# CHAPTER II

# LITERATURE REVIEW

## 2.1 Solid waste information

Thailand produces nearly 22 million tons of waste annually (Table 2.1). Municipal solid waste, which is made up of the everyday waste produced by households and businesses, makes up 67 percent of the total waste generation, while non-hazardous waste produced by industries accounts for 13 percent. The remainder of the waste, though produced in lower volumes, is potentially more dangerous due to its hazardous or infectious properties. This includes infectious waste from hospitals and hazardous waste produced by industries and communities, including households and small businesses such as gas stations. (Thailand Environment Monitor, 2003)

**Table 2.1** Waste generation in Thailand in 2003. (Thailand Environment Monitor, 2003)

| Types of waste | Waste generation (thousand tons/year) | | |
|---|---|---|---|
| | Total | Total minus reuse and recycling | Largest-producing province (% of total) |
| Municipal solid waste | 14,400 | 12,800 | Bangkok (67%) |
| Infectious waste | 21.3 | 21.3 | Bangkok (21%) |
| Industrial hazardous waste | 963 | 788 | Samut Prakarn (19%) |
| Industrial non-hazardous waste | 5,890 | 1,271 | Samut Prakarn (13%) |
| Community non-hazardous waste | 372 | 182 | Bangkok (34%) |

Nearly two-thirds of the industrial hazardous waste comes from metal and electronic industries, while more than half of the community hazardous waste is created by automotive service stations, and nearly all infectious waste comes from hospitals. Municipal solid waste is produced by a combination of residential and other sources, determined by the relative proportion of industrial, commercial, or tourism activity in the area. (Table 2.2) (Thailand Environment Monitor, 2003)

**Table 2.2** Waste composition in Thailand. (Thailand Environment Monitor, 2003)

| Types of waste | Major sources | Major constituents |
|---|---|---|
| Municipal solid waste | Residential<br>commercial/tourism<br>Agriculture | Kitchen waste (51%)<br>Plastic and foam (22%)<br>Paper (13%)<br>Glass (3%)<br>Other (11%) |
| Infectious waste | Hospitals (93%)<br>Educational and labs (7%) | Tissue sample<br>Blood and other liquids<br>Surgical waste and syringes |
| Industrial hazardous waste | Metal industries (33%)<br>Electronic industries (28%)<br>Plastic industries (8%)<br>Chemical and Petroleum industries (7%) | Filter materials, waste sludge (35%)<br>Fuel, oil and grease (28%)<br>Liquid organic compounds (8%) |
| Industrial non-hazardous waste | Metals industries (36%)<br>Food industries (13%)<br>Furniture (7%) | Metals and metal alloy (30%)<br>Parts of wood (16%)<br>Animals part (13%) |
| Community non-hazardous waste | Automotive stations (54%)<br>Residential (19%)<br>Agriculture (10%)<br>Gas station (10%) | Recyclable waste oils (27%)<br>Lead acid batteries (21%)<br>Other toxicchemicals (8%)<br>Other waste oils (6%) |



Roughly 42 percent of Thailand's municipal solid waste is comprised of glass, plastic, paper, and metal, which has the potential to be recycled commercially and then reused in various manufacturing and industrial activities. Almost 4.5 million tons of commercially recyclable materials are discarded each year. The potential market value of these materials is 16 billion Thai Baht per year. Metal and paper, in particular, have tremendous recycling potential and approximately two thirds of these recyclables are currently discarded.

Separation of recyclables by households is currently limited to that which is encouraged through Garbage Banks and the relatively small quantities of paper and glass that households store for sale or donation to recycling shops.

Composting involves the decomposition of the organic portion of municipal solid waste and using the product as a soil conditioner. There is a large potential use for this material, however, only 2,700 tons of waste per year is processed in the composting operations found in municipal areas of Thailand and in Bangkok plans were abandoned to develop a composting plant. Studies indicate that the major use for compost in the Bangkok and vicinity is by farmers cultivating tree crops, vegetables, and flowers, and amounts to 1.4 million tons of compost, valued at Thai Baht 4.5 billion annually. Additionally, another 150,000 tons of compost could be used by transportation each year in public parks and green areas. Besides reducing the amount of waste for landfills, composting also helps to reduce Thailand's greenhouse gas emissions as envisioned under the United Nations Framework Convention on Climate Change. (Thailand Environment Monitor, 2003)

## 2.2 Composting and enzyme involved in the compost process

Compost is a mixture of decayed organic materials decomposed by microorganisms in a warm, moist, and aerobic environment, releasing nutrients into readily available forms for plant use (Cline and Rodd, 2000).

