collected and disposed of or on behalf of a local authority (Paul T., 2005) or normally assumed to include all non-industries, community waste: residential wastes, commercial wastes, and municipal service wastes (excluding treatment facilities) (Tsai, 2007). In addition, municipal waste mainly consists of household and commercial waste. It may also include waste derived from civic amenity waste collection/disposal sites by general public, street sweeping, gully emptying and construction and demolition.

2.3 Leachate

Leachate is the important problem from landfill beside the gas and odor problem. It might pollute the underground water quality and surface water around the sites. So, leachate is the also main concern of environmental issue in landfill. There are definitions of leachate from landfill are Leachate represents the water that 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 degraded by various microorganisms (Paul T., 2005) or Leachate is mobile portion of the solid waste in a landfill. It is generated from liquid squeezed out of the waste itself (primary leachate) and by water that infiltrate into the landfill and the percolates through the waste (secondary leachate). Leachate consists of carrier liquid (solvent) and dissolved substances (solutes). A leachate collection and removal system is used to collect the leachate produced in a landfill, to prevent the buildup of leachate head on the liner, and to drain leachate to a wastewater treatment plant by a sanitary sewer line or a leachate storage tank for treatment and disposal. (Xue et al., 2002).

2.4 Gas phases and biological effects

Biodegradability rate is in function of waste composition, waste nutrient level, the presence or absence of buffering agent and operational management practices. As degradation takes place, the solid mass is converted to gas, and void ratio increases, with consequent increase in the compressibility of waste. The settlement component due to biodegradation of solid waste can be related to landfill gas production and enhanced biodegradability with leachate recirculation.

In general, gas production is in function of waste composition. Waste composition has performed by visual or chemical methods. Cellulose and hemicellulose comprise 45-60% of the dry weight of MSW and are its major biodegradable constituents (Sahadat, 2002). The decomposition of these compounds to methane and carbon dioxide in landfills is well documented and their decomposition contributes to long-term settlement and stability of landfills. The conversion of cellulose and hemicellulose to CH_4 and CO_2 is carried out by three groups of anaerobic bacteria working together; (1) the hydrolytic and fermentative bacteria, (2) the acetogenic bacteria and (3) the methanogens. This process proceeds efficiently over a relatively narrow pH range around neutral. For cellulose, conversion reaction is shown in Equation 2.1 (Oonk&Boom, 1995).

$$(C_6\,H_{10}\,O_5)_n + nH_2O \rightarrow 3_nCH_4 + 3_nCO_2 \qquad (2\text{-}1)$$

Cellulose Monomer Bacteria

As cellulose and hemicellulose will be surrounded by lignin, they will not fully decompose due to the inhibitory effect of lignin. There are five phases of gas production, with the initial phase (phase 0) is taken as the fresh refuse before biological and chemical reactions take place. The four phases of waste were characterized (Sahadat, 2002).

Phase 1: Aerobic Phase:

During this phase oxygen present in the voids will be consumed for the CO_2 production and this will continue until all the oxygen is consumed. In aerobic phase leachate strength is relatively low and the gas produced are mainly CO_2 and N_2 with no methane production. The solid with gas potential remains almost same as the fresh refuse (may be 5-10% decomposition of solids) because this phase continues for a short period of time.

Phase 2: Anaerobic Acid Phase:

In anaerobic phase carboxylic acids accumulate and pH decreases. The gas produced is still mainly CO_2 with little methane production at the end of the phase. As transition to phase 3 takes place, pH starts to increase and carboxylic acid accumulation goes down with measurable production of methane. Cellulose and hemicellulose starts to decompose during this phase. The decomposition of solid is estimated to be between 15-20% based on laboratory data. The acid phase explains the time lag between the refuse burial and the onset of methane production.

Phase 3: Accelerated Methane Production Phase:

An increasing rate of methane production, increase in pH, decrease in carboxylic acid concentration, methane concentration of 50-60% marks the onset of this phase. Due to decrease in accumulation of carboxylic acid, pH increases significantly. Some additional solids decomposition occurs in this phase but much of the methane is due to depletion of carboxylic acids accumulated in phase 2.

Phase 4: Decelerated Methane Production Phase

The rate of methane production decreases but methane and carbon dioxide concentrations remains same as previous phase, 60% and 40% respectively. The rate of cellulose and hemicellulose decomposition is maximum in this stage. In earlier phases refuse decomposition leads to the accumulation of carboxylic acid whereas in fourth phase the rate of polymer hydrolysis exceeds the other phases and no accumulation of carboxylic acids are observed. Solid decomposition is 50-70% in this phase depending on methane production and operational management practices.

2.5 Waste generation

Chandak, (2010) showed that waste generation in Asian countries is about 657 million tones in 2025, twice higher than in 1998 of only 277 million tones. This rise is caused by many factors such as population and economic growth. European Commission (2009) showed that in 2015, almost 61% of world population will be increase in Asia population. In addition, GDP of Asia will increase up to 30% higher than Europe, which is only at 20%. Moreover, produces outcome of Asia will increase from 29% to 35% in 2025. Table 2-1 shows that the generation of MSW in Asian countries is in average between 0.2-1 kg per person per day. However, Thailand has highest MSW generation comparing to other developing countries, which shows that Indonesia, Cambodia, China, Sri Lanka and Philippine have only 1.1, 1, 1, 0.8, 0.9 and 0.7 kg/person/day respectively. This means that the higher developing countries are generating the MSW more than lower developing ones (in MSW generation kg/person/day).

Table 2-1 Waste generation rates of some Asian Countries, sorted by ascending gross national income (GNI) (Zurbrugg, 2002)

Country	GNI	Waste generation [kg/capital.day]
Nepal	240	0.2-0.5
Cambodia	260	1.0
Lao PDR	290	0.7
Bangladesh	370	0.5
Vietnam	390	0.55
Pakistan	440	0.6-0.8
India	450	0.3-06
Indonesia	570	0.8-1.0
China	840	0.8
Sri Lanka	850	0.2-0.9
Philippines	1040	0.3-0.7
Thailand	2000	1.1

Thailand experienced a surplus in the current account, ranging from USD 2.1 billion to 21.9 billon, before slowing down to USD 11.9 billion (0.8% in 2008, 8.3% in 2009, and 3.4% 2011 of GDP). Forecast of the population for the BMR[1], 2050 the information on population projections for Thailand 2003-2030 prepared by NESDB[2] was used as a base for the estimation (NESDB is a report, the projection was made to year 2030 for the whole counties

[1] BMR = Bangkok Metropolitan Region

[2] NESDB = National Economic and Social Development Board

and to year 2025 and 2020 for Bangkok and some provinces respectively made at provincial level).

The indicator to determines the increases of waste generation everyday all around the world are population growth, changes of income, change of consumption, economic development, and urbanization. Those sectors have more effects to consumption of human and waste generate back into environment (Uyen &Hans, 2009).

Population growth:

World population growth is a concerning problem for scientist because of this increase negative effect to environment and natural resource. As a prediction in 2015 world population is about 7.2 billion and going on growth over 2/3 in 2025. This increase still be going on to 125 billion in 2030 and 54% of them lived in the city (Ashok, 2008). Table 2-2 show the population in ASEAN has been grown faster from 1950 till 2010. Specially, in Indonesia (239,872,000), Philippines (93,211,000), Vietnam (87,848,000) and Thailand (69,122,000) have most population growth as shown in Table 2-2 waste support to population growth by population density increasing in all ASEAN nations. The highest population density is Singapore (7447.2 persons per km^2) and lowest population in Lao PDR (262 persons per km^2). However, in Thailand also 4^{th} higher population density rate in the regions after Singapore, Philippines and Vietnam who have rate about (1347 Persons per km^2) and look forward to Cambodia is lower range only 78.1 persons per km^2 in 2010.

Table 2-2 Population density by country, 1950-2010 (Persons/km^2) (UN, 2011)

Major area, country	1950	1960	1970	1980	1990	2000	2005	2010
South-Eastern Asia	38.5	48.8	63.4	79.9	99.1	116.5	124.6	132.0
Brunei Darussalam	8.3	13.9	21.7	32.8	43.7	56.7	63.0	69.2
Cambodia	24.0	30.0	38.3	35.9	52.7	68.8	73.8	78.1
Indonesia	39.3	48.3	62.1	79.2	96.8	112.0	119.3	125.9
Lao PDR	7.1	9.0	11.4	13.7	17.7	22.5	24.3	26.2
Malaysia	18.5	24.7	33.1	41.9	55.2	71.0	79.1	86.1
Myanmar	25.4	31.0	38.7	48.6	58.0	66.4	68.5	70.9
Philippines	61.3	86.7	118.2	156.9	205.4	257.7	285.2	310.9
Singapore	1496.5	2391.9	3036.7	3535.2	4416.7	5738.4	6246.0	7447.2
Thailand	40.2	53.2	71.9	92.5	111.2	123.1	130.0	134.7
Timor-Leste	29.1	33.6	40.6	39.0	50.0	55.8	67.9	75.6
Viet Nam	85.2	106.0	135.5	162.9	202.3	237.4	250.7	264.9

Income changes:

Following the Asian Development Bank (2010a), the ASEAN nations have increase incomed from 2 dollars to 20 dollars per day. This means GDP have been increased from 21% in 1990 to 56% in 2008. Table 2-3 shows that the GDP of ASEAN countries also increasing such as highest GDP in top three countries are 45,979 USD for Singapore, 12,724 USD for Malaysia and 7260 USD per year for Thailand. However, Cambodia is less developed countries so GDP level has only 1,739 USD per year.

Consumption changes:

In 2006, world expenses over $30.5 trillion for product and service supply that include food &household material. In addition, because of income changes it improved their livelihood to use consumer goods such as television, modern car, and so on (The world watch institute, 2010).

Economic development:

In 1999, product export is over 50.5% of GDP for ASEAN nations and it increases GDP to 62.7%. This means the economic development of ASEAN nation is increasing 5.3% from 1999 to 2008 (ADB, 2010b).

Urbanization

Between 1970-1995, urbanization increased from 37% to 45% for people living in the city. Moreover, rate of people the city will increase between 2005 and 2015 is over 55% to 60% in 2025 (Cavallier, 1996). Following the United Nation in population division (2011) showed in ASEAN average annual rate of population has over 1.163 and urban rate is 2.5 between 2005 and 2010. Moreover, urban population in Thailand 23,476,000 (about 34%) with annual growth rate of 2.5% and Cambodia 2,843,000 (about 20%) with annual growth rate of 3%.

Table 2-3 Urban Population, Development and Environment (UN, 2011)

Major area, country	Total Pop, 2010 (×10^3)	Urban Pop, 2010 (×10^3)	Urban Pop, 2010 (%)	AGA of urban pop[3], 2005-2010	CO_2 Emission (metric tones / cap, 2008)	GDP, 2009 (USD)
South-Eastern Asia	593,415	248,291	42	2.2	2.3	4,737
Brunei Darussalam	399	302	76	2,5	19.7	-
Cambodia	14,138	2,843	20	3.0	0.3	1,739
Indonesia	239,871	106,217	44	1.7	1.8	3,813
Lao PDR	6,201	2,058	33	5.6	0.3	2,048
Malaysia	28,401	20,497	72	3.0	7.3	12,724
Myanmar	47,963	16,138	34	2.9	0.3	-
Philippines	93,216	45,607	49	2.1	0.8	3,216
Singapore	5,086	5,086	100	2.5	11.8	45,979
Thailand	69,122	23,476	34	1.7	4.1	7,260
Timor-Leste	1,124	316	28	4.8	0.2	731
Viet Nam	87,848	26,687	30	3.3	1.3	2,682

2.6 Properties of Municipal solid waste

2.6.1 Classification of solid waste

The classification of waste can be based on different criteria and objectives, relating therefore to statistics of notoriously, population, fame. It is difficult to compare between sites or countries, which have different situation such as classification system, economic, social behavior of waste generation are part of waste classification. For example, the physical composition of MSW in Taiwan (A tropical country that has similar waste components to Cambodia and Thailand), are separated into papers, fibers/cloths, wood/leaves, kitchen garbage, plastic, rubbers/leathers. Tchobannoglous et al. (1993) showed that in the management process of solid waste based on sources and category of waste, component, generation rate are basis to propose the plan and process of waste management. Classifications of waste based on source are followings:

- Household sources: food, paper, plastic, box, glass
- Commercial: paper, plastic, wood, food, and some hazardous waste.
- Office waste: iron (Fe), and special waste

[3] AGA: Annual grown rate (%)

- Construction site: wood, cermet, iron and dust
- Urban service: road waste, waste at parking, garden and tree
- Treatment plan: sludge and sewage from treatment plan
- Industrial waste: hazardous waste, production waste, sewage and dust. (McDougall et al., 2003)

However, municipal solid waste classified into three main categories are household waste, commercial waste, and institutional waste (McDougall et al., 2003). Some studies show the important key strategies to manage the waste sector by Cambodian government policy to reduce and recycle waste by its component such as paper, plastic, paper box etc. In addition, paper and organic waste are generated more than others (Kumar, 2004). Move to waste classification in Mumbai, India by Sudhakar & Jyoti (2002) show the highest percentage of compostable (organic waste) around 60% and then paper, rag, glass, plastic, metals and moisture are 7, 4, 7, 9, 7 and 6 % respectively. Tsai W. T. (2007) is research paper of developed region in Asia Taiwan who has high population density and urbanization as well. In the waste classification of this countries are highest percentage is papers which amount 32.97 % which deferent from India and other developing countries. For other waste component in fiber/cloth, woods/leaves, kitchen/garbage, plastics, rubber/leathers are 3.78, 3.88, 27.19, 21.36 and 0.22 respectively.

