Chapter 3
Methodology

3.1 Site selection for this study

The selected site for this study is a wastewater treatment plant of one electronic products factory where it is settled in export zone, Northern Region Industrial Estate (NRIE) in Lamphun. NRIE is the first Industrial Estate (IE) in Northern Region following the decentralization policy in 1982 and this estate is ISO 14001 certified. Enterprises come from mixed sectors, with concentration in electronics and automotive suppliers. These two companies are presently expanding production, creating additional demand for 2,500 workers (Chavanich, A., 2001). The number of electronic products factories is not only the highest at approximately 35% from of all operated factories in NRIE, but also, they have a high number of labors, which is more than 70% of all labor in NRIE. The central WWTP is aerated lagoon at a capacity of 12,000 cubic meter per day.

The main products of this factory is electronic parts of computers and mobile telephones produced to famous customer's requirements. Almost all products are internationally exported. The manufacturing plant and support facilities are situated in a 46,000 square meter area, and the production operators work for 2 shifts. The factory has certified ISO 9002 for many years, and are implementing ISO 14001 for environmental management and OHSAS 18001 for safety.

3.2 Procedure

The methodology of this study is illustrated in Fig. 3.1, which is modified from the general methodology as described in detail below:

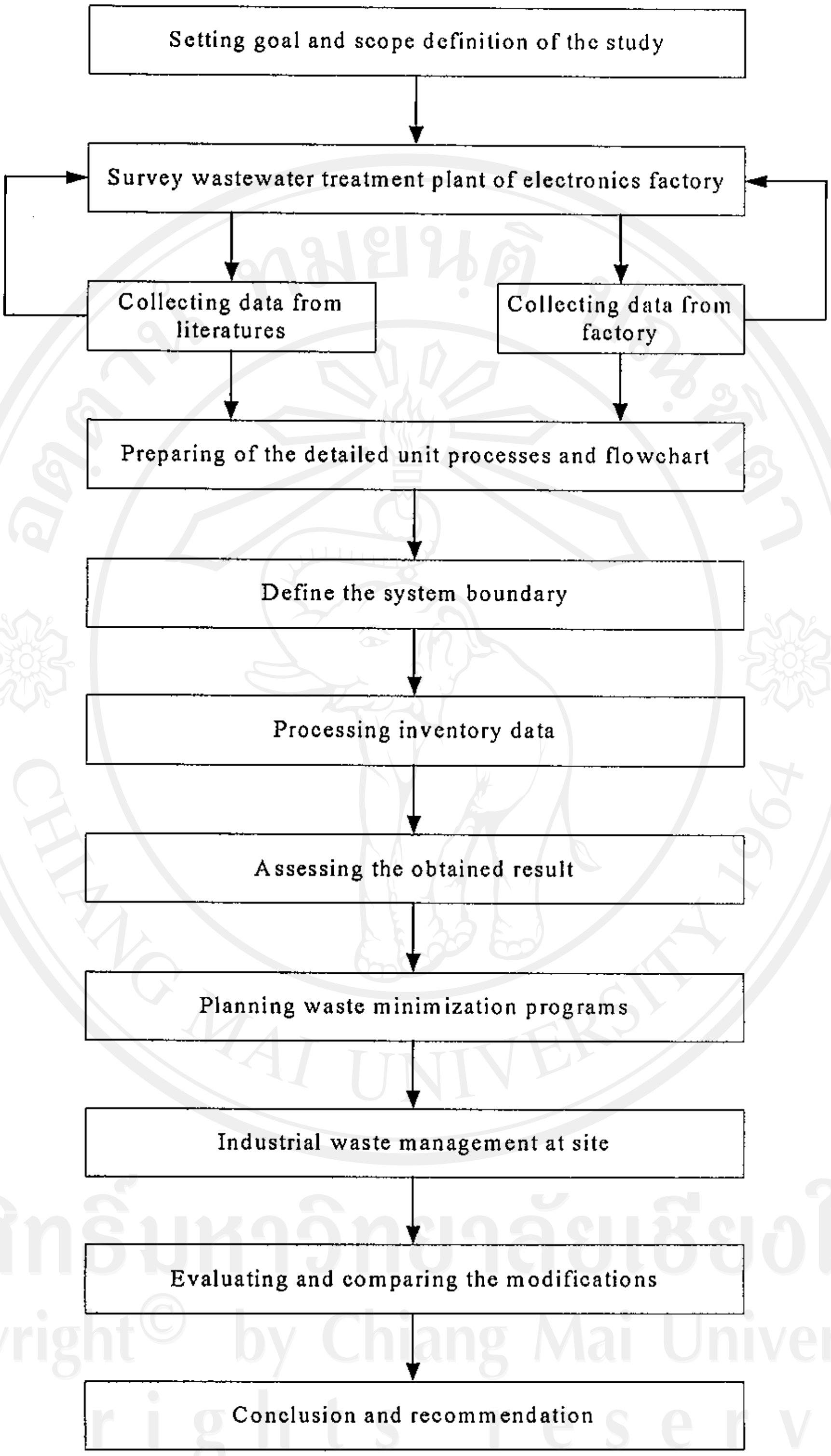

Figure 3.1 General methodology for this LCA study.

3.2.1 Setting goal and scope definition of the study

The first stage, goal definition and scoping stage of LCA, defines the purpose of the study to investigate LCA approach and evaluate the electronic products wastewater treatment plant (WWTP) in each system. The identification of this process function is pollutant removal, collection and transfer of wastewater and sludge treatment. An important issue of this subject is specified in the functional unit 1 m^3 of the treated wastewater with satisfied quality to meet the standard for discharged effluent of the Industrial Estate Authority of Thailand. The scope of the study was focused on the operation phase, excluding phase of construction and demolition.

3.2.2 Survey wastewater treatment plant of electronics factory