Composting is a biological process by which microorganisms convert organic materials into a dark humus-rich soil-like material called compost. It is the same natural process that produces the dark humus layer on the forest floor. Composting differs only in the intentional creation of conditions that result in more rapid decomposition of organic material than what would normally occur in nature (Pedraza-Reyes and Gutierrez-Corona, 1997).

**2.2.1 Bioprocess of composting.**

Composting is a mass of interdependent biological processes carried out by a myriad of microorganisms essential for the decomposition of organic matter. Most systems are aerobic, meaning the microorganisms required oxygen (Stoffella and Kahn, 2000). The overall biochemical equation can be written:

$$\text{Organic matter} + O_2 + \text{Aerobic bacteria} \longrightarrow CO_2 + NH_3 \text{ containing Products} + \text{Energy}$$

For anaerobic systems, oxygen is absent and the overall biochemical equation takes a different form:

$$\text{Organic matter} + \text{Anaerobic bacteria} \longrightarrow CO_2 + NH_3 \text{ containing Products} + \text{Energy} + H_2S + CH_4$$

Adding cultures of microorganisms to organic materials to promote composting should be necessary. Aerobic composting can occur under a wide range of temperature conditions. Initial decomposition is carried out by mesophilic organisms that exist in temperature ranges from 10°C to 45°C. They break down soluble and easily degraded compounds. As they give off heat, the temperature in the compost increases rapidly. The mesophilic organisms are replaced by thermophilic organisms that thrive under temperatures between about 45°C and 65°C. These high temperatures promote the breakdown of proteins, complex carbohydrates, and other organic compounds that provide important nutrients for the microorganisms. Most thermophilic microorganisms involved in composting begin to die off at temperatures above 65°C and few can survive above about 70°C. If temperatures are allowed to exceed these high levels, rapid decomposition will cease and the pile will return to mesophilic conditions. Therefore, temperature management is an important part of a composting operation. Aeration and mixing are used to keep temperatures from falling too low or rising too high. Figure 2.1 shows the various temperature phases over time in a compost pile. Like humans and animals, organisms involved in composting need the right amounts of water, nutrients, and oxygen to survive (Eberle, 1997).

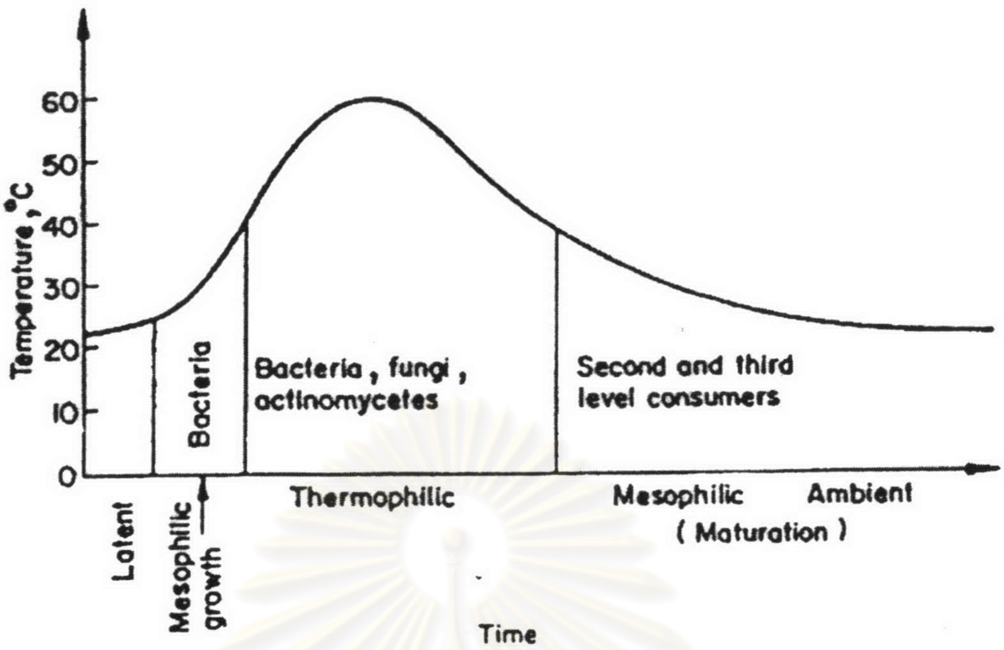


**Figure 2.1** Phase of temperature and microbial growth between composting: the first phase (mesophilic) may last only a few days as the compost heats rapidly. The second phase (thermophilic) is where rapid decomposition occurs over a few weeks to a few months. Mesophilic conditions return during the third cooling and curing phase that may take several months. (Polprasert, 1989)

### 2.2.2 Microbial compost

The active component mediating the composting process is the resident microbial community. The diversity and structure of microbial communities of composts through their constituent populations has been interesting. (Insam, Riddech and Klammer, 2002)

### 2.2.3 Enzymes involved in composting

**Cellulase**

Cellulose is the major component of municipal solid waste. It constitutes 40 to 60% of the solid waste in American cities and is generated at the rate of 681 to 1589 grams per person per day. Microbiological degradation is the major cause of cellulose disappearance.