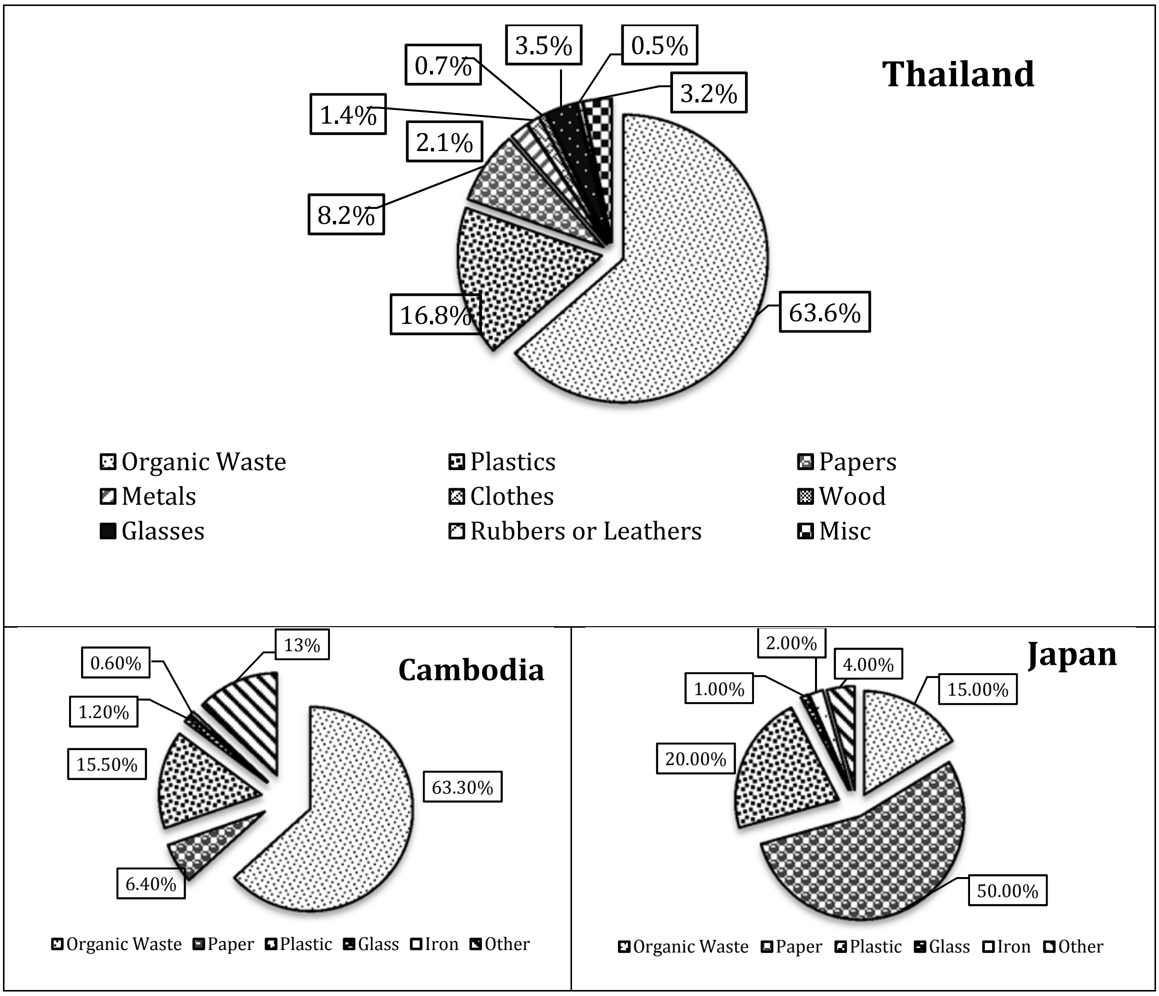


Figure 2-1 Comparing of waste generation with Cambodia, Thailand and Japan (AIT/UNEP, 2010; Heng et al., 2011 & Waste management SIAM, 2009)

Based on Figure 2-1, we got that waste generation in Cambodia is also a developing country. So, waste components generate is highest percentage in food or organic waste (63.3%) and then plastic has 15.5%, iron 0.6%, paper (6.4%), class (1.2%) and other waste of 13%. Moreover, the Cambodian waste has higher percentage in organic waste from food waste more than Japan over 48.2%. However, statistics of waste in Cambodia and Thailand are similar in the term of organic waste this type of waste related to landfill gas generation about 63%. Plastics are 15.5% and 16.8%. The moisture content shows that organic waste is high 64% of the waste being categorized as rapidly decaying. In 2004, moisture content of waste ranged from 50-60% with little difference between dry and wet seasons in tropical countries such as Thailand and Cambodia. Generally, the average moisture content that are assumed and applied in the landfill gas model should be 55% (Waste Management SIAM, 2009).

2.6.2 Moisture content

Howard et al, (1985) mentions the moisture content of solid waste usually is expressed at the mass of moisture per unit mass of wet and dry material. Typical data on the moisture content for the solid-waste components are given in Table 2-4.

Table 2-4 Typical data on moisture content of municipal solid waste components

Component	Moisture percent	
	Range	Typical
Food waste	50-80	70
Paper	4-10	6
Cardboard	4-8	5
Plastics	1-4	2
Textiles	6-15	10
Rubbers	1-4	2
Leather	8-12	10
Garden trimming	30-80	60
Wood	15-40	20
Misc. organic	10-60	25
Glass	1-4	2
Tin cans	2-4	3
Nonferrous metals	2-4	2
Ferrous metals	2-6	3
Dirt, ashes, brick, etc	6-12	8

2.6.3 Organic Contents

The organic content in a landfill affects the compressibility characteristics of the waste. Barlaz (1990), and Landva and Clark (1990) showed that the organic content ranges from 5 to 75 % with the major constituents being cellulose and hemicellulose. The organic content, cellulose and hemicellose, is higher at surface level and low at a deeper depth. The author suggested that due to the complete decomposition at the deeper depth, the cellulose content is lower. Landva and Clark (1990) showed that with increasing organic content, water content also increases and surface area increase due to the breakdown of particles. Wall and Zeiss (1995) reported that with the increasing organic content, the compression index increased. Therefore the organic content in the waste material should play a vital role for the development of compressibility model.

2.7 Impact of solid waste

Many researches showed that the rapid generation of urban waste, that action also impacts to social and economic aspect. Solid waste around the world is 2000 million tons per year (Giusti, 2009). Landfill produces many types are leachate, landfill gases, trance organics, litter, vermin and noise:

- Leachate: arises from the moisture contained in the deposited waste from the infiltration of water into site and from the biodegradation process itself.
- Landfill gases: mixture of methane and carbon dioxide, it can cause damage to vegetation, and also an explosion and hazardous. These gases are potential of greenhouse gases are methane and carbon dioxide.
- Trance organic: a variety of trance organic compound can be entrained with landfill gas such as chloride, alkanes, organic sulfur compound, etc. Many of these compounds has potential toxic, concentration in offsite air general too low to pose a threat to public health.
- Litter, noise, vermin: the nuisance aspects of landfills and their operation are potentially the most intrusive in the terms of disturbance and disruption to the amenities enjoyed by the surrounding population.

2.7.1 Economic Aspect

Solid waste management in the landfill and community management will have more impact to the economic, social and public health if it has not management or less management. As many researches got that chemical pollution in water, soil, air and transition in to human body by many ways from chemical component such as;

- Eye irritation: volatile organic compounds (VOCs)
- Bronchitis: particulate matter (PM), sulphur dioxide
- Increased susceptibility to respiratory infection: sulphur dioxide
- Asthma attacks: nitrogen dioxide

- Reduction in oxygen-carrying capacity of blood: carbon monoxide
- Effects on the central nervous system: lead, manganese, carbon monoxide
- Effects on the immune system: lead, dioxins, mercury, polycyclic aromatic hydrocarbons, benzene, polychlorinated biphenyls, organochlorine compounds including vinyl chloride, nickel, chromium, &toluene
- Reproductive effects: arsenic, benzene, cadmium, chlorinated compounds, lead, mercury, polycyclic aromatic hydrocarbons, polychlorinated biphenyls
- Cancer: polycyclic aromatic hydrocarbons, arsenic, nickel, chromium, vinyl chloride, benzene
- Effects on the liver: arsenic, polychlorinated biphenyls, chloroform, vinyl chloride
- Effects on the kidney: mercury, cadmium, chromium, arsenic, lead, halogenated hydrocarbons, organic solvents, and pesticides

2.7.2 Air Quality

Smoke, dust, mono organic and chemical toxic will ascend into environment after waste burn. Many researches said that when we burning, solid waste it will be grill waste in to small atom (with over 5 micro-mini meter) might be 12% will ascend into the environment. Following Lystbak (2004) many of them are kind of Ester, HS, P, Alkylbenzenes, Limonene, HCO, VOCs, CO, HCl, NOx, H_2COx all of have impact into air quality. Oyelola et al. (2009) show that when we less burning or burning without management all atom carbon, monoacid, formaldehyde and some chemical toxic will chance into Methane (CH_4) as site effect to global warming.

2.7.3 Water Quality

Many kinds of waste dissolve in the water or leach into underground water and aquatic area of water used by people around. Leaches of wastewater from landfill improves the BOD process in the water and decrease quantity of oxygen. The kind of leaches is oil, vinylchbride and hydrocarbon dioxide (Lystbak, 2004). In addition, Oyelola et al, (2009) give reason that material decomposition in the leaches is very harmful to pollution the environmental of ground water and underground water in the area near the landfill site.

2.7.4 Soil Quality

The soil pollution is causes by the problem from leaches and emission of toxic gases from landfill that have less management system. Base on waste component, climate, and aeration system that have relation with soil pollution. The chemical toxic leaches from landfill are heavy metal, salt and some gases that smog were travelled across the soil layer. It could disturb to some bacteria, who increase nutrient level in soil and other significant bacteria for soil quality. That is the way to soil pollution has been appear around the landfill site (Lystbak, 2004).

2.7.5 Climate Change

Pail T. (2005), Human activity increases the concentration in the atmosphere of greenhouse gases. The GHGs effect is produced by certain gases in the atmosphere which allow transmission of short wave radiation from the sunbeam are opaque to long wave radiation reflected from the earth's surface, thereby causing warming of atmosphere. Among others, waste generated GHGs have been considered as one of the most serious causes (Barton et al., 2007). However, follow IPCC (2006) considers that the carbon dioxide (CO_2) in landfill gas to be biogenic is part of the natural carbon cycle. So, IPCC concern only the methane content of the gas is included in calculations of atmospheric greenhouse gas emissions. This is expected to result a significant warming of the earth's surface and other associated changes in climate within the next few decades. The greenhouse gases that are making the largest contribution to global warming are carbon dioxide (CO_2), methane (CH_4) and nitrous oxide (N_2O). All three are produced during the management and disposal of wastes. The estimate total emissions of these gases from the EU are shown in Table 2-5, which also shows the contributions from solid waste disposal. It should be noted that there is considerable uncertainty surrounding these estimates.

Table 2-5 Anthropogenic emissions of CO_2, CH_4 and N_2O in the EU in 1994

Direct GHG	Emission (Mt)	GWP* (Over 100 years)	GWE** of all emission Mt equiv. CO_2 (% from SWD)	GWE emissions from SWD Mt equiv. CO_2 (% of total waste component for each gas)
CO_2 fossil	3,215	1	3,215 (<0.5%)	15 (9%)
CH_4	22	21	460 (33%)	152 (89%)
N_2O	1.05	310	325 (1%)	3 (2%)

*The Global Warming Potential (GWP), ** Global Warming Equivalence (GWE)

Global Warming Potential (GWP) is a factor that allows the concentrations of greenhouse gases to be expressed in terms of the amount of CO_2 that would have the same global warming impact. It depends on the spectral properties of the gas in question, its lifetime in the atmosphere and the time horizon chosen for climate change impacts. Follow table 2.6 the GWP of CO_2 from fossil sources is assigned a value of unity. Methane and N_2O are, respectively, 21 and 310 times more potent in global warming terms than the same mass of CO_2 (over a 100-year horizon). In the table also explain the data of CO_2 from solid waste disposal (33%) and waste management component (89%) is methane gas. The impact of solid waste management on the global warming equivalence of European greenhouse gas emissions comes mostly from CH_4 released as biodegradable wastes decay under anaerobic conditions in landfills. About one third of anthropogenic emissions of CH_4 in the EU can be attributed to this source. In contrast, only 1% of N_2O emissions and less than 0.5% of CO_2 emissions are associated with solid waste disposal. For this reason it is often assumed that reducing the amount of CH_4 emitted from landfills would have the greatest potential for reducing the overall climate change impacts of solid waste management. Furthermore, because the atmospheric lifetime of CH_4 is relatively short (only 12 years), it is estimated that overall emissions would need to be reduced by about 8 % from current levels to stabilize CH_4 concentrations at present's levels. This is a much smaller percentage reduction than those needed to stabilize the concentrations of the other two major greenhouse gases, CO_2 and N_2O.

So, developed countries have agreed under the UNFCCC (the Kyoto protocol) to reduce emissions of greenhouse gases. For the EU, the GHGs reduction for emission in 1990 is 8% in the period 2008-2012. Waste management policy will play a role in achieving this objective.

2.8 Calculation of GHGs as Methane Emission

The methane emission at landfill has three processes of emission, which are waste disposal into landfill, incineration without energy recovery, leachate and waste treatment operation. In 1994 a study (Oonk et al., 1994) was performed at several landfills in The Netherlands. Both first order and multi-phase models showed low mean relative errors in contrast to zero order models. The study resulted in the development by the TNO research institute of the first order model used by the Dutch government to calculate and report national methane emissions as if the waste were deposited at one landfill. The UK

Environment Agency (2006) prefers GasSim as the model for individual landfill operators to calculate and report their methane emission. Recently many models were developed in order to calculate landfill gas emission by countries that base on different situation of side disposal. In this present case study many different models are used to calculate the methane emission of landfill from other research. There are for types of model to calculation of methane emission are zero order models, first order model, modified first order model, and second order model.

2.8.1 IPCC Model, Zero order model

Intergovernmental Panel on Climate Change (IPCC) has been provides methodology for estimating national inventories of anthropogenic emission by source and removal by sinks of greenhouse gases. The IPCC have previously developed the revised 1996 IPCC guidelines, good practice guidance and uncertainty management in 2000, and 2006 IPCC guidelines. Follow the IPCC (2006) showed in the three volume of 1996 IPCC guidelines defines the coverage of the national inventory in term of gases and categories of emissions by source and removal by sinks, and the IPCC guideline in 2000 provide additional guidance on choice of estimation methodology, improvements of the methods, as well as advice on cross-cutting issues, including estimation of uncertainties, time series, consistency and quality assurance, and quality control. In 2006 UNFCCC invited IPCC stakeholder to revise the model of 1996 IPCC guidelines, taking into consideration the relevant work under the Convention and the Kyoto Protocol. IPCC Model (2006) is a method for estimate CH_4 emissions from solid waste disposal sites (SWDS) based on default method (DM). This methodology assumes that the degradable organic component (DOC) in waste decays slowly throughout few decades, during which CH_4 and CO_2 are formed. If conditions are constant, the rate of methane production depends solely on the amount of carbon remaining in the waste. As a result emissions of CH_4 from waste deposited in a disposal site are highest in the first few years after deposition, then gradually declined as the degradable carbon in the waste that are consumed by the bacteria responsible for the decay.

In IPCC's default methodology for waste, all greenhouse gas fluxes are treated as though they take place instantaneously. In fact, some fluxes such as emissions from landfills occur over a period of decades, and the greenhouse impacts will vary with time. There we assess the total emissions, not their phasing. This simplification does not undermine the value of the approach in comparing waste management options in terms of overall greenhouse gas contributions. Short-cycle carbon stored on land for longer than this time scale is considered. IPCC model is important to improve the estimation of methane following Tier 1 is default method (DM), Tier 2 and Tier 3 is IPCC-first order decay (FOD) and greenhouse gases emission inventory. Tier 1, Tier 2, and Tier 3 are showed below.

Tier 1: The estimations of the Tier 1 methods are based on default method (DM) using mainly default activity data and default parameters.

Tier 2: Tier 2 methods use the IPCC FOD method and some default parameters, but require good quality country-specific activity data on current and historical waste disposal at SWDS. Historical waste disposal data for 10 years or more should be based on country-specific statistics, surveys or other similar sources. Data are needed on amounts disposed at the SWDS.

Tier 3: Tier 3 methods are based on the use of good quality data of specific countries activity and then use of either the FOD method with nationally developed key parameter or measurement derived of specific country parameters. The inventory compiler may use specific method to country for equal or higher quality above FOD-based Tier 3 method. Key parameter was including the half-life, methane generation potential. However, in the both countries are have less site information and countries information to including in the model so Tier 3 is unavailable to use in the study.