Prior to surveying WWTP of the electronics factory, the researcher discussed and reviewed with the WWTP operation team for overview. The walk through and observation of WWTP was done to understand the wastewater treatment processes and their operations, material input and output, emission to air, water and solid waste generation. Otherwise, the technical data sheets, safety data sheets, recorded worksheets, calculations, statistic analysis and laboratory results were surveyed for collecting in the next item.

3.2.3 Collecting data from factory and literatures

The collection of data dealt with many processes and environmental burdens of resource consumption, air emissions, water emissions and wastes. The gathered data were checked and verified for consistency by mass balance. From the observation, some general data in WWTP were obtained as follows:

a) Electricity consumption

The measurement of electricity usage for WWTP was separated from the main electricity line of the factory by meter counting.

b) Raw material and resource use

The usage of raw materials and resources was collected from recorded worksheets for both normal and abnormal WWTP operations and maintenances.

c) Wastewater

Wastewater analysis was done on a daily basis by grab sampling following the Standard Method 20th edition (American Public Health Association, 1998). The volume of wastewater was measured by electromagnetic flow meter, flow meter and weir. Sometimes, the factories information could not be provided, it might be found within the factory's recorded data or specifications to estimate the approximate data.

d) Solid waste and hazardous waste generation

The main hazardous waste generated from the sludge dewatering process was recorded on each shipment to disposal. Among the most significant factors determined the choice of dewatering methods were the types of sludge produced, the size of WWTP, and the method of final sludge disposal.

e) Miscellaneous data

Due to the limitation of time and the unavailability of some data, the literature data were used in order to complete the missing data, i.e.; electricity production in Thailand, land fill conditions, waste and material transportation data and some material production.

3.2.4 Preparing of the detailed unit processes and flowchart

Start the process flowchart with the wastewater treatment operation processed and added the input/output for each unit process, then combined the processes to the full detailed flow diagram of WWTP system boundaries. The process flowchart of WWTP, started with the collection of wastewater, wastewater treatment systems, sludge treatment and concluded with waste disposal. An iterative process run through each step of the inventory several times until the result was suitable for the purpose of the study.

