CHAPTER III
METHODOLOGY

Leaching tests and lysimeter tests were conducted in this study. The details of the experiments are described in this chapter.

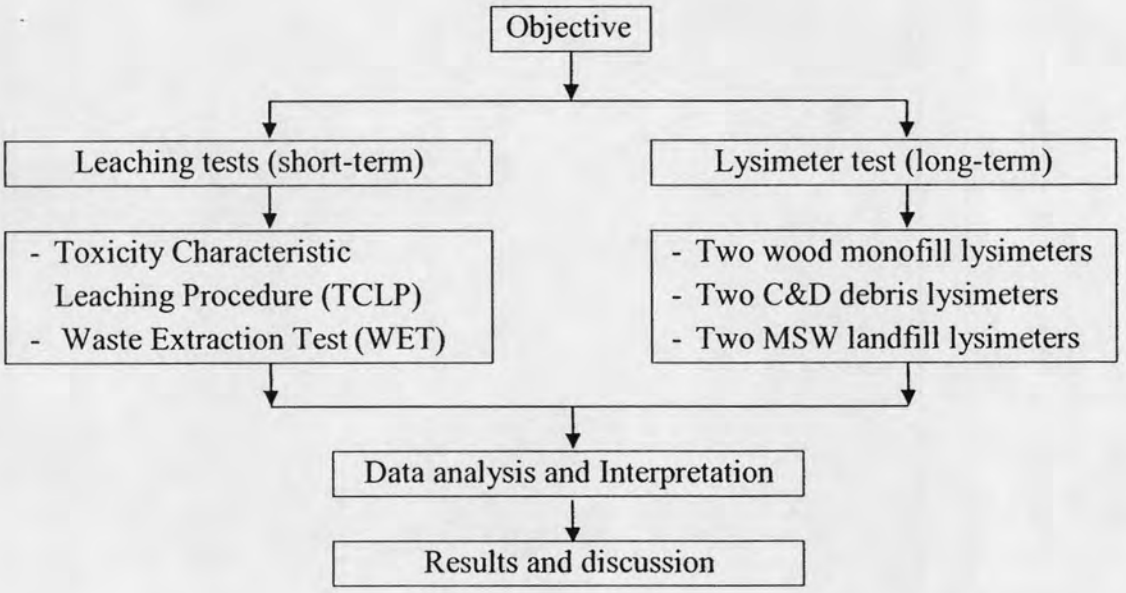


Figure 3.1 Overview of a study

3.1 Leaching tests

3.1.1 Sample description and pre-processing

For the leaching tests, the samples included weathered wood, new wood and ash from new wood. A listing of these samples is provided in Table 3.1. It should be noted that the samples were purchased from two wood manufacturers located in the city of Chiang Mai. There was no information provided about the type of wood from the manufacturers. The retention level indicated from both manufacturers during the purchasing of the treated wood was 0.5 pcf or 8.1 kg/m^3, and CCA solution used contained 39.0% chromium as CrO_3, 31.5% copper as CuO, and 24.5% arsenic as As_2O_5 which is widely used in the northern region in Thailand. The wood samples were reduced in size and capable of passing through a 9.5 mm

(0.375 inch) sieve before the extraction process using a table saw and radial arm saw at the Department of Mechanical Engineering, Faculty of Engineering, Chiang Mai University. The sawdust generated was kept for analysis.

3.1.2 Total Metal Concentration

The samples were digested following U.S. EPA SW 846 Method 3050B (U.S. EPA, 1996) and were analyzed for the total concentrations of chromium, copper, and arsenic using an atomic absorption spectrophotometer, GBC Avanta Model HG 3000. The analysis of each sample was replicated.

Table 3.1 A listing of the samples used in the leaching test

Sample category	Description
Hardwood[*] • Untreated wood • CCA-treated wood	New 0.5 pcf CCA-treated wood
Softwood[**] • Untreated wood • CCA-treated wood	New 0.5 pcf CCA-treated wood
Weathered wood[*] • CCA-treated wood	The age of the weathered wood was estimated at 14 years
Ash from hardwood[*] • Untreated wood ash • CCA-treated wood ash	The new 0.5 pcf CCA-treated woods were placed in the furnace and heated at 550°C for 2 hours.

Remarks: [*] - from manufacturer A

[**] - from manufacturer B

The analysis was conducted on two sets of sawdust samples, which were obtained from the entire cross section of the wood and outer 6/10" of wood. The outer 6/10" sample corresponds to the "rated" retention level of the wood sample in

accordance with American Wood Preservers Association standard procedures (AWPA, 1999). The retention values were based upon the sawdust collected from the entire cross-section, which more directly represents the metal concentrations throughout the wood sample and is a more useful value when comparing the resulting leaching test values.

3.1.3 Leaching and analytical procedures

The Toxicity Characteristic Leaching Procedure (TCLP) and the Waste Extraction Test (WET) were conducted in this study.

U.S. EPA SW 846 Method 1311, (U.S. EPA, 1992) was followed to perform the TCLP. A representative 100-g sample was weighed and placed in a high density polyethylene (HDPE) plastic container. Two liters of TCLP extraction fluid was added to the sample in the vessel. The sample was placed in the extractor and rotated at 30 rpm for 18 hours (± 2 hours). The picture of a rotary agitator is shown in Figure 3.2. The sample was removed from the extractor and filtered with a glass fiber filter (pore size 0.6-0.8 μm). An acid-rinsed 1-L plastic bottle was placed under the vessel to collect the filtered sample. The extract was preserved by adding enough nitric acid to lower the pH to below 2 pH units. The extract was stored in a cold room (below 4 °C) before metal digestion. The digestion was performed by using either U.S. EPA SW-846 Method 3010A or 3020A, depending on the metal concentrations in the sample. Extraction fluid #1, a buffered organic acid (CH_3COOH) solution at pH 4.98, was used on all the samples except for the ash samples. Extraction fluid #2 (pH 2.88) was used on the ash samples due to their high alkalinity.