As the report of IPCC in Model (1996, 2000, 2006 and good practices) explained for calculation the methane emission is based on statistics and data in the site because it is very necessary to find specific value for calculation of methane emission. However, some default values have been show following the region and country. The possible model for Cambodia and Thailand are IPCC Model, 2006 base on quantity of waste and landfill information have limited. There is the information need to add for calculation:

- Geographical information
- Total population of waste generation's source
- Amount of waste generation in kilogram per capita per year (kg/cap/year)
- The percentage of solid waste disposal site
- Total amount of waste generated in (Gg)
- Waste component such as food, paper, garden, carton, sewage, plastic etc.
- Degradable of organic waste (DOC)
- Fraction of DOC dissimilated (DOC_F)

- Methane generation rate constant (k)
- The process to transition waste into landfill in year (M)

Table 2-6 SWDS classification and methane correction factors (MCF)

Types of Site	Methane Correction Factor (MCF) Default values
Managed - anerobic	1.0
Managed - semi-aerobic	0.5
Unmanaged - deep (>5 waste) or high water table	0.8
Unmanaged - shallow (<5 m waste)	0.4
Uncategorised SWDS	0.6

2.8.2 IPCC First Order Model

The IPCC, First order decay (FOD) model introduced is default model method for calculation methane emission from solid waste disposal sites. In IPCC's *Revised 1996 IPCC Guidelines* and the *IPCC Good Practice Guidance.* Methane generation from SWDS is highest the first few years after deposition and then decreases as the available carbon is consumed. The assumption in the former default method that all methane is generated in the year in which waste is deposited creates inaccuracies in emissions estimates in situations where waste quantity, composition, and conditions are not the same every year. If waste disposal is increasing, this method will overestimate emissions.

According to IPCC guideline, 2006 said emissions are to be reported for "the calendar year during which the emissions to (or removals from) the atmosphere occur."5 The Guidelines strongly encourage the use of the FOD model, which produces more accurate emissions estimates that reflect the degradation rate of wastes in a landfill. To assist those countries that evaluated SWDS emissions with mass balance in the past and will now produce estimates using the FOD model, the IPCC developed the Waste Model, and improved default values.

Table 2-7 New FOD calculation method of IPCC model

Year	DDOCm disposed	DDOCm accumulation	DDOCm decomposed
0	100	100	0
1	100	190.5	9.5
2	100	272.4	18.1
3	100	346.4	25.9
4	100	413.5	33.0
5	100	474.1	39.3
6	100	529.0	45.1

2.9 Mitigation Options

Solid waste management is complication problem for all cities in the world especially in developing countries (Olar, 2003). So, mitigation and reduction options needed for reduction the impact of solid waste. So, mitigation options should be joined between governments and stakeholder involving from solid waste management experts to prepare the policy and strategy to solve this problem. Ashok (2008) showed that the countries with better economic growth and high income always have better SWM than developing countries who have problems with economic and human behavior that have effect to quantity of waste disposal and indirectly to GHGs emission to the atmosphere. So, mitigation should be thinking on gas emission by waste reduction because while the methane emission rate will decrease after a landfill is closed (as the organic fraction is depleted), a landfill will typically continue to emit methane for many (20 or more) years after its closure. There are two natural pathways by which gas can leave a landfill: by migration into the adjacent subsurface and by venting through the landfill cover system. In both cases, they use without capture and control, methane containing will ultimately emit into the atmosphere. The volume and rate of methane emissions from a landfill are in function of the total quantity of organic material buried in the landfill, the material's age, moisture content, compaction techniques, temperature, waste type, and particle size.

A common method for controlling landfill gas emissions is to install a landfill gas collection system that extracts landfill gas under the influence of a small vacuum. Good quality landfill gas (high methane content with low oxygen and nitrogen levels) can be utilized as a fuel to offset the use of conventional fossil fuels or other fuel types. The heating value typically ranges from 400 to 500 Btu/ft^3 (or 14.9 to 18.6 MJ/m^3), which is approximately a half the heating value of natural gas. Mitigation options for sanitary landfills may include landfilling, composting, recycling, MBT, anaerobic digestion and gas recovery.

Table 2-8 Advantages and Disadvantages of Reduction Options of Solid Waste

No	SWM Options	Advantages	Disadvantages
1	Landfilling	- Faster and Easier to operation - No need incinerator	- Large Landfill side - No Produce Energy - Leachate & Water Pollution - GHGs emission
2	Incineration	- Quantity waste reduction to disposal - Delay Landfill life - Produce Energy - Reduction Pollutant emission - Destroy some bio-organism and batteries	- Produce new chemical pollutant - High investment for operation and maintenance - Need end of pipe material - High Technology - Produce some smoke - Daily O & M - Need separated waste before incinerate
3	Recycling	- Waste reduction - Use as raw material - Improve recycling market	- No Energy production - Need Energy to operation - Investment for mechanical - Need separated waste before operation
4	Composition	- No need incinerator - Produce bio composting for agriculture - Increase quality of soil that use composting	- Separated waste before operation - No energy production - Reduction only organic waste
5	Anaerobic Digester	- Treatment and Energy produce in the same time - Reduce odor pollution - GHGs emission reduction - Convert from waste to composting for agriculture - Destroy some batteries, coli-form, parasite, and pesticides.	- High investment - Some problem with sludge from digester - Need space for gas storages - Need much water in the process - Need composting storages - Cannot destroy all batteries
6	MBT	- Small fraction of inert residual waste	- High expected value

No	SWM Options	Advantages	Disadvantages
		- Reduction of the waste volume to be deposited to at least a half (density> 1.3 t/m³) - Lifetime of the landfill is at least twice as long as usually - Utilization of the leachate - Landfill gas not problematic as biological component of waste has been stabilized - Daily covering of landfill not necessary - Huge scale (Possible to calculation carbon credit)	- Need more space - Some part of process effected to environment

2.10 Leachate

2.10.1 Composition of Leachates

The composition of the leachates depends on biodegradation reached by the waste, the moisture content and the operational procedures. The characteristics of leachate are influenced following by the waste material deposited in the site, Paul T. (2005). Not only the water from waste produces wastewater and then leach at the bottom of landfill as leachate but the drainage of the rainwater falling on the site is required to ensure that excessive water does not infiltrate the waste directly or from run-off from surrounding areas. Some study showed that integrated samples of leachates can be collected during wet and dry periods and analyzed for pH, suspended solids (SS), biochemical oxygen demand (BOD), chemical oxygen demand (COD), ammonia, nitrate, phosphate, sulphate and trace metals among others;

(i) Dissolved organic matter is quantified as chemical oxygen demand (COD), or total organic carbon (TOC) and volatile fatty acids.

(ii) Inorganic macro-components include: Ca, Mg, Na, K, NH_4, Fe, Mn, Cl, SO_4 and HCO_3.

(iii) Xenobiotic organic compounds (XOCs) are organic compounds, which originate from household or industrial chemicals and are usually present in relatively low concentrations.

(iv) Heavy metals include: Cd, Cr, Cu, Pb, Ni, Hg and Zn.

2.10.2 Amount of Leachate Generation

The loading history describes how the concentration of a contaminant or its rate of production varies as a function of time at the source. Leachates rates at a landfill are controlled by seasonal factors or by a decline in source strength as components of the waste such as organics & biodegrade. Many factors influence leachate composition; these include the types of wastes deposited in the landfill, the amount of precipitation in the area and other site-specific conditions. The rates of biological and chemical activities taking place in the landfill can also affect to leachate quality by altering the way that waste dissolves or migrates with leachates. The factors affecting to quantity of leachate in the landfills are:

- Composition of garbage, leachate is decomposed liquid from fresh garbage. The composition of fresh garbage directly relates to the properties of leachate. Since the garbage varies from sites to site and from time to time the composition of the leachate will follow the same pattern.
- Type of landfill is also effective to leachate of the influence of hydrogeological and geo-hydrological conditions according to whether it is located above or below the ground.
- The age of landfill is the important role that related to degree of decomposition and times of landfill that running.
- Weather influences the stability of a landfill and consequently, will affect the quantity of leachates inside the landfill by rainfall, flood as the weather condition.
- The characteristics of leachate will affect the subsurface soil condition, fluctuation of groundwater, characteristic of aquifers and geological formations. That sectors are directly to the characteristic of a landfill site and consequently affect the properties of leachate.
- Chemical and bacterial on breakdown are activities, which changes the properties of leachate.

2.10.3 Impact of Leachates

Municipal landfill leachate is considered one of the types of wastewater with great potential to impact the environment, if migration is allowed, due to the presence of diverse pollutants. Landfills have liners at the base, which act as barriers to leachate migration. However, it is widely acknowledged that such liners deteriorate over time and ultimately fail to prevent the movement of leachates into an aquifer. It can take years before groundwater pollution reveals itself; and chemicals in the leachates often react synergistically and often in unanticipated ways to affect the ecosystem. Leachates have been implicated as environmental pollutant such as air, soil, surface water and groundwater pollution. The knowledge of the quantity and composition of leachates usually gives an insight into appropriate, effective and sustainable treatment approach. Some studies documented the physical, chemical and traces metals characteristics of leachates from the major repository of municipal solid wastes are different in the different sites.

The leachate from MSW dumping site is a highly concentrated (chemical soup), so chemical concentrated that small amounts of leachate can pollute large amounts of groundwater rendering it unsuitable for uses in domestic water supply. In addition to potential carcinogens and highly toxic chemicals, MSW leachate contains a variety of conventional pollutants that render a leachate-contaminated groundwater unusable or highly undesirable due to tastes and odors, reduced service life of appliances such as dishwashers, water heaters, plumbing, fabric (clothes), etc. Furthermore, both gas and leachate from uncontrolled MSW landfills contain many organic chemicals that have not been characterized with respect to specific chemical content or their associated public health or other hazards. These non-conventional pollutants include more than 95% of the organics in MSW leachate. Leachates contain a host of toxic and carcinogenic chemicals. Which may cause harm to both humans and the environment. Leachate-contaminated groundwater can adversely affect industrial and agricultural activities that depend on well water. For certain industries, contaminated water may affect product quality, decrease equipment lifetime, or require pretreatment of water supply, all of which cause additional financial expenditures. The use of contaminated water for irrigation can decrease soil productivity, contaminate crops, and move possibly toxic pollutants up to the food chain as animals and humans consume crops grown in an area irrigated with contaminated water

2.11 Methane Calculation from Leachate

A significant amount of methane can be emitted from the treatment of wastewater and also in leachate with high organic matter content. The principal factor that determines the methane generation potential of wastewater is biochemical oxygen demand (BOD) loading. Abdulla (2000) showed that organic content of wastewater determines the methane generation potential of wastewater. The amount of biodegradable organic matter in wastewater is referred to BOD under the same condition if wastewater has higher value of BOD concentration, which yields more CH_4 than wastewater with lower BOD concentrations.

The IPCC (2000) default methodology used for estimating CH_4 emission from Waste Water Treatment Plants (WWTPs). This methodology is simple and straightforward and can be presented by the equation (29) Abdulla and Al-Ghazzawi (2000) was showed that fraction of wastewater treated anaerobically (FA) is the most difficult step in estimating methane generation from wastewater treatment plants. Because IPCC Model guidelines suggest approximation of fraction value it is best on region of countries; 0.15 for Oceania, North America, and Europe and for Asia, Africa, Latin America is less than 0.10 for non-treatment plant. So it is should be base on specific sites or local condition. And base on FA value, we can approximated the treatment system for operation such as highest value (0.6) is WSP plants lowest Value (0.15) is Bio-filtration+ Activate sludge ad Rotating Biological Contactor + Activate sludge treatment system, 0.2 is Activate Sludge, and 0.25 is Bio-filers and Bio-filtration + Membrane plant.

2.11.1 IPCC model

The BOD for domestic wastewater is a function of population. The IPCC (2000) default methodology was used for estimating CH_4 emission from Wastewater Treatment Plants (WWTPs). This methodology is simple and straightforward and can be present by Equation for wastewater.

This methodology is simple and straightforward and can be present by Equation below

$$MEWW = D \times FA \times EF \tag{2-2}$$

where: MEWW = Methane emission from wastewater (Gg)

D = Annual organic material BOD in the wastewater (Gg)

FA = Fraction of wastewater that is anaerobically treated about 0.1

EF = Emission factor (the recommended emission factor is 0.22 Gg CH_4/Gg BOD

2.12 Other Researches

Municipal solid waste is complex seriously concerning for environment and public health. It can result in water pollution, air pollution, global temperature rising. In face on this problem, many research studies is pay attention only on greenhouse gases emission with using calculation methane emission from solid waste, landfill and leachate. There are many research studies related to issues thought the methodology, research finding:

Ziad D. Al-Ghazawi, (2000) about Methane emission from Domestic Waste Management facilities in Jordon. The research characterize municipal solid waste generated and estimates the methane generated from waste management facilities in the country, and use IPCC guidelines were used for calculation all emission from waste; wastewater and solid waste. In addition, the research also use uncertainties associated to developing more sophisticated methodologies for estimation of methane emissions. Also show the criterion some different treatment technologies such as aerobic, anaerobic or both to improve the efficiency of methane reduction from wastewater.

Ziad D. Al-Ghazawi, (2008) about Mitigation of methane emission from sanitary landfill and sewage treatment plant in Jordan. The research was summarized in the three major steps by estimated the GHG inventory with provides baseline data and requires the reduction and elimination to minimizing the net emission of GHGs and then develop the action plans and policies. There are using calculate of emission from wastewater treatment plant and solid waste by IPCC Model as default method (DM) because the default method needs less information, are total MSW generate and waste characteristic is enough for solid waste and data of BOD for leachate. Moreover, the research used uncertainty analysis method to inherent within any kind of estimation emission inventories when input parameters have large number especially error number during estimation of the methane generation potential. In addition, they used emission forecast to estimate the methane emission prediction from 2005 to 2030. The paper also gives the mitigation options and strategies from both MSW-landfill biogas was recovery for electricity generation and investment on WWTP ponds and activated sludge technology for WWTPs.

Kumar et al., (2004) studies about the estimation method for national methane emission from solid waste landfills in India by using IPCC Model (2006) as default methodology to assumes all the potential methane emitted in the year of waste deposition and a triangular model for biogas from landfill has been proposed for compared the result. In the paper also gives information that for better estimated LFG by using the fist-order decay (FOD) in two phase such as rate of generation keep on increasing till the peak is reached and then keep on declining till the material is stabilized is might be necessary to adopt empirical relationship coupled with scientific logic. The values estimated using triangular form give realistic values as it is based on the assumption that the gas generation follows triangular form and the gas keeps on generating for the next 15 years. Every year the methane is generated due to waste deposited in the past 15 years.