Cellulase, a cellulosic enzyme system, consists of three major components: endo-ß-glucanase (EC 3.2.1.4), exo-ß-glucanase (EC 3.2.1.91) and ß-glucosidase (EC 3.2.1.21). The mode of action of each of these being:

(1) Endo-glucanase, 1,4-ß-D-glucan glucanohydrolase, CMCase, Cx: "random" scission of cellulose chains yielding glucose and cello-oligosaccharides.

(2) Exo-P-glucanase, 1,4-ß - D-glucan cellobiohydrolase, Avicelase, C1: exo-attack on the non-reducing end of cellulose with cellobiose as the primary structure.

(3) ß-glucosidase, cellobiase: hydrolysis of cellobiose to glucose.

Limtong *et al* (1990) presented the results of isolation and selection of thermophilic cellulolytic microorganisms from samples taken from various locations throughout Thailand for compost production.

Microorganisms effective in cellulose decomposition were selected in four steps.

- The first step was the microorganism isolation and following by the test of the abilities to decompose cellulose in solid medium.
- The second step was the evaluation of enzyme capable of decomposing filter paper (FPase activity).
- The third step involved the evaluation of activities of crude enzyme to decompose carboxymethyl cellulose (CMC) and avicel.
- The fourth step was the test of microbial capability to decompose rice straw under laboratory and field conditions.

Abd-Alla and Omar (1998) studied the ability of cellulolytic fungi and wheat straw incorporation to improve the nodulation, growth and nitrogen status of fenugreek grown in saline soils. Three fungi, *Aspergillus niger*, *Chaetomium globosum,* and *Trichoderma harzianum,* showed the highest enzymatic activity.

Krishna (1999) isolated the bacterial strain, *Bacillus subtilis* (CBTK 106), from banana waste in solid state fermentation.

Badr EL-Din, Attia and Abo-Sedera (2000) cultivated sandy soil and sugar beet composted by highly effective cellulose-decomposing microorganisms, *Trichoderma viride* NRC6 or *Streptomyces aureofaciens* NRC22 and evaluated as organic manure for tomato plants.

Singh, Batra and Sobti (2004) purified and characterized an alkaline carboxymethyl cellulase (CMCase) from a novel isolate, *Bacillus sphaericus* JS1.

**Protease**

Protease [serine protease (EC. 3.4.21), cysteine (thiolo protease (EC. 3.4.22), aspartic protease (EC. 3.4.23) and metallo-protease (EC. 3.4.24)] constitute one of the most important groups of industrial enzymes and have applications in different industries, for example, detergent, food, pharmaceutical and leather. Proteases are produced by a wide range of microorganisms including bacteria, mould and yeast and also mammalian tissues. Among bacteria, *Bacillus* spp. are specific producer of extracellular protease. (Singh, Batra and Sobti, 2001)

A number of thermophilic fungi have been isolated by various investigators, from self-heating material and other sources. It has been assumed that thermophilic fungi and other thermophilic microorganisms play an important role in decomposing plant materials and other organic matter at evaluated temperature. Hashimoto, Iwaasa and Yokotsuka (1972) isolated a thermophilic bacterium, namely *Pseudomonas duponti* K1014, from compost and it produced thermostable alkaline protease, at 45-50 °C.

Yang *et al* (2000) studied the use of microorganisms or proteolytic enzymes for deproteinization of marine crustacean wastes. The bacteria were identified as strain of *Bacillus subtilis.* For the other microorganisms which produced protease, Bayoudh *et al* (2000) isolated a protease producing bacterium, *Pseudumonas aeruginosa* MN1, from waste water.

Some bacteria cause food poisoning but they can produce protease. *Bacillus cereus* excretes several kind of extracellular protease into the growth medium, reported by Kim *et al* (2001).

Chuntawannakul *et al* (2002) examined the microorganisms responsible for fermentation. *Bacillus subtilis* showed the highest protease activity. They developed a laboratory-scale process for making fermented soybean using *B. subtilis* as a pure starter culture.