The Waste Extraction Test (DTSC, 2005), which has been used in Thailand for identifying hazardous waste, was utilized in this study. Each 50-g sample was weighed and placed in a high density polyethylene (HDPE) plastic container. Five hundred milliliter of WET extraction fluid (a solution of sodium citrate, pH 5.0±0.1) was added to each sample in the vessel. The sample was placed in the extractor and rotated at 30 rpm for 48 hours (± 2 hours). The sample was removed from the extractor and filtered with a glass fiber filter (pore size 0.45 μm).

All of the extracted samples were digested by following U.S. EPA SW-846 Method 3010A (U.S. EPA, 1986), a method for analyzing arsenic, chromium, and copper by using an atomic absorption spectrophotometer, GBC Avanta Model HG 3000.

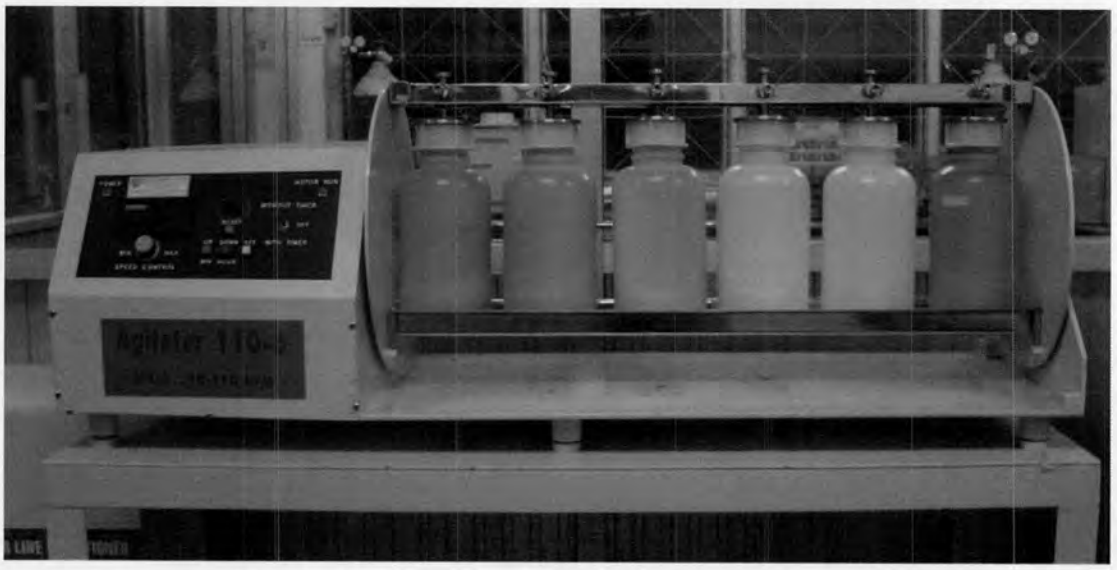


Figure 3.2 Rotary agitator used in the leaching test

3.2 Lysimeter tests

Lysimeter tests or column tests were designed to evaluate the potential for heavy metal contamination in the leachate generated by CCA-treated wood. The details of the tests in this study are as follows.

3.2.1 Lysimeter preparation

A total of six 2-meter high lysimeters made of 20.32-cm diameter PVC columns were prepared for the leaching simulation. A cross-section view of a lysimeter is shown in Figure 3.3. The lysimeters were prepared indoors at the Department of Environmental Engineering, Faculty of Engineering, Chiang Mai University. Two lysimeters simulated wood monofills, two simulated C&D debris landfills, and the final two simulated MSW landfills. The two lysimeters within each set were identical except for their wood components. The details of the lysimeter

experiments are summarized in Table 3.2. Each lysimeter was filled with a 1.5-meter layer of waste. Each component of waste was reduced in size to 4-cm by 4-cm pieces whenever possible.

Table 3.2 Summary of the lysimeter contents

Lysimeter No.	Lysimeter type	Total amount of wood weight	Total amount of waste filled	Proportion of wood contained inside
1	Wood monofill	26.2	26.2	100 % of untreated hardwood
2	Wood monofill	23.6	23.6	100 % of new CCA-treated hardwood
3	C&D debris	3.61	26.1	14 % of untreated wood
4	C&D debris	1.90 untreated and 1.90 CCA-treated wood	27.3	7 % of untreated hardwood and 7 % of new CCA-treated hardwood
5	MSW	0.57	29.2	2 % of untreated hardwood
6	MSW	0.57	29.2	2 % of new CCA-treated hardwood

The wood-monofill lysimeters (100% of wood) represent the storage or disposal of CCA-treated wood in a separate area. These lysimeters (Lysimeter Nos. 1 and 2) provided information on the leaching of the wood without other materials present to interact with.

The C&D lysimeters (Lysimeter Nos. 3 and 4) contained construction and demolition waste based on a construction model of a typical house in Chiang Mai, Thailand (see the composition in Table 3.3). The wood used to build a house can be categorized as inside and outside structural wood. CCA-treated wood may be used for the outside wood structure to prolong its service-life and its proportion is around 50% of the total wood used. Figure 3.4 shows the waste compositions in the C&D lysimeters.