Arvind K. et al., (2007) showed that in developing countries such as India, estimated methane emission for landfill have large uncertainties due to inadequate data availability on management and emissions. Municipal solid waste was disposed to landfill with recyclable and compostable material. So the measurements of GHG emission needs reduce uncertainties in the inventory estimates from source is important factor. This study using three approaches of field measurement and empirical model equation as recommended in Tier I and Tier II of IPCC guidelines. As a result, during the increase of population of Mumbai to 12.3million in 1991, a 49% growth as compared with 1981. However, MSW generated increased fro 3.2 to 5.35 Gg per day (~67%). That is shown the pressure for garbage on available landfill for alternate arrangement of MSW management. So, The options of MSW are disposal apart from landfill in topographic depression. Physical composition of waste has not significantly changed in recent time.

Tsao-Chou, (2008) also published about correlation between municipal solid waste management and GHGs emission with the volume and physical composition of the waste with difference local environments and lifestyles related to generate quantity and composition of waste. They are leading differences of waste treatment methods and causes different volumes of GHGs that need local research by using Life Cycle Assessment to analysis. As result the research study give some options for reduce waste generate such as using for fuel in transportation, recycling method, incineration, compositing, landfilling and swine feeding in pig industrial. However, some limitation of options was shown depending on the information quality of waste generation.

R. Couth, (2011) research in the Africa. Some uncertainties over the quantity of GHGs emission from waste managements are notably from waste disposal. The data have been collected on SWM for territories in Africa. After this introduction, the paper provides background information on GHGs emissions from waste management, and method and model used to assess GHGs emissions, The paper then describes the methodology used to calculate GHGs emissions, and this is followed by a model description. The result, the modeling was described for the FOD model and summarized for current GHGs emission and the potential increase in GHGs emission from SWDS in Africa over next 10 years.

Chapter 3 Research methodology

3.1 Introduction

Solid waste sector is a new issue for any countries including Cambodia and Thailand. A few research paper been discussed about the impact and some activities related to solid waste. This research is finding the much information related in the topic “Estimation of Methane Emission and Proposed Mitigations of Sanitary Landfill” case studies at Dang Kor, Phnom Penh City, Cambodia and Saensook, Chonburi Province, Thailand. This research will extend the findings the information related to leachates analysis then we find the total methane emission at landfill from many models. Moreover, study will predict the methane generation over 15 years.

3.2 Sampling

3.2.1 Sampling Period

Cambodia and Thailand have the same weather conditions excluding the north part of Thailand with cold weather. However, both of sides has common range of temperature at its maximum in April at 35 °C and minimum to around 30 °C from November to January. The temperatures have important role that affects moisture content and solubility of organic matter and other waste in rainwater. So, the research will conduct twice sampling selection is two times or two samples in wet season, which wettest season in the year for show the limitation of waste characteristic and other two samples in dry season which is hottest season in the year for show the limitation of waste characteristic when driest; low moisture content. The study can represent the whole year of waste disposal.

3.2.2 Sample Selection

The selected sample should to present the whole waste in landfill. Two steps will be used to run the experiment: waste collection and waste separation. The research collected total 100 kg, by collect 11.1 kg of waste from each truck that transported waste from municipal from different district to represent waste generation from city into site study. The collection will be done 4 times during the whole year, therefore, twice in each season.

3.2.3 Waste collection process

After we collected waste sample from all the trucks that represent all the areas of waste generation then we uses equipment to mix waste together by using Quartering Method and follow the structure below:

- Take out some waste sample might be ¼ from total sample
- Prepare material and mix the waste again
- Collect waste to be pile of waste.
- Separate it into four pieces and mark A, B, C, and D in Quartering Method (Figure 3-1)
- Take Side B and Side C out, then mix waste of part A and D together again
- Separate again to get the mid-total of waste is 50 kg
- Put sample in to Plastic Bag and then waste separation process.

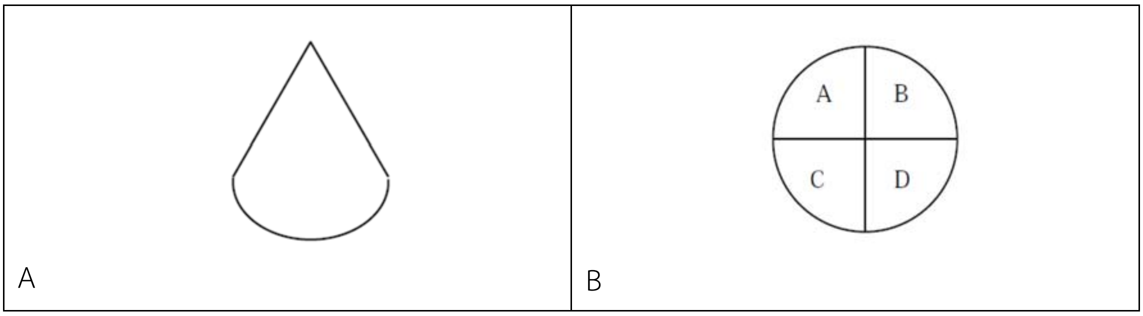


Figure 3-1 Quartering Method

3.2.4 Waste separation process

There are the steps of waste separation process for waste component:

(i) Pull out of waste in to carpet plastic then separated it by separate's materials

(ii) Separate waste into different 14 classifications below different models are IPCC Model and EPA's LandGED Model

- Papers and cardboard
- Vegetables and food waste
- Textiles
- Wood
- Nappies (disposable diapers)
- Garden and park wastes
- Leathers
- Plastics
- Iron materials
- Glasses
- Stone and ceramic including animal bones
- Rubbers
- Clothes

- Other components which weight smaller than 5 mm (ash, dirt, dust, soil

(iii) During the separation, note separate waste component that have weight smaller and bigger than 5 mm in different class

(iv) Weight the each type of waste and jotted down the amount of some type, which have low percentage.

(v) Cut each class of waste to small then mix together

(vi) Take out the waste the outside of class

(vii) Weighted each type of waste again

(viii) Take each waste in to digester for organic waste to experiment

3.3 Methane Calculation from landfill

Annual European Union GHGs inventory report 2010 to UNFCC secretariat in 2010 got that the highest percentage of emission factors is landfill disposal stand on 93% of total emission in landfill. And for the leachate and wastewater treatment plant has 3% of emission and the last one is incineration without energy recovery with 4%. However, at Saensook sanitary landfill is operation without incineration, so 100% of total methane emission from landfill has only waste disposal and leachate in the consideration of research study. Moreover, Dang Kor sanitary landfill has incineration for operation with hospital waste and biological research facilities. Which was separated from municipal solid waste. So the total methane emission is the same as Saensook sanitary landfill for consideration.

Zero order models are kind of models that biogas generated from landfills is remained steady against time on this basis such as waste age and waste type have no effect on gas production. Some of models are based on zero order decays are EPER Germany, SWANA zero order and IPCC model have been selected for this study.

First order model (FOD) is available which predicted biogas from landfills in among ones developed based on first order decay models. These models have been considered quality of waste (such as moisture content, carbon content, age of waste and ability of waste to be digested, waste quantity and condition on landfill (climate, temperature, precipitation) implicitly. Methane emission might be obtained from models and general calculation from the methane balance in Eq. (3-1).

$$\text{Methane Emission} = \text{Methane Generation} - \text{Recovery} - \text{Oxidation} \quad (3\text{-}1)$$

When the modelling methane emission, most of discussion are about modelling methane or landfill gas formation. There are numerous models around, most of the based on a first-order decay model or a multi-phase first order model. Modelling oxidation has received less attention. In most cases 10% of methane flux through the top-layer assumed to be oxidized. To find the total methane generation from landfill is based on each model below by IPCC first order model, SWANA, Belgium, US EPA's LandGEM, TNO, GasSim, Afvalzorg, EPER France, LFGGEN, Scholl Canyon, Modifies Triangular model, and model my specific countries such as Thailand, Mexico, China, Colombia, Philippine etc.

3.3.1 IPCC zero-order default model (DM)

IPCC, 2006 calculates the methane emission from landfill with the general equation:

Methane Emission = $(MSW_T \times MSW_F) \times MCF \times DOC \times DOC_F \times F \times (16/12\text{-}R) \times (1\text{-}OX)$ (3-2)

where: MGP = Methane Generation Potential (Gg CH_4 /Gg Waste)
(When 1Gg of Waste = 1000 Tons of Waste)

MCF = Methane Correction Factor (The Value base on waste disposal and height of landfill. IPCC was determine that the initial value of MCF is 0.4 for Open Dumps and have height lower than 5 m. The fraction depends upon the method of disposal and depth available landfills. The IPCC document indicated those values by types of landfill site.

DOC = Degradable Organic Carbon (The Volume of DOC is necessary for methane calculation because it is based on waste component at landfill. It always changes every site of landfill. It is calculation from formula below:

DOC = 0.4×(A%) + 0.17×(B%) + 0.15×(C%) + 0.3×(D%)

A = Paper + Rags is percentage (%) from waste component

B = Leave + Garden + Dry herb &Straw is (%) from waste component

C = Fruit + Vegetable is percentage (%) from waste component

D = Wood is percentage (%) from waste component

DOC_F = it is based on DOC convert waste into gases (LFG). They could be determines the value by changes of the climate in the anaerobic condition. The Temperature in 35 Celsius the initial values is 0.77. The model is described as 0.014 T + 0.28, where T is temperature in (°C). It is assumed that temperature remains constant at 35°C in the anaerobic zone of the landfill.

F = Quantitative of Methane in landfill is the Default values is 0.5 (In anaerobic condition 50 % of biogas released is methane)

16/12 = it is the ratio of molecular weight of methane to carbon.

So, CH_4 emission from landfill = CH_4 potential (Gg) × Waste disposal to landfill (Gg)

Some data is not included in the equation

- MSW_T is the total municipal solid waste (MSW) generated (Gg /year). Total MSW_T can be calculated from population (in thousand persons) × annual MSW generation rate (Gg 10^{-3} persons /year).
- MSW_F is fraction of MSW disposed of at the disposal sites. The percentage of 70% is based on field investigative studies. The remaining 30% is assumed to be lost due to recycling, waste burning at source as well as at disposal site, waste thrown into the drains and waste not reaching the landfill due to inefficient solid waste management system.
- R is recovered methane (Gg/year). The recovery of LFG is not adopted in sites study hence the value is zero.
- OX is the oxidation factor (default is 0). It accounts for the methane that is oxidized in the upper layer of disposal sites where oxygen is present. Oxidation may reduce the quantity of methane generation that is ultimately emitted. However, there is no internationally accepted factor and can be assumed as zero.

3.3.2 IPCC First Order Decay (FOD) Model

The basic equation for the FOD in the IPCC, 2006 Model using the option and a time delay is presented below (see Eq. (3-3)). This is the simplest inventory calculation performed by the model. The rate of LFG production is predicts by a first order kinetic model in Equation 3-18a, where the generation rate of the decomposable degradable organic carbon $DDOC_m$ (Gg of organic carbon) decays exponentially with time.

$$\frac{d[DDOCm]}{dt} = -k(DDOCm) \quad (3\text{-}3)$$

where: k = Reaction rate constant (year^{-1})

DDOCm = Defined as W × DOC × DOC_f × MCF. DOC is the organic carbon content in respect to the solid waste total amount (Gg of organic carbon/Gg of total SW), W is the total waste mass (Gg), DOCf indicates the fraction of DOC that is supposed to undergo anaerobic reactions (dimensionless), and MCF is the methane correction factor (dimensionless).

The integration of Eq. (3-3) leads to the expression of the decomposable degradable organic carbon as a function of time, as:

$$DDOC_m(t) = DDOC_m(0)\,(e^{-kt}) \quad (3\text{-}4)$$

where: DDOCm(0) = Initial value of DDOCm (Gg of organic carbon)

t = Time (years).

In order to evaluate LFG generation, IPCC (2006) alternatively rewrites Eq. (3-5) for

$DDOCm_{dec,i}$, which is the amount of $DDOC_m$ present in the landfill that is decomposed at end of one year of site operation for a specific waste component,

as presented by Eq. (3-5).

$$(DDOCm\ decomp)=((DDOCmdec_T)+(DDOCma)) \times (1-e^{-ki}) \quad (3\text{-}5)$$

where: $DDOCm_0$ is the DDOCm value of the mass disposed in the first day of the analysis year (Gg of organic carbon), if any, DDOCma (Gg of organic carbon) is the residual amount of DDOCm that was not decomposed in previous years (for the first year of landfill operation is null).

In the present work, the mass of generated methane CH_4g (Gg) was determined for a specific waste as,

$$CH_{4g} = F_{CH_4} \times MW_{Ratio} \sum_{t=1}^{z} (DDOC_{m\ decomp.})_i \quad (3\text{-}6)$$

where: F_{CH4} = volume fraction of methane in final LFG

MW_{Ratio} = molecular weight ratio of CH4 to C (16/12)

z = number of waste components.

3.4 Leachate Sampling and Testing

Standard method will be used for physicochemical analysis for leachate, well water and spring water samples. The purpose of ground water and leachate sampling and analysis are aimed to compare physicochemical properties water and leachate quality with nationally and internationally accepted protocols (standards). Sample collection, shipment, storage and analysis were conducted in the study period.

Analysis of sample period will have a 5-day carbonaceous BOD below 1 mg/L. Moderately polluted rivers may have a BOD_5 value in the range of 2 to 8 mg/L. Municipal sewage that is efficiently treated by a three-stage process would have a value of about 20 mg/L or less. Untreated sewage varies, but averages around 600 mg/L in Europe and as low as 200 mg/L in the U.S., or where there is severe groundwater or surface water infiltration/inflow. The generally lower values in the U.S. derive from the much greater water use per capita than in other parts of the world (Timothy, G., 2004)

The ratio of BOD/COD can only be found by measuring BOD and COD over time and by using this data to find a correlation. Once gathered COD and BOD data for the sample, divide the average BOD result by the average COD result to find the ratio or conversion factor. Multiply the COD results by this factor to estimate your BOD concentration. COD values are almost always higher than BOD as results for the same sample; the conversion factor should be less than one.

3.5 Leachate Prediction and Methane Calculation from Leachate

3.5.1 Water Balance Model (WB)

Precipitation is on the basis of the leachate volumetric flow rate estimation. Generally, it represents the main source of moisture in the landfill, and by consequence the source for leachate production. It allows for the determination of landfill generated leachate by quantifying the change in landfill moisture storage through a mass balance between the main source of incoming water (precipitation; snow; initial moisture in the SW; initial moisture in the covering material; infiltration from underground water sources; leachate recirculation etc.) and exiting soil moisture (emissions for the environment; leachate to collection system; saturated water vapor within LFG; lost in formation of LFG) (Thomazoni & Schneider, 2013).