3.2.5 Define the system boundary

The identification of system boundary is important to the level of detail, that depended on the required and applied results. The system boundary contributes to determine the goal definition, the process flowchart and the data collection that refer to included/excluded processes in this study. The excluded process was due to a lack of information or less amount of raw materials, resources and energy used, which described in Chapter 4. It was assumed that this limitation was due to low concentrations of these components, contributing less environmental impact potentials comparing with the whole life cycle and no serious affect to the outcome of the study.

3.2.6 Processing inventory data

This section is the last past of the inventory that processes the data to carry out the calculation. The first step is the transformation of all the gathered data to a convenient form. This study did not have any LCA software. The calculation could be carried out with an Excel program by allocation where necessary. In this study, the specific amount of the components were calculated focusing on important emissions and resources (Curran, M.A. ,1996).

3.2.7 Assessing the obtained result

The weighting method, EPS default as explained in section 2.1.4, was used for impact assessment in this study relating the outcome of an inventory analysis to environmental themes. The raw material extraction and emissions released processing from LCI data were calculated with the environmental indices for each emission or resource demand to be environmental load values at each stage of the WWTP life cycle stage. They could be added together to arrive at an overall ELU based on 1 m^3 of treated wastewater to effluent. The weighting factor is obtained from EPS default method, version 2000 (Steen, B. 1999 and Steen, B. 2001). The process that have the highest ELU score, highly contributes to environmental impact to the entire system. The outcome was checked for soundness with a sensitivity analysis to identify the consequences of uncertainties and deviations in the data.

3.2.8 Planning waste minimization programs

The environmental impact of wastewater treatment process that had the highest ELU, must be planned to implement minimization programs as describe in section 2.3. These tasks included the following: planning and organization, assessment phase, feasibility analysis, and implementation and evaluation. The benefits of these programs could reduce environmental burdens that effected to ELU value and identify opportunities. The various improvement options were compared and the suitable one were selected.

3.2.9 Industrial waste management at site

To perform any improvement of WWTP, the alternative of industrial waste management was implemented as planned. During this period, all concerning data were collected and assessed following the first results of the weighting method. Duration of implementation depended on the consistency result.

3.2.10 Evaluating and comparing the modifications

In this step, the obtained results from the modification of waste management were evaluated and compared with the results of the existing condition to find changes of environmental impact potentials and expenses, which were described in Chapter 4.

3.2.11 Conclusion and recommendation

Detail of conclusions and recommendations of this study were considered from LCA of WWTP based on 1 m^3 of the treated wastewater and comparison result from industrial waste management by waste minimization method. This part was elaborated in Chapter 5.

3.3 Objective of this study

The purpose of this LCA represents to be a potentially useful and powerful tool to identify and maximize the environmental benefits to an electronic products wastewater treatment plant by using waste minimization.

3.4 System boundaries in the study

The diagram of system boundary in this study is defined in Fig. 3.2 that shows all processes included in this study and some exclusion parts.