**Lipase**

Lipase (triacyl glycerol acylhydrolase; EC. 3.1.1.3) are a group of enzymes that catalyze the hydrolysis of triacylglycerols to diacylglycerols, monoacylglycerols, fatty acids and glycerol at the interface between aqueous and the lipid phase. Some lipases are nonspecific, catalyzing reaction at all positions in triacylglycerols, while others are regiospecific, catalyzing reactions at specific positions on the lipid molecules. The latter group of enzymes has many industrial applications including the improvement of flavor through removal of lipids for dairy, bakery, alcohol beverage, meat and fish products, removal of oil stains as detergent additive, digestion of oils and fats in foods as digestive acids, and removal of fats from animal skins for leather products. (Ko *et al*, 2005).

Dharmsthiti and Kuhasuntisuk (1998) studied the biochemical properties and application of lipase for wastewater treatment. The lipase was produced from a bacterium, *Pseudomonas aeruginosa* LP602. Furthermore, Dharmsthiti and Luchai, (1999) purified and characterized extracellular lipase from *Bacillus* sp. THL027 for potential industrial applications.

Many microorganisms such as bacteria, yeast and fungi are known to secrete lipases during growth on hydrophobic substrates which renders the lipid substrates available to the cells. Haba *et al* (2000) screened lipase producing microorganisms from used frying oil. Forty seven strains of bacteria and yeasts were identified as the member of *Pseudomonas, Bacillus, Candida, Rhodococcus* and *Staphylococcus.* The best lipase producer in this study were *Pseudomonas* sp. 3AT and *Pseudomonas aeriginosa* ATCC 111.

Markossian *et al* (2000) isolated lipid-degrading *Bacillus thermoleovorans* IHI-91 from an Icelandic hot spring for application in various biotechnological processes such as wastewater treatment.

The use of mixed culture of bacteria was studied by Mongkolthanaruk and Dharmsthiti (2002) to lower the biological oxygen demand (BOD) value and lipid content of lipid-rich wastewater. The bacteria, *Pseudomonas aeruginosa* LP602, *Bacillus* sp. B304 and *Acinetobacter calcoaceticus* LP009, were used as mixed culture and gave good results to reduce BOD and lipid content.

#### 2.3.4 Termination of the compost

At compost maturity, the temperature in all parts of the pile drops to 33-35°C, or approximately air temperature, after the 2nd or 3rd turning. The different materials in the substrate are no longer recognizable. The compost color is dark brown to black, and looks like soil. Some composts such as rice do not emit a foul odor. The period of composting is shown in Table 2.3.

**Table 2.3** Maturing period and composition of compost from different materials, using rapid composting technology (Insam, Riddech and Klammer, 2002).

| Materials | pH of mature compost | Maturing period (days) | Composition | | | | | |
|---|---|---|---|---|---|---|---|---|
| | | | Total carbon | Total nitrogen | Final C:N | Phosphorus $P_2O_5$ (%) | Potassium |
| Rice straw + ipil leaves | 8.4 | 28 | 29.5 | 2.5 | 12:1 | 1.0 | 3.7 |
| Rice straw + chicken manure | 8.1 | 22 | 30.0 | 2.6 | 12:1 | 3.5 | 3.6 |
| Grass | 7.2 | 35 | 31.0 | 2.1 | 15:1 | 0.3 | 1.0 |
| Carabao grass | 7.4 | 32 | 36.0 | 4.0 | 9:1 | 1.0 | 4.5 |
| Bagasse + animal manure | 7.2 | 42 | 17.0 | 1.3 | 13:1 | 1.3 | 2.0 |
| Average | 7.5 | 32.3 | 31.4 | 2.6 | 13:1 | 1.3 | 2.7 |

Microorganisms in the composting process must have sufficiently balanced nutrient sources. This is usually described as the carbon:nitrogen ratio (C:N). Microbes rely on carbon in the composting material for their energy source and it is a basic composition of their cell structure. The most biodegradable carbon forms, such as sugars and starches, provide most of the energy. Some less biodegradable carbon forms, such as lignin in wood, can be broken down by only a few microbes whereas some carbon compounds, such as those in plastics, may not be biodegradable at all. Those easily broken down carbon compounds will be consumed by the organisms and eventually be released to the atmosphere as carbon dioxide. The least biodegradable carbon compounds may remain as a basic part of the remaining humus. Though microbes require a broad range of other nutrients, nitrogen is the most important because it may be lacking in many organic materials and because it is necessary for the synthesis of nucleic acids, and amino acids that make up the bodies of microbes. The amount of nitrogen will affect, to a great extent, how many microbes will be present in the compost. Therefore, the C:N ratio is one of the most important factors successful composting. The ideal C:N ratio is about 20:1 (20 parts carbon to one part nitrogen). Ratios wider or narrower than that range will likely cause the materials to decompose much more slowly. (Insam, Riddech and Klammer, 2002).