The method proposed to relies on the fact that the main source of moisture comes from the precipitation over the landfill area. Equation (3-18) accounts for the water balance *WB* for the soil moisture determination on the landfill cover layer, given by:

$$L_A = P + S - E - WA \quad (3\text{-}7)$$

where: L_A = Leachate from active area (L^3/T)

P = Precipitation (L^3/T)

S = Pore squeeze liquid from waste (L^3/T)

E = Evaporation (L^3/T)

WA = Waste moisture adsorption (L^3/T)

3.5.2 Methane generation Estimate by IPCC model

A significant amount of methane can be emitted from the treatment of wastewater with high organic matter content. The principal factor that determines the methane generation potential of wastewater is biochemical oxygen demand (BOD) loading. The BOD for domestic wastewater is a function of population. The IPCC (2000) default methodology was used for estimating CH_4 emission from Wastewater Treatment Plants (WWTPs). This methodology is simple and straightforward and can be present by Equation below

$$MEWW = D \times FA \times EF \quad (3\text{-}8)$$

where: MEWW = Methane emission from wastewater (Gg)

D = Annual organic material BOD in the wastewater (Gg)

FA = Fraction of wastewater that is anaerobically treated about 0.1

EF = Emission factor (the recommended emission factor is 0.22 Gg CH_4/Gg BOD

Chapter 4 Results and discussions

4.1. Description of Dang Kor Sanitary landfill

4.1.1 Collection, transportation and landfill design

Phnom Penh capital city has nine communes that disposal municipal solid waste into Dang Kor sanitary landfill is a new landfill after Stung Mean Chey landfill full in 2004. In Figure 4-1 show the map of Phnom Penh with Dang Kor Sanitary landfill. It is located in Phnom Penh City approximately 11 km southeast of Phnom Penh near flat area. The nearest residential properties are reported to be 5 km west and 2 km northeast of the site. The site is located at the southern edge of the municipality area under the jurisdiction of Phnom Penh. All municipal solid waste in Phnom Penh is transport into this site without separation.

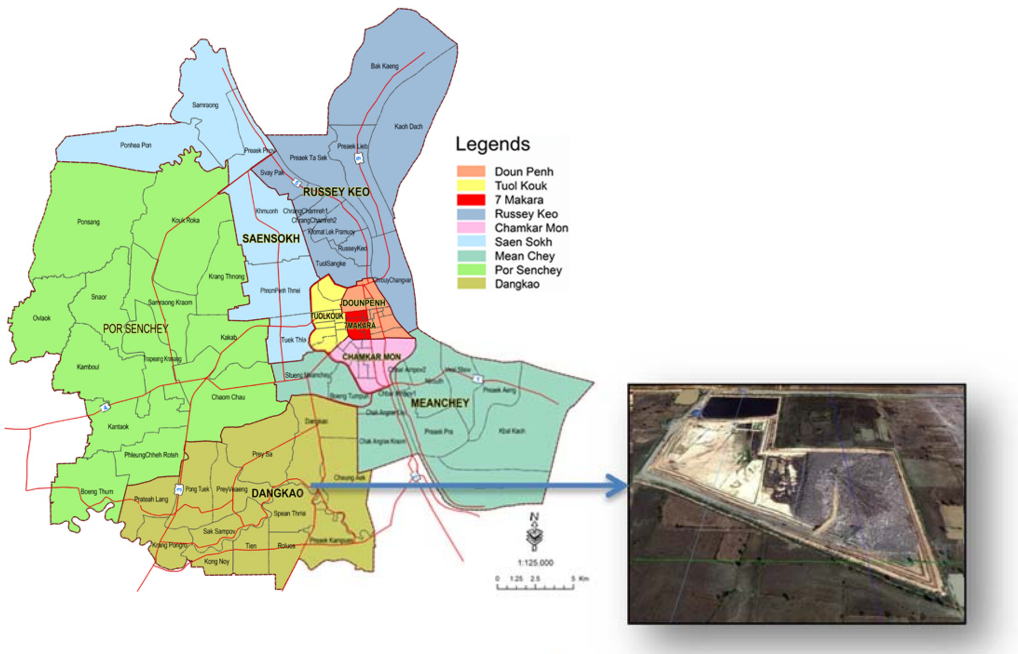


Figure 4-1 Map of Phnom Penh Municipality and Dang Kor Sanitary Landfill

Dang Kor Sanitary Landfill was designed and constructed at 2009 under management by Phnom Penh Municipal Hall. Moreover, it is also under manage co-operation between the Department of solid waste management, Phnom Penh Municipal Hall responsibility on operational system and the Department of Environment, Ministry of Environment in responsibility on population control and regulation.

The new sanitary landfill at Dang Kor site is a new space for disposal of waste from Phnom Penh. This site was developed to have leaches system, incinerator and bio-digestion.

This new site has total area over 31 hectares and far from Phnom Penh City is 10 km. In 2009, is the first step of development processing of landfill management is an operation processes. The first step area was separated this site in to two areas (Area A and Area B) in area about 84,200m^2.

Figure 4-2 Dang Kor Sanitary landfill Map

4.1.2 Landfill Physical Characteristics

The site is located in a paddy field area and there are no visible dwellings in the vicinity of the site. The Prek Thnaot River, which is a tributary of the Bassac River, runs west to east in the south of the project site. The area used to be flooded by the Prek Thnaot River. The flooding had stopped since 2007 when the riverbanks were constructed. With available information and some research from surrounding area, the disposal site is envisaged to be covered with a clay layer about 10 m in depth and there is a sand layer with a permeability of 1 x 10^{-3}cm/s in the eastern part of the site, between 3 to 4 m in depth from the ground surface. The clay layer has a permeability of 1 x 10^{-6}cm/s. Groundwater table as inferred is below 10m from ground level.

Cambodia has dry and raining seasons. The dry season occurs from December to April and the wet season from May to November. Up to 70% of annual rainfall occurs from May to October. The annual rainfall in Cambodia is in the range of 1,400 mm up to 1,800 mm. In Phnom Penh, rain from May to August produces a monthly rainfall of about 150 mm. The maximum rainfall of 300 mm falls from September to October. Temperature reaches maximum in April at 35 °C and dropping to around 30 °C from November to January.

Table 4-1 Precipitation and Evaporation in Dang Kor Sanitary landfill

	2004	2005	2006	2007	2008	2009	20010	2011	2012	2013	2014
Precipitation	1250	1400	-	1253	1270	1400	1350	1500	1350	1130	-
Evaporation	1351	1382	1310	1370	1425	1402	-	-	-	-	-

Note: Evaporation data from Tomonori et al, (2011) for Bornean tropical rainforest.

4.1.3 Disposal history and estimated future disposal

At Dang Kor sanitary landfill receives higher amount of waste about 927.8 tones per day from Phnom Penh city disposal into landfill in 2005 and Analysis of the data generated shows that on average, the dumpsite receives 1,273 tones per day of waste with maximum of 1,425 tones per day and minimum of 1,007 tones/day as shown in Table 4-2. This number will increase if there is no separation of waste from the sources (before disposal). Base on the report of JICA (2005) show that, only 584.1 tones from household waste and over 343.7 tones from commercial waste per day. Moreover, solid waste from Phnom Penh city will increase from 924 in 2007 to 1,550 tones per day in 2015 as shown in Figure 4-1. In fact of waste generated from municipal solid waste in Phnom Penh noted that the percentage of municipal solid waste (MSW) disposed in to landfill is nearly doubled from 25% to 49% in 2008. In 2010, the monthly average was 34,026 tones/month while the maximum was 39,445 tones/month and the minimum was 29,843 tons/month. Follow the monthly record of total amount for the year 2009 to 2010 is average increasing 15% and 2010 to 2011 have about 2.7%. From year 2010 to 2011 the amount disposed in Dang Kor remains fairly constant as disposal at Dang Kor depends very much on the amount of waste collection by Cintri and Phnom Penh Municipality. Moreover, in 2011, the area served by Phnom Penh Municipality had doubled. However, a mount of waste that will be disposed at Dang Kor remains heavily depend on the amount of waste captured by Cintri. However, in 2010 solid waste have been disposed to Dang Kor sanitary landfill over 409,335 tones, which exceed the prediction of JICA's authorities in 2005. In table 4-1 mention about population forecast in Phnom Penh city which important indicator to waste generation prediction. Because of Phnom Penh faster developing so new rural area that have been including into Phnom Penh municipal is Por Senchey and Saensook district which have low population and no waste collection services in that area yet.

Table 4-2 Population forecast in Phnom Penh by areas (excluding new areas)

No	District	2003	2007	2012	2015
1	CHAMKAR MON	208,750	227,664	246,777	253,935
2	DAUN PENH	137,186	141,744	146,320	148,028
3	PRAMPIR MAKAKRA	104,013	110,815	117,681	120,253
4	TOUL KORK	178,373	199,115	220,109	227,941
Urban Area		**628,322**	**679,338**	**730,887**	**750,157**
5	DANG KOR	114,333	126,904	161,871	208,136
6	MENG CHEY	210,027	258,336	307,295	325,489
7	RUSSEI KEO	246,732	307,403	381,379	418,384
Rural Area		**571,092**	**692,643**	**850,545**	**952,009**
8	POR SENCHEY	-	-	-	-
9	SAEN SOKH	-	-	-	-
Whole Phnom Penh		**1,199,414**	**1,371,981**	**1,581,432**	**1,702,166**

Because of increasing of population in Phnom Penh city, the waste generation into disposal sites also increases from year by year as showing in Table 4-3 the estimated waste disposal Phnom Penh city into landfill from 2004 to 2023. History can of waste disposal in Phnom Penh are first disposal into Stung Mean Chey disposal sites till 2008 and then move to Dang Kor Sanitary landfill in 2009 till 2023.

Table 4-3 Estimated waste disposal history and future for Dang Kor Sanitary landfill

Year	Disposal rate (tones/days)	Total waste disposal (tons)	Other
2004		260586	Waste generation disposal into Stung Mean Chey disposal sites
2005		274634	
2006		326961	
2007		343657	
2008		361833	
2009		393141	Waste generation disposal into Dong Kor Sanitary Landfill
2010		409335.64	
2011		442468.97	
2012		492380.55	
2013		532471.18	
2014		542983	Future waste generation prediction will disposal into Dong Kor Sanitary Landfill
2015		571935	
2016		600887	
2017		629839	
2018		658791	
2019		687743	
2020		716695	
2021		745647	
2022		774599	
2023		803551	

4.1.4 Waste composition

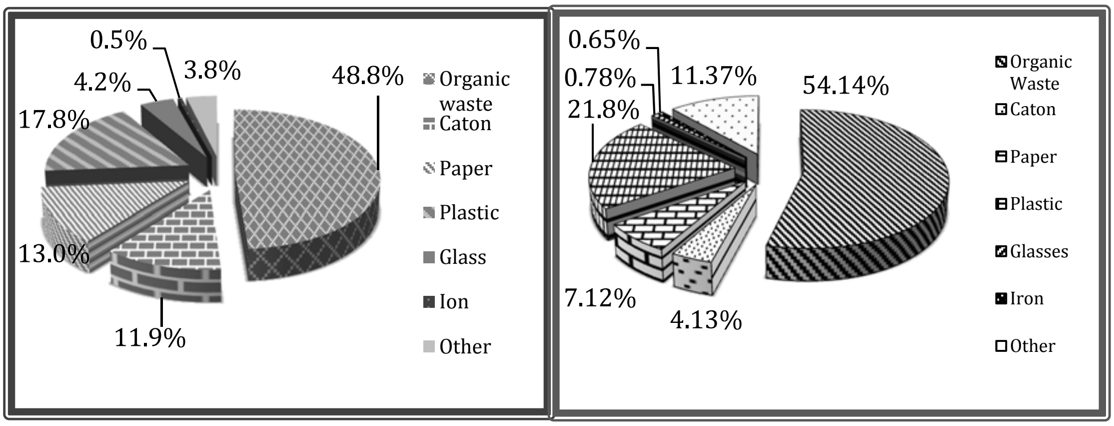
According to Heng S. et al., (2011) show the similar result of waste component with the research study. The result showed that carton and organic waste has percentage similarity in four times of waste component. The result of waste component from both seasons in 2011 was showed that 50.45% (in Figure 4-3) that highest percentage of total solid waste for experiment is organic waste and then plastic is second rank with 17.8%. So, organic waste is main component to emission the methane from landfill than other component. It can be assumed that if we can reduction the percentage of organic waste from Dang Kor landfill that quantity of methane emission as GHGs also decrease.

Table 4-4 Comparing waste component in both seasons. (Heng. et al, 2011)

Waste Component	Dry Season (%)	Raining Season (%)	Yearly	Dry Season (%)	Raining Season (%)	Yearly
	2011			**2014**		
Organic Waste	45.5	55.4	50.45	53.84	54.44	54.14
Carton	13.7	8.4	11.05	2.9	5.35	4.13
Paper	13.5	12	12.75	7.86	0.39	7.12
Plastic	17.8	17.8	17.8	21.86	21.77	21.81
Glass	4.5	3.6	4.05	0.8	0.75	0.78
Iron	0.4	0.2	0.3	0.6	0.7	0.65
Others	4.6	2.6	3.6	12.14	10.6	11.37
Sum	100	100	100	100	100	100

However, it is important to note that the amount of other organic waste is high in the dumpsite in both seasons (45.51% in dry season to 55.49% in raining season, 2014). Most of organic wastes are sources from agriculture activities, market, and garden around the Phnom Penh. Apart from this yard waste, also coming in from dedicated trucks, which account for about 22% (Maximum) of the total waste dumped daily. For the total organic component of the waste, food waste and other organics makes up to a total of about 66% (maximum) of the incoming waste.

As for plastics, there is a high demand for this kind of waste from the industries and market. As such, the amount ending up in the landfill is low. This indicates that a good scavenging system is in place. There is also a big amount of paper waste that had been removed from the waste.



Figures 4-3 Waste Component in Dang Kor Sanitary Landfill in 2011 (Life) and 2013

Apart from the waste categories mentioned above, the composition of waste is relatively typical for urban waste composition. Generally, the study had been able to show the characteristics of the waste that were discarded in the Dang Kor Sanitary Landfill. The waste is relatively dry but a large amount of organics was discarded. Active recycling in the dumping site was also observed.

4.1.5 Waste component

Following experiment showed that nutrient (N), potassium (K), phosphorus (P) and moisture contain still in above standard of chemical contaminate in leachate. Seema (2007) shown that the standard of P, N and K for municipal waste are between 0.5%, 0.5 to 0.7% and 0.5 to 0.8% in order. In Dang Kor landfill has higher then standard is over 1.6% both chemicals N and K. Seema (2007) also got that the higher then standard of nutrient is potential to waste composition for agriculture. Moreover, other chemical is P in the standard value. Serkan nas et al. (2007) show that moisture contain has standard value between 77-87%, At Dang Kor has 78,1% is in the standard of moisture show in Table 4-5.

Table 4-5 Comparison the standard chemical in Municipal Waste at Dang Kor landfill

Organic Composition	Dang Kor, 2011 (%)	Dang Kor, 2014 (%)	Standard Value* (%)
Moisture Contain	78.10	80.53	77-87
Nutrient (N)	1.60	2.10	0.5-0.7
Potassium (K)	0.50	1.35	0.5-0.8
Phosphorus (P)	1.60	2.10	0.5-0.8

Source: Heng, et al, 2011; Seema, 2007 & *Serkan na et al, 2007

To find the waste component need to experiment on raining season and Dry season mix together for finding mean of waste disposal in the whole year. As a result, they got that the percent of organic waste is higher percent then other kind of waste is over 54.14% of total waste in the sample.

4.1.6 Leachate collection system

In Tables 4.6 and 4.7 show that quantity of leachate range from 49,680 to 50,800 L (the study record starting on August, 2009 till April 2012). However, the quantity of leachate will be change base on season and rain level around the landfill site. And other ways, the major characteristic of leachates has higher BOD (1200 mg/l), COD (1177 mg/l), TSS (144 mg/l) and color then standard before and after flowing out to the water body: Prek Thnot river, because Dang Kor sanitary landfill used only pond that store quantity of leachate till full of pond and flowing leachate out without any treatment solution. While the quantity of leachate has been increased, it means quantity of BOD also increase it is have effect to quantity of CH_4 emission to atmosphere which kid of Green House Gases emission concern from landfill.