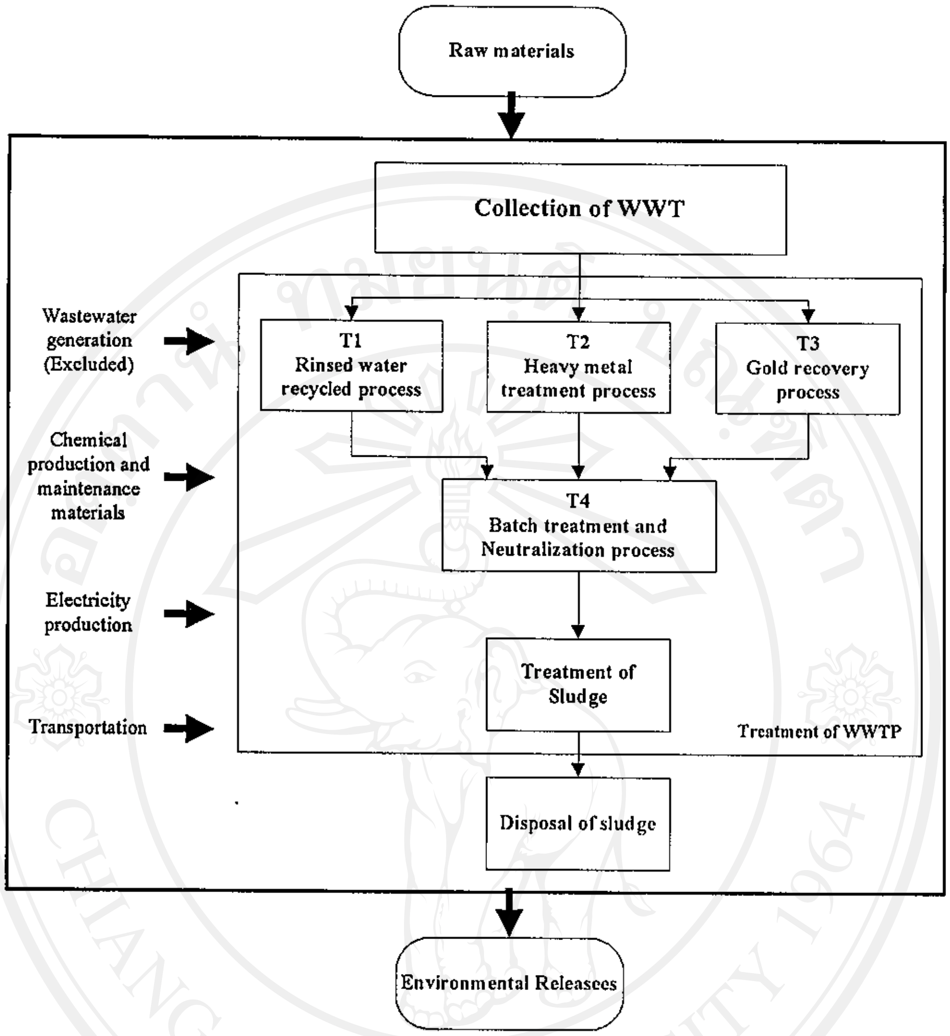

Figure 3.2 LCA of the electronic products wastewater treatment plant (WWTP) and the system boundary analysis.

3.5 Data specification

Data specification of this study was to classify the data source of unit wastewater treatment processes as shown in Table 3.1, which used for calculating in LCI. The duration of data collection at this site was approximately 1 year by measurement and laboratory analysis and the other general data were found from concerned literatures.

Table 3.1 Data specification of this study

Unit process	General data from factory	Data from literature	Comments
1. Extraction of resource			
1.1 Electricity production (kW-h)		*	
1.2 Petrol production and use (litres)		*	
1.3 Diesel production and use (litres)		*	
2. Extraction of raw material and maintenance part			
2.1 Wastewater	*		
2.2 Chemical		*	
2.3 Resin production		*	(Polystyrene)
2.4 PP filter production		*	(Polypropylene)
3. Wastewater treatment process			
3.1 Rinse water recycled process (T1)	*		
3.2 Heavy metal treatment process (T2)	*		
3.3 Gold recovery process (T3)	*		
3.4 Batch treatment and neutralization process (T4)	*		
4. Waste management			
4.1 Solid waste land filling		*	
4.2 Sludge land filling		*	
5. Transportation			
5.1 Chemical transportation		*	
5.2 Waste transportation		*	

The detail of each unit process that included in the assessment was described as below;

3.5.1 The electricity production

In this study, the source of electricity production was studied from information of Thailand Environmental Institute (TEI) and Electricity Governmental Authority of Thailand (EGAT) as shown in Appendix C. Thai electricity is produced mostly from coal, oil, natural gas ,and hydro power and their inventory of electricity production per kWh is found from data of year 1999 (Ongmongkolkul, A. et. al., 2001).