Table 4-6 Statistic of Wastewater and Leachate Prediction

Year	Weight (Liters)	Other
2009	33,300	Start on August
2010	50,800	-
2011	49,680	-
2012	3,645.953	-
2013	1,172.187	-
2014	2,127.734	-
2015	2,354.207	-
2016	-	-
2017	-	-
2018	-	-
2019	-	-
2020	-	-
2021	-	-
2022	-	-
2023	-	-

Table 4-7 Major Characteristic of leachate in Dang Kor Landfill

Parameter	Unit	Average	Standard*
Biochemical Oxygen Demand (BOD)	mg/L	1200	20
Chemical Oxygen Demand (COD)	mg/L	1177	400
Total Suspended Solid (TSS)	mg/L	144	50
Colour	ADMI	6950	100

Standard* refer to Annex 2- effluent standard for pollution source discharging wastewater to public water areas, legislation related to environment, Cambodia, 2004.

4.1.7 Future Plan

The landfill operation have been started in 2009 in the area A, B, C, and D (In Figure 4-2) on surface area around 54,300 m^2, 38,900 m^2, 55,300 m^2, and 38,200 m^2 respectively. Which have been disposed amount of municipal waste in August, 2009 to 2011, 2012 to the mid of 2014, 2014 to 2016, and 2017 to 2019 with total amount of waste 1,244,945.61 tones, 1,024,851.73 tones, 1,715,805 tones, and 1,288,630 tones respectively. However, from 2009 until 2014 the first step of operation are around Area A and Area B has been nearly full at the end of 2014. New landfill site in area C and D are constructing that will be start disposed at 2015.

4.2 Description of Saensook Sanitary landfill

4.2.1 Collection, transportation and landfill design

Saensook municipal is located in Muang commune, Chonburi province. It is far from Bangkok city about 74 km and far from central of Chonburi provinces about 13 km. Saensook municipal bounder at the east with Muang district, west with gulf of Thailand, north part with Ban Bong village, Hoy Kapi village and south with Bang Pra District, Sriracha commune. Saen Suk municipal have 20 villages under control equal to 20.268 km^2 (12,667.5 Rai[1]). In the Table 4-8 show about population of Saensook commune over 46,000 persons and population density about 2137 persons/km^2 in 2012. In addition, population and waste generation is not equal because Saensook commune has many attractive tourism sites and a famous university of southeast park of Thailand (Burapha University has 46441 students in 2013), follow of these increase business as rest room, hotel, restaurant etc. So, 10,000 persons have been added total population, who generate the waste.

When ever Saensook sanitary landfill is under control of Saen Suk municipal but the located of Saen Suk sanitary landfill is operating in site 11, Bang Pra commune, Siracha district Chonburi Province the approximately 20 km southeast of Saen Suk municipal. This site is nearly the mountain on the total area over 28 hectares. Saen Suk municipal was separated waste collection sites to nine sites is better condition for truck’s waste collector to collect everyday.

[1] Rai: Thailand’s standard unit of area (1Rai = 0.016 km^2)

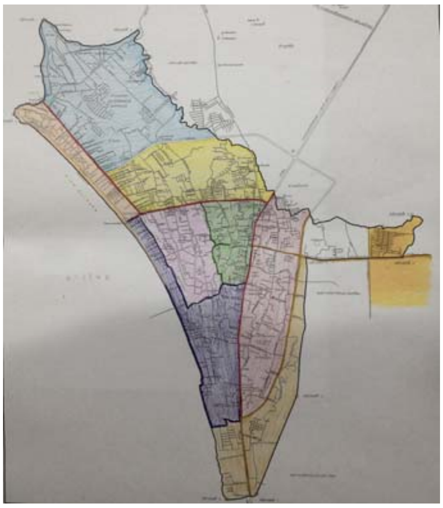


Figure 4-4 Map of Saensook Municipal, Chonburi Province.

Table 4-8 Population Predictions in Saensook Commune, Chonburi Provinces

Year	2552	2553	2554	2556	2560	2564
Population (person)	43,312	43,840	43,322	46,000	52,000	57,00

Design

Saensook Sanitary landfill is solid waste disposal areas that following the Thailand stardard of landfill. The total area of Saen Suk sanitary landfill is 275,200 m^2 (172m×1600m). Planning for waste separation also designated for normal operation and emergency case. The emergency case such as heavy rain, fires in landfill the vechicle cannot be operation as normally. Prepared the better condition for truck to access the waste into each phase of disposal area and around the landfill and time for in-off of site disposal from 5:00am to 18:00pm. They was separated this site into three areas are official and Infrastructure area, wastewater and leachate area, and dumping area.

Office and Infrastructure area

This area including office building is for manager and staff, and place for saving the site documentary after Saensook municipal. Weight scales is also the place that prespond for record amount of solid waste collection vehicles and waste entering the waste disposal site on a daily basis, and garage equipment and repair units (Operating for the park service and repair machinery for waste collection vichicle and truck in landfill).

Leachate pond areas are responding on the water flowing out from dumping area. Follow Fig. 4-5 map of Saensook sanitary landfill, they separated to three blocks for chemical treatment process are Block 7th, 8th and 9th. The design of leachate system is a single composite barrier type which have diameter about 1.0 mm thick of HDPE to prevent obstruct of leachate, and geotextile part is type three to connect to HDPE. Water treatment system is a waste stabilization facultative pond (WSFP), which consists three ponds are 1st, 2nd, 3rd. For 1st pond curing depth is 6.5 m and the retention time of water is not less than 35 days. In 2nd pond is oxidation pond have depth about 3.75 m and the retention time of water is not less than 44 days and the 3rd is incubated with depth about 3.1 m of storage period is not less than 7 days.

Dumping Area

Following the report of Saen Suk municipal (2011) said that total waste disposals into dumping about 70 to 80 tonnes per day, which collecting from Saen Suk residential area and two villages from Bang Pra residential area. The dumping area has been developed to six blocks that filling one by one. However, in 2013 five blocks (Block1st, 2^{ed}, 3rd, 4th, 5th) have been full. So, it is a last block (Block 6th) in operating. That is the problem for Saen Suk municipal to find the solution with waste generates after block 6th have been full in 2015. Follow monthly report of Saen Suk municipal show the quality of waste must be compacted to a density not less than 550 kg / m (depending on the nature of the waste). Landfill have been design in form waste over the ground by the thickness of the layer over the filling ratio of 0.30 days. The final 0.60 m thick soil cover over a day. By figure 3.6 show the groundwater monitoring wells in landfill.

4.2.2 Landfill Physical Characteristics

Saensook sanitary landfill has been operated since 16 December 1999 and disposal in 2000. This site is under control of Saen Suk Municipal. Waste disposal history in 2000 starting to disposal municipal waste and commercial waste from Saensook until mid of 2004. In 2004-2006 was disposal only municipal waste in the evening because landfill in the checking operation. Till 2006 from 2015 start to disposal again from Saen Suk municipal and some part of Bang Pra municipal. In 2000 Saen Suk municipal was calculation landfill closure year that this landfill is operated only 15 year from 2000 to 2015. As figure 3-3 show the map of Saen Suk sanitary landfill that in site have six block of dumping (1st, 2nd, 3rd, 4th, 5th, 6th) and three pond of waste water and leachates (7th, 8th, 9th) and some part for office and infrastructure areas.

Source: www.google-map.com, 2014

Figure 4-5 Map of Saensook Sanitary Landfill

Climate Condition

Saensook municipal has the same weather in Thailand has dry and raining seasons. The annual rainfall in Saensook municipal is 1,703.8 mm. The dry season occurs from December to April that has annual rainfall lower then 0.1 mm (December-January) and 64.28 mm (January-April). The raining season start from May to November that have annual rainfall about 235.18 mm (May-August) and (Saen Suk municipal three year planning, 2011)

Temperature is from 17.7 °C to 36.7 °C. The temperature annually are 32.75 -35.93 °C (January-April), 33.28 - 25.03 °C (May-August), and 35.05 - 35.58 (September-December). Temperature reaches maximum in April at 35.93 °C and dropping to around 26 °C from May to August.

Table 4-9 Precipitation and Evaporation in Saensook Sanitary landfill

Year	Precipitation	Evaporation
2001	-	1306
2002	-	1293
2003	-	1210

2004	-	1351
2005	-	1382
2006	1236.4	1310
2007	1254.3	1323
2008	1271.0	1425
2009	1574.4	1402
2010	1376.5	1323
2011	-	-
2012	-	-
2013	-	-
2014	-	-
2015	-	-

4.2.3 Disposal history and estimated future disposal

Looking for non-registered population of Chonburi at the rate of 1.84% is taken into account, population density of 857 person/km^2 and the total population of Chonburi will be 1,800,000 in 2008 and increasing in 2050 respectively. However, in Saensook municipal have total population over 43,321 in 2009 and 46,000 in 2012 are following the Table 4-10. By the way look for waste sector in Saensook municipal, Chonburi province has waste generate only 240 to 320 tones per day and 20,283.44 tones in 2007 and rise to 25,874 tones in 2011.

Table 4-10 Estimated waste disposal history and future for Saen Suk Sanitary landfill

Year	Disposal rate (tones/days)	Total waste disposal (tons)	Other
2000		38,647	Starting Disposal and mixed with commercial waste
2001		54,669	
2002		-	No Data
2003		-	
2004		29,929	
2005	15	5,580	- Stop to disposal a year for operation checking - Disposal only municipal waste at the evening
2006		2,249	- Start to disposal again in September

2007		20,283	- Bang Pra area start to disposal waste in landfill at June
2008		23,494	
2009		23,873	
2010		23,402	
2011		25,277	
2012		35,874	
2013		37,358	
2014		38,130	
2015		40,893	Year of Landfill Close

4.2.4 Waste composition

The methodology and landfill situation in Saen Suk sanitary landfill also similarity to Dang Kor sanitary landfill. So, the result of waste component also similar by following in Fig. 4-6, it is important to note that the amount of other organic waste is high in the dumpsite is around 46.70%. Most of organic wastes are sources from market, restaurant, resort and garden waste around Saensook. Apart from this yard waste, also coming in from dedicated trucks, which account for about 1.3% of the total waste dumped daily. For the total organic component of the waste, paper makes up to a total of about 4.69% of the incoming waste.

As for plastics, there is a high demand for this kind of waste from the industries and market. As such, the amount ending up in the landfill is high around 23.66% this indicates so the less of scavenging system in place. In addition, amount of plastic and paper also increase by public university and office around the city.

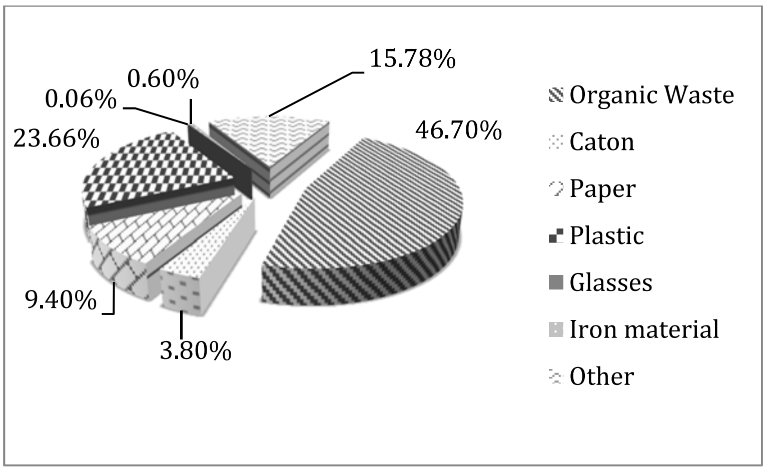


Figure 4-6 Waste Component in Saensook Sanitary Landfill in 2014

4.2.5 Waste component

Follow the Fig. 4-6 show the quality of organic matter in organic waste is very high then standard of waste composting. It means we can use it for mitigation option as compositing or transport it into bio-digester to produce compose in agricultural sector because high percentage of moisture contain help to improve the situation for bacterial to compose the waste. In addition, the high level of N, P, K is help to increase organic matter in soil as fertilizer to improves natural substance that is put on land for make better soil condition for plant. The solution will be show below which one is possible solution from organic waste in Saensook sanitary landfill.

Table 4-11 Comparison the standard chemical in Municipal Waste at Saen Suk landfill

Organic Composition	Saen Suk, 2013 (%)	Standard Value* (%)
Moisture Contain	55.11%	77-87
Nutrient (N)	2.10	0.5-0.7
Potassium (K)	1.35	0.5-0.8
Phosphorus (P)	2.10	0.5-0.8

4.2.6 Leachate collection system

There are the parameters of leachate quality that experimenting by Saensook municipality every three months to control the quality of surface water and ground water around the landfill site at the point after waste desposal site to pond and after three ponds on the point of flowing the leachate out to water body. The result show the better condition of leachate qaulity after across all ponds in landfill with discreases from 50.2 mg/l to 3.2 mg/l. It is nearly the standard values of National governemnt committee declear about water quality and surface water quality standard for Thailand in 1992. before flowing wastewater out into water body need lower then 2.0 mg/l. it is show the better leachate codition design in Saensook sanitary landfill for BOD. However, during the galoon of pond has treatment on landfill, leachate in landfill need store in the open pond around a month before flowing off. In that time CH_4 also emission from the pond to atmosphere by chemical reaction during stabilization in the pond. So, solution of gas emission should be finding for resolve the problem from this fact.

Table 4-12 Major Characteristic of leachate in Saensook sanitary landfill (Inlet point)

No	Parameter (Unit)	1st	2nd	3rd	4th	Standard***
1	PH	8.22	7.83			5-9
2	Temperature (°C)	34.8	28.5			≤ 3°C of Natural water
3	DO (mg/l)	0.69	-			> 4.0
4	Total Hardness (mg/l)	179	-			-
5	BOD** (mg/l)	50.2	36.4			< 2.0
6	COD (mg/l)	426	348			-
7	Nitrate-nitrogen (mg/l)	ND*	-			< 5.0
8	Ammonia-nitrogen (mg/l)	518.36	308.39			< 0.5
9	Mercury (mg/l)	ND*	ND*			< 0.002
10	Manganese (mg/l)	1.32	0.19			< 1
11	Lead (mg/l)	ND*	< 1.0			< 0.05
12	Total Coliform Bacteria (MPN/100ml)	35000	-			< 20000
13	Fecal Coliform Bacteria (MPN/100ml)	1400	-			< 4000

Note *Not Detected

** Method Detection Limit of BOD = 2.0 mg/l

*** Declaration of National Environmental Committees, Article 8 (1994) by Royal declaration on National Support and Conservation Environmental Quality (1992). Issues improve water quality and surface water standard, type three.