3.5.2 Extraction of resource, raw material and maintenance parts

Not only the time limitation and unavailable of some information of extraction of resource, raw material and maintenance parts, but also this LCA study used the weighting method instead of software program. Therefore, no database were provided for this relevant data and the assumptions need to be utilized for completing the outcome.

The assumption of petrol production and use was modified for oil utilization in WWTP. The inventory of oil per liter included energy consumption, air and water emissions, and solid waste (Tchobanoglous, G., Theisen, H. and Vigil, S., 1993).

General chemicals used in WWTP were extracted to chemical elements but utilization of Hydrochloric acid and Sodium hydroxide, which were the main volume of wastewater treatment consumption, could be considered in each their production and calculated with inventory of electricity production to be inventoried by each chemical (Pandy, G.N., 1994).

Resin production, was referred to their composition of DVB 8-12% and polystyrene 88-92% (APME, 2001) to assume that the main part of resin was come from polystyrene production (Pandy, G.N., 1994).

PP filter production was assumed from LCI data for the production of polypropylene data as virgin PP (per ton) include energy consumption, air emissions, water emissions and solid waste (Tchobanoglous, G., Theisen, H. and Vigil, S., 1993).

3.5.3 Wastewater treatment process

The inventory of main material in WWTP was included data from rinse water recycled process (T1), heavy metal treatment process (T2), gold recovery process (T3) and batch treatment and neutralization process (T4) as shown the total amount of treated wastewater 1 m^3. The main parts of these inventories were wastewater, used chemicals and electricity. Wastewater was considered by extraction of influent and effluent analysis result. The inventory result of WWTP is shown in Appendix D except some factory's confidential data.

3.5.4 Waste management

The generated solid waste is separated into 2 main types: plastic and paper which use percent weights from typical physical composition of municipal solid waste and energy content of MSW. It is found that cardboard consists of carbon 44%, hydrogen 5.9%, oxygen 44.6%, nitrogen 0.35%. Plastic consists of carbon 60%, hydrogen 7.2% and oxygen 22.8%. It is assumed that the organic wastes are stabilized completely and landfill is not provided by any device of air emission which has a significant impact to environment. Thus, gas release can be calculated by the corresponding expression by Eq. 3.1 defined as (Tchobanoglous, G., Theisen, H. and Vigil, S., 1993).

$$C_aH_bO_cN_d + \left(\frac{4a-b-2c+3d}{4}\right)H_2O \longrightarrow \left(\frac{4a+b-2c-3d}{8}\right)CH_4 + \left(\frac{4a-b-2c-3d}{8}\right)CO_2 + dNH_3$$

(Eq. 3.1)

The result of air emissions of treated wastewater 1 m^3 in landfill was determined by the weight of methane, carbon dioxide and ammonia. The detail of the estimation of gas amount produced in MSW landfill is shown in Appendix E.

Due to regulations in Thailand, sludge from WWTP is classified as toxic industrial waste under the regulatory name “metal hydroxide sludges and oxide sludges” from the sludge analysis result. The analytical data is content on a dry weight basis in ppm with mild odor and does not present any vapor. Therefore generated sludge is considered and assumed in chemical element which are mostly concerned to soil emission.

3.5.5 Transportation

Trucks are used for waste and chemical transportation which is driven by diesel engines. The assumed truck in this study was a lugger truck weighted at 10 tons each. Total diesel consumption was separated and calculated from factory distance. The estimation of distance from factory to waste destination is 850 km. and chemical factory to factory is 750 km., which is assumed as truck long distance. The emission factor for transportation is multiplied with each weight of chemical and waste at ton per cubic meter, then summary to inventory of waste and chemical transportation (Rydh, C.J. and Karlstrom, Magnus., 2001).