4.2.7 Future Plan

Saensook landfill site has almost reached its maximum capacity for waste dumped, so it is expected that there will be no waste deposited space after 2015. In this case in site waste reduction should be better option for Saensook sanitary landfill better the find new dumping site for continues disposal activities for future waste disposal and environmental sustainable. In the Saensook sanitary landfill have not plan to reduction the waste into landfill yet. However, many purpose project have been proposed for solves with waste problem in Saensook.

4.3 Methane generation of Dang Kor Sanitary Landfill

4.3.1 IPCC Model, Zero Order Model

The methane emission from solid waste disposal sites for years 2009 -2023 in Dang Kor sanitary landfill have been estimated by the default methodology taking the values of emission coefficients, methane correction factor (MCF) as 0.4 fraction of DOC in MSW taken as per the calculated values for different waste component based on field experimental of identified cities, fraction of DOC is 0.798. Fraction of carbon released as methane (F) is 0.5; conversion ratio between methane and carbon or stoichiometric factor is 16/12. Because of DOC values based on waste component in dumping site as 0.101 equal to Paper and Rag is 8.352 %, Leave and Garden (4.98%), Vegetable and Fruit (53.363%), and wood (4.166%). So, the potential methane generation rate as 0.029, and realized methane generation rate per unit of waste as per the category per year as shown in Fig. 4-7. Shown the methane emission from 8,434.098 Gg CH_4 (2009) increasing to 17,238.670 Gg CH_4 (2023) per waste.

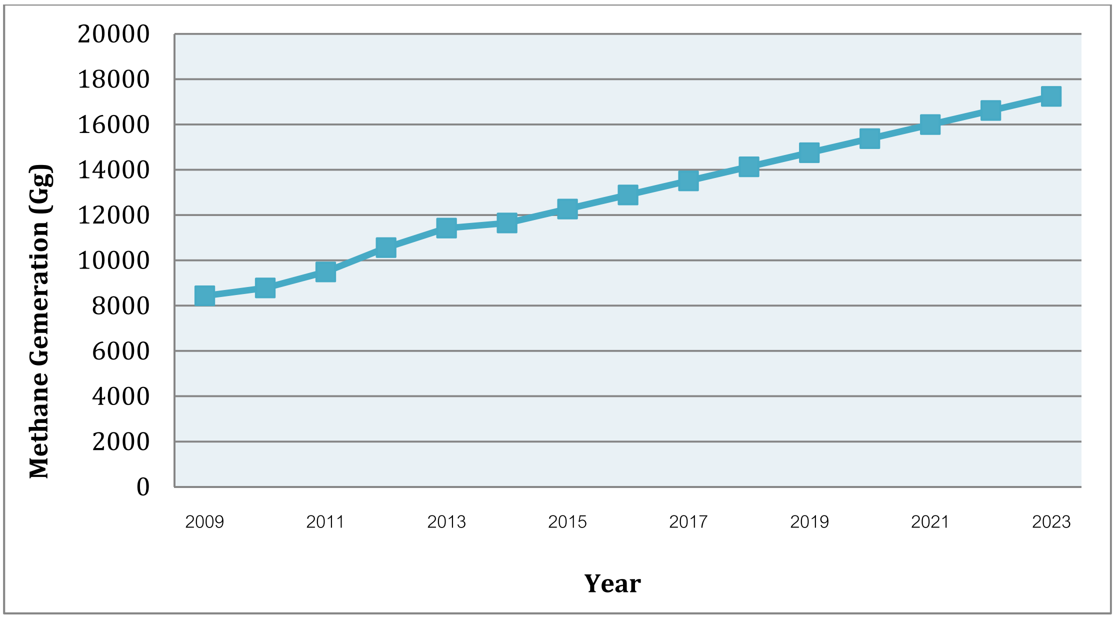


Figure 4-7 Methane emission and methane generation prediction from Dang Kor landfill by using IPCC model (Default method).

4.3.2 IPCC First Order Decay Model

The basic equation for the first order decay in the IPCC model, 2006 using the option and a time delay is presented below (Equation 3.15d). The rate of LFG production is predicts by a first order kinetic model in Equation 3-15a, where the generation rate of the decomposable degradable organic carbon $DDOC_m$ (Gg of organic carbon) decays exponentially with time as showing in

$DDOC_m$ = W × DOC × DOC_f × MCF, While DOC is the organic carbon content in respect to the solid waste total amount (Gg of organic carbon/Gg of total SW) have been mention in IPCC zero order model. Total mass of solid waste, W followed the report from landfill (Gg). DOCf indicates the fraction of DOC that is supposed to undergo anaerobic reactions is described as 0.014 T + 0.28, where T is temperature in (°C). The average temperature in Phnom Penh capital is 30.6 Celsius. So, DOC_F is equal to 0.708 (dimensionless), and MCF is the methane correction factor (dimensionless). IPCC was determined that the initial value of MCF is 0.4 for (Unmanaged – shallow (<5m waste). The fraction depends upon the method of disposal and depth available landfills which not meeting the criteria of managed SWDS and depths of less than 5 meters.

The integration of Equation 3-15a leads to the expression of the decomposable degradable organic carbon as a function of time, as $DDOC_m(t) = DDOC_m(0)(e^{-kt})$ is for waste disposal in year zero. IPCC model has recommended default value of generation rate (k) is 0.17 because Dang Kor landfill have precipitation 1200 mm per year, which stayed in the tropical countries with wet and moist area (Mean Annual Precipitation > 1000).

In order to evaluate LFG generation, IPCC (2006) alternatively rewrites for $DDOCm_{dec,i}$, which is the amount of $DDOC_m$ present in the landfill that is decomposed at end of one year of site operation for a specific waste component, as (DDOCm decomp) = ($DDOCm_0$) × ($1-e^{-ki}$).

In the present work, the mass of generated CH_4g (Gg) was determined for a specific waste is $CH_{4g} = F_{CH_4} \times MW_{Ratio} \sum_{t=1}^{z} (DDOC_{m\ decomp.})_i$. Where, MW_{ratio} is molecular weight ration of methane to carbon dioxide as 16/12 following recommended from IPCC model (2006). z is the number of waste components.

The methane emission from solid waste disposal sites for years 2004 - 2039 (35 years) in Dang Kor sanitary landfill have been estimated by IPCC first order model. The amount of inert waste and methane generation increased between 2004-2024 at Dang Kor sanitary landfill and decrease methane generation in the year later. Shown the methane emission from 2.206 Gg CH_4 (2010) increasing to 12.012 Gg CH_4 (2024) per with total of methane generation is 169.621 Gg.

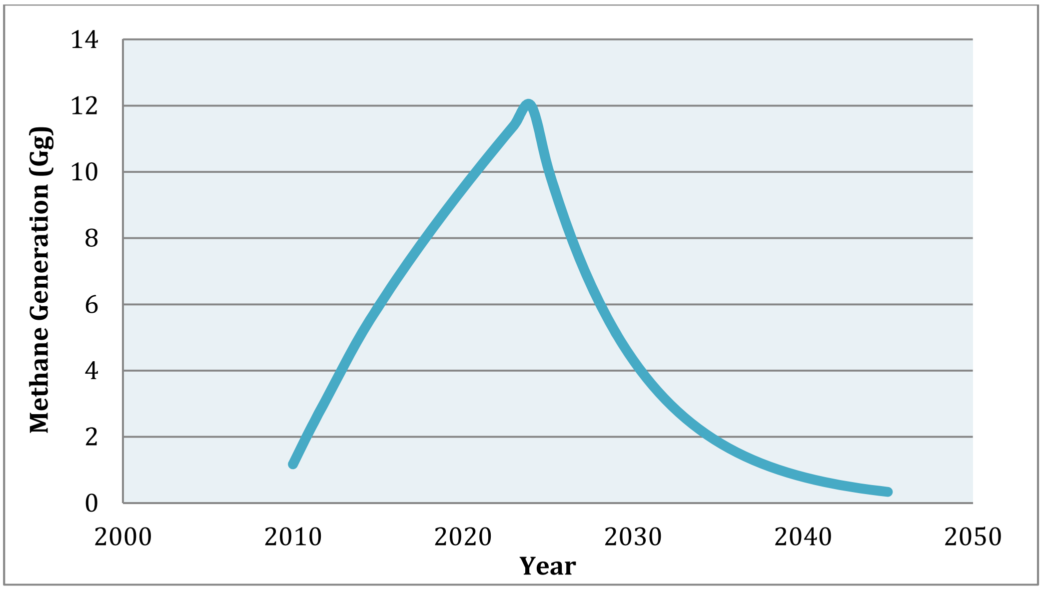


Figure 4-8 Methane generation prediction from Dang Kor Sanitary landfill by using IPCC (first order model)

4.3.3 Methane generation model from Leachate - IPCC model for leachate

The methane emission from leachate from disposal sites also estimate follow the years 2009 - 2024 (15 years) in Dang Kor sanitary landfill have been estimated by IPCC model. Which using annual organic material BOD in the wastewater (Gg) following in Table 4-6, Fraction of wastewater that is anaerobically treated about following by situation of leachate storage with no treatment facilities equal to 0.1, and the emission factor which the recommended emission factor is 0.22 Gg CH_4/Gg BOD all kind of leachate pond in municipal or sanitary landfill. The amount of inert wastewater and methane generation increased between 2009-2024 are also effect from life of landfill and component of waste disposal into landfill.

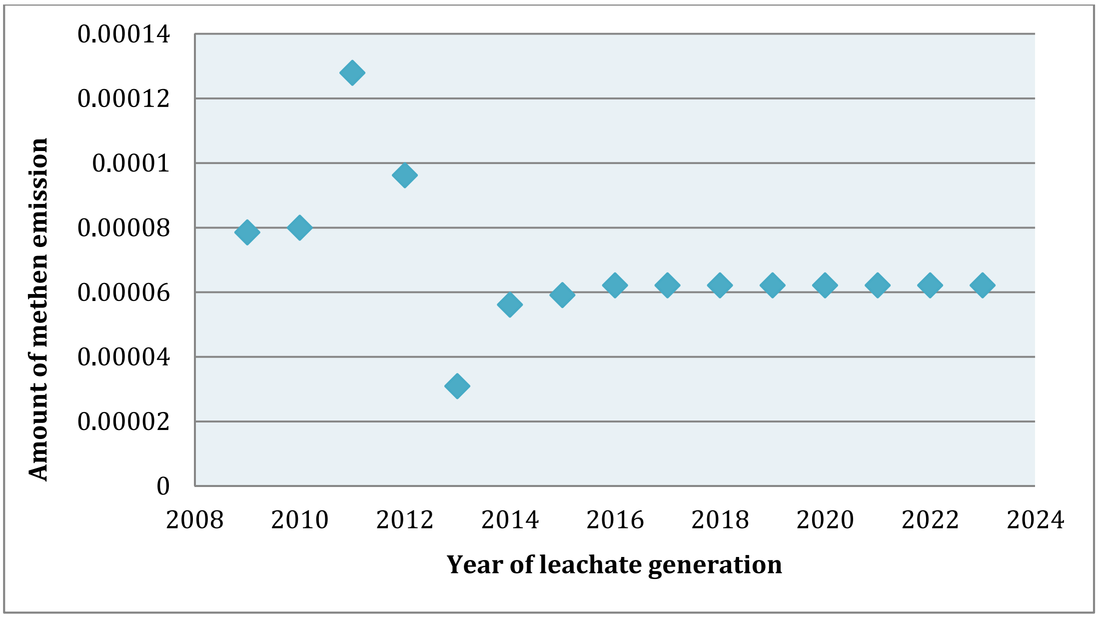


Figure 4-9 Methane generation prediction from Dang Kor landfill by using IPCC model for leachate facility

4.4 Methane generation of Saensook Sanitary Landfill

4.4.1 IPCC Model, Zero Order Model

The methane emission from solid waste disposal sites for years 2001-2015 in Saensook sanitary landfill have been estimated by the default methodology taking the values of emission coefficients, methane correction factor (MCF) as 0.4 fraction of DOC in MSW taken as per the calculated values for different waste component based on field experimental of identified cities, fraction of DOC is 0.798. Fraction of carbon released as methane (F) is 0.5; conversion ratio between methane and carbon or stoichiometric factor is 16/12. Because of DOC values based on waste component in dumping site as 0.101 equal to Paper and Rag is 8.352 %, Leave and Garden (4.98%), Vegetable and Fruit (53.363%), and wood (4.166%). So, the potential methane generation rate as 0.029, and realized methane generation rate per unit of waste as per the category per year as shown in Fig. 4-10. Shown the methane emission from 63.075 Gg CH_4 (2001) increasing to 1169.901 Gg CH_4 (2015) per waste.

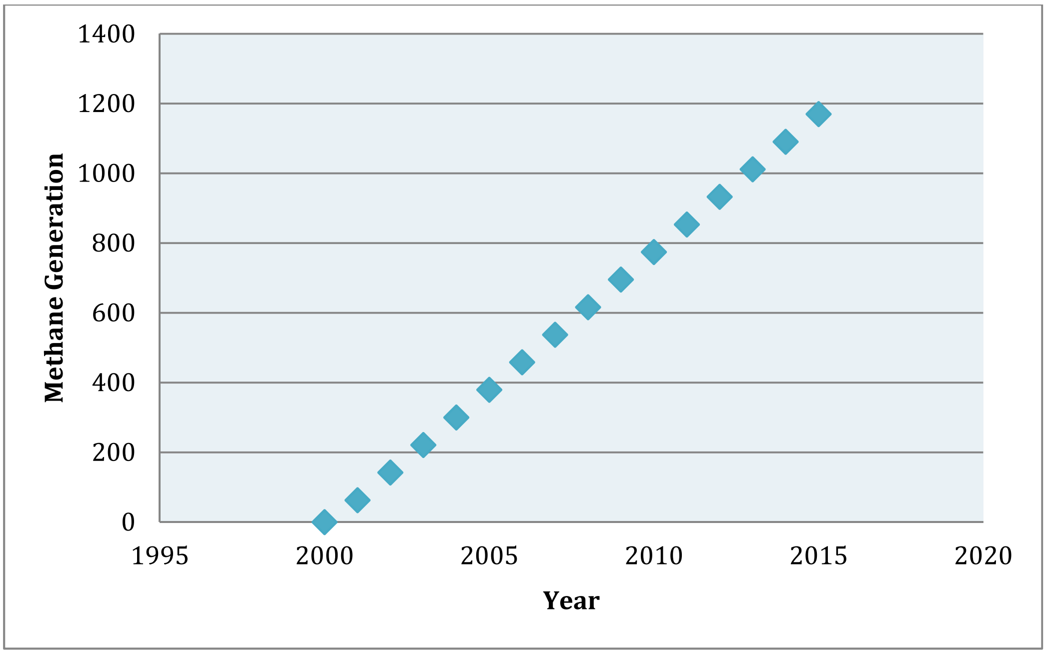


Figure 4-10 Methane emission and methane generation prediction from Saensook landfill by using IPCC model (Default method).

4.4.2 IPCC First Order Decay Model

The basic equation for the first order decay in the IPCC model, 2006 using the option and a time delay is presented below . The rate of LFG production is predicts by a first order kinetic model, where the generation rate of the decomposable degradable organic carbon $DDOC_m$ (Gg of organic carbon) decays exponentially with time.

$DDOC_m = W \times DOC \times DOC_f \times MCF$, While DOC is the organic carbon content in respect to the solid waste total amount (Gg of organic carbon/Gg of total SW) have been mention in IPCC zero order model. Total mass of solid waste, W followed the report from landfill (Gg). DOCf indicates the fraction of DOC that is supposed to undergo anaerobic reactions is described as 0.014 T + 0.28, where T is temperature in (°C). The average temperature in Chonburi is 30 Celsius. So, DOC_F is equal to 0.708 (dimensionless), and MCF is the methane correction factor (dimensionless). IPCC was determined that the initial value of MCF is 0.1 for (Managed – aerobic).

The integration leads to the expression of the decomposable degradable organic carbon as a function of time, as $DDOC_m(t) = DDOC_m(0)(e^{-kt})$ for waste disposal in year zero. IPCC model have recommended default value of generation rate (k) is 0.17 because Saensook landfill have precipitation 1190 mm per year, which stayed in the tropical countries with wet and moist area (Mean Annual Precipitation > 1000).

In order to evaluate LFG generation, IPCC (2006) alternatively rewrites for $DDOC_{m_{dec,i}}$, which is the amount of $DDOC_m$ present in the landfill that is decomposed at end of one year of site operation for a specific waste component, as presented by (DDOCm decomp) = $(DDOCm_0) \times (1-e^{-ki})$.

In the present work, the mass of generated CH_4g (Gg) was determined for a specific waste is $CH_{4g} = F_{CH_4} \times MW_{Ratio} \sum_{t=1}^{z} (DDOC_{m\ decomp.})_i$. Where, MW_{ratio} is molecular weight ration of methane to carbon dioxide as 16/12 following recommended from IPCC model (2006). z is the number of waste components.

The methane emission from solid waste disposal sites for years 2001 - 2057 (56 years) in Saensook landfill have been estimated by IPCC first order model. The amount of inert waste and methane generation increased between 2001-2015 at Saensook landfill and decrease methane generation in the year later. Shown the methane emission from 0.0067 Gg CH_4 (2001) increasing to 0.17 Gg CH_4 (2016) and then starting decreases in the year later (2025) to 0.00013 Gg in 2058 per waste with total of methane generation is 2.027 Gg.

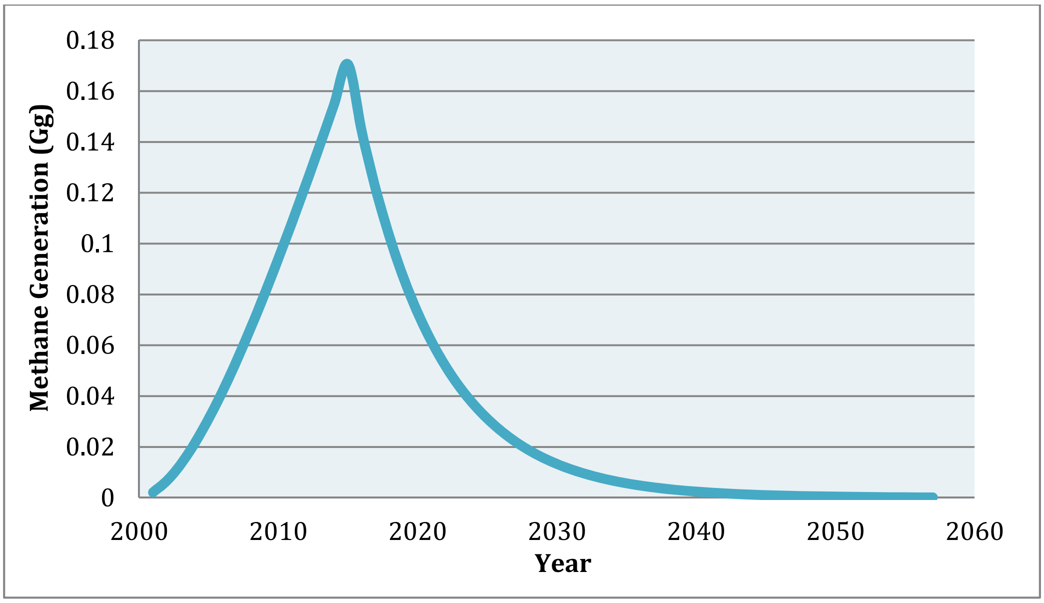


Figure 4-11 Methane generation prediction from Saensook landfill by using IPCC (first order model)

4.4.3 Methane generation model from Leachate - IPCC model for leachate

The methane emission from leachate from disposal sites also estimate follow the years 2001 - 2015 (15 years) in Saensook sanitary landfill have been estimated by IPCC model. Which using annual organic material BOD in the wastewater (Gg) following in Table 4-9, Fraction of wastewater that is anaerobically treated about following by situation of leachate storage with no treatment facilities and spent only natural treatment equal to 0.1, and the emission factor which the recommended emission factor is 0.22 Gg CH_4/Gg BOD all kind of leachate pond in municipal or sanitary landfill. The amount of inert wastewater and methane generation increased between 2001-2015 are also effect from life of landfill and component of waste disposal into landfill.

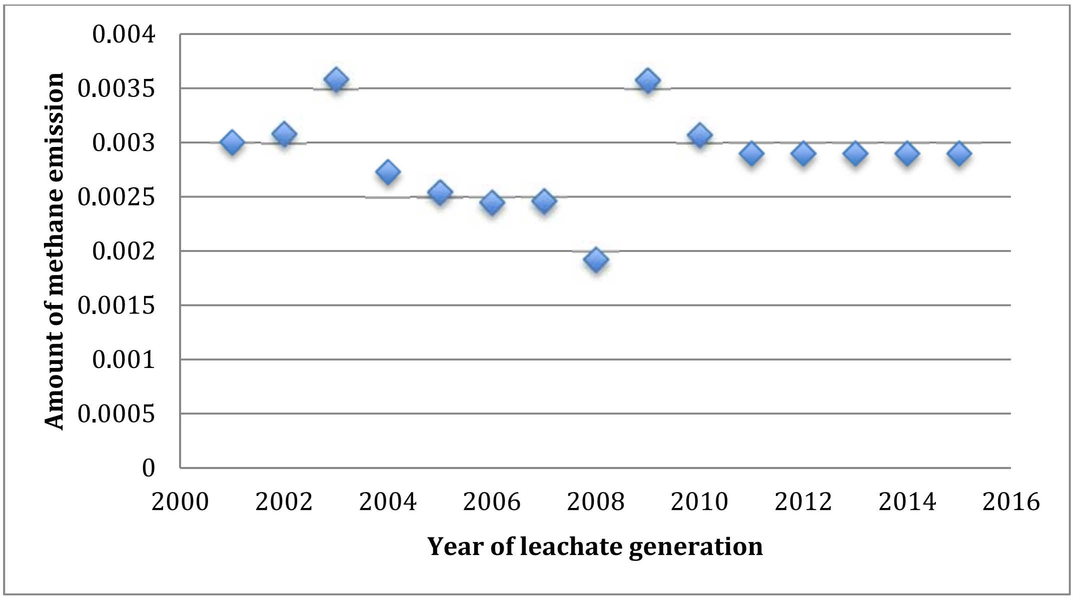


Figure 4-12 Methane generation prediction from Saen Suk landfill by using IPCC model for leachate facility

4.5 Comparison of two landfill sites and discussion

For the case studies of two landfills operation guidance base on waste policy of each county is aiming for diversion of organic waste from landfills and consequently landfills that contain amount of organic matters. In the Saensook sanitary landfill, Thailand most is household and municipal waste have been disposal since the 2000 with the total surface area is 27,52 hectares of which 15 hectares is used to dispose of waste. The landfill still operation from 2000 until the end of 2015 a total amount of 323,286 tones of waste was landfilled at Saensook sanitary landfill. The annual amounts of different types of waste are present in Fig. 4-12. In another sites study is the Dang Kor sanitary landfill, Cambodia most is household and municipal waste have been disposal since the 2009 with the total surface area is 54.3468 hectares of which 17.77 hectares is used to dispose of waste. The landfill still operation from 2009 until 2023, a total amount of 3,837,468.34 tones of waste was landfilled at Dang Kor sanitary landfill in the end of 2013. The annual amounts of different types of waste are present in Fig. 4-13. Saensook Dang Kor sanitary landfill is not only characteristics by the high content in organic matter. It also contains organic matter the readily biodegradable. This makes it a good case study for the future conditions of waste policy in both landfills because of the high organic content of the waste.

4.5.1 Waste Composition

From site sampling and experiment in both sites show that organic waste is a main waste composition in landfill with 54.14% (Dang Kor) and 46.70% (Saensook) it mean almost higher the a half of waste disposal into landfill. Which have the same result to literature review mention about amount of organic waste in developing countries have around 50-60% of total waste. By the result of Dang Kor have been accepted as literature review. In the percentage, Saensook sanitary landfill has a bit lower then literature review because in Saen Suk municipal is tourism sites and largest university of south-east part of Thailand that is make Saensook increasing generation the amount of waste in a paper and plastic higher then Dang Kor. The area around of Saen Suk municipal has less of agricultural activities and most of them are sea site and residential area.

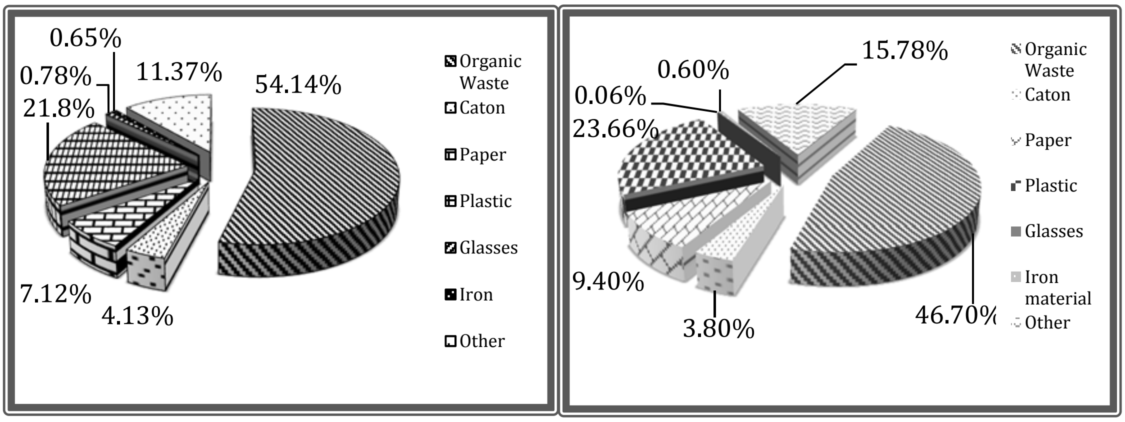


Figure 4-13 Comparing the waste composition of Dang Kor and Saendook Sanitary landfill

4.5.2 Methane Generation, Zero Order Model

There have different result between both site studies because the amount of methane generation from each model showed in the different ways. Firstly, In Dang Kor sanitary landfill IPCC model is better methodology to calculation because the amount of methane generation is very high the others model when the SWANA and US EPA's LandGEM model are have lower result. In another ways, the estimation methane generation from Saensook sanitary landfill showing in strange result with SWANA model with the highest result as triple values then other model. This is can make assume that IPCC model have more accuracy the SWANA and US EPA's LandGEM. So, it can be apply well for both case sites of study.

4.5.3 Methane Generation, First Order Model

Not allowing for the differences in organic matter content of LandGEM that have effected to strongest on the Dang Kor sanitary landfill. For instance in 2024 the GasSim estimate was 14 times higher than LandGEM, Thailand and TNO as lowest estimate. No explanation could be found as to why GasSim gave slightly higher results than LandGEM US-EPA in all cases. In the TNO it has the difference was most pronounced on the Saensook landfills with the highest amount of inert waste. It was least pronounced on the Dang Kor landfill with the lowest amount of inert waste. The SWANA, the results from the Saensook and Dang Kor landfills were at the highest end of the range of estimates. On the Saensook site a different set of parameter values was used to try to compensate for the deviation from the measurement values because have some waste material from tourism waste. The maximum result was therefore more towards the center of the range of estimates.

Chapter 5 Conclusions

Work in this paper utilized data from field experiment to illustrate compressibility parameters for refuse at different models and different degree of decomposition condition. The extent of degradation of waste composition in landfill was documented by production rate as well as methane generation rate. Three zero order model and ten first order model of methane gas generation estimation were run for approximately year between 2001-2015 and 2009-2023 for waste generation in Saensook and Dang Kor sanitary landfill until closure year of both sites. Base on the results obtained in this study, the following conclusions are advanced.

The amount of waste disposal into landfill almost a half are organic waste. Second rank of waste composition is plastic because both of sites are municipal sites in developing countries. In the waste component the amount of Nutrient, Potassium, and Phosphorus are very high as 2.10, 1.35, and 2.10 for Dang Kor and 2.10, 1.35, and 2.10 for Saensook respectively. The moisture content level is 80.54% for Dang Kor and 55.11% for Saensook. The amount of BOD is about 1200 mg/L and 1300 mg/L for Dang Kor and Saensook, respectively during storage in the storage pond.

Dang Kor landfill which they got the same result in peak values in 2023 (17^{th} after landfill gas started to emission) from first year of disposal start increasing the amount of landfill gas emission till year of peak values which changes the degradation process to be slowly as the result is decreased the amount of landfill gas generation after 17 years of waste disposal. The amount of methane emission from Multi-phase model, Afvalzorg model have highest level than models in-group of US EPA's LandGEM revises model. The single-phase first order TNO model is a very straightforward model. It has a limited number of parameters and is therefore easy to use. The TNO model estimated methane emission with the same waste categories as used in the Afvalzorg model but value of Afvalzorg dissimilation factor is higher than the TNO dissimilation factor and the results has a higher methane generation potential in Afvalzorg model than TNO model. Thailand and Mexico model is modified model from LandGEM to be fixed with the countries situation. The lowest result of methane emission is US EPA's LandGEM because has a disadvantage LandGEM that it cannot allow for differences in organic matter content. LandGEM considers all waste to be MSW. Expected of estimates would be among the highest of all the models, which applies both to LandGEM US-EPA and the GasSim in estimation. In addition, The amount of methane from SWANA model has the highest level then others because methane generation potential (L_0) that using in SWANA model is so high if compared to methane generation potential that used in other models. In modified triangular model also have higher values because of assumes of waste generation only 16 years that is effect to amount of methane generation in previous year is higher.

Because of Saensook landfill site has almost reached its maximum capacity for waste dumped, so it is expected that there will be no waste deposited after 2015. After closure the first-order model predicts an immediate decrease of the landfill gas production rate, whereas the triangular model predicts maximum production 3 years later. However, the decrease is more gradual in the case of the first-order model, leading to larger gas production prediction after more than 10 years of closure. In the worst-case scenario, the current methane emission is up to 50% higher than in the base case, but the emissions decrease more rapidly after closure of the landfill. Methane generation from Saensook sanitary landfill by zero order models are IPCC, LandGEM and SWANA models showing in result that methane estimation from the SWANA zero order model have highest amount then two others model which have been increase from 3450.71 m^3 in 2001 to 2015. The result can be assume that SWANA zero order model is possible to calculation of methane emission for Saensook sanitary landfill of Thailand with the highest values of estimation.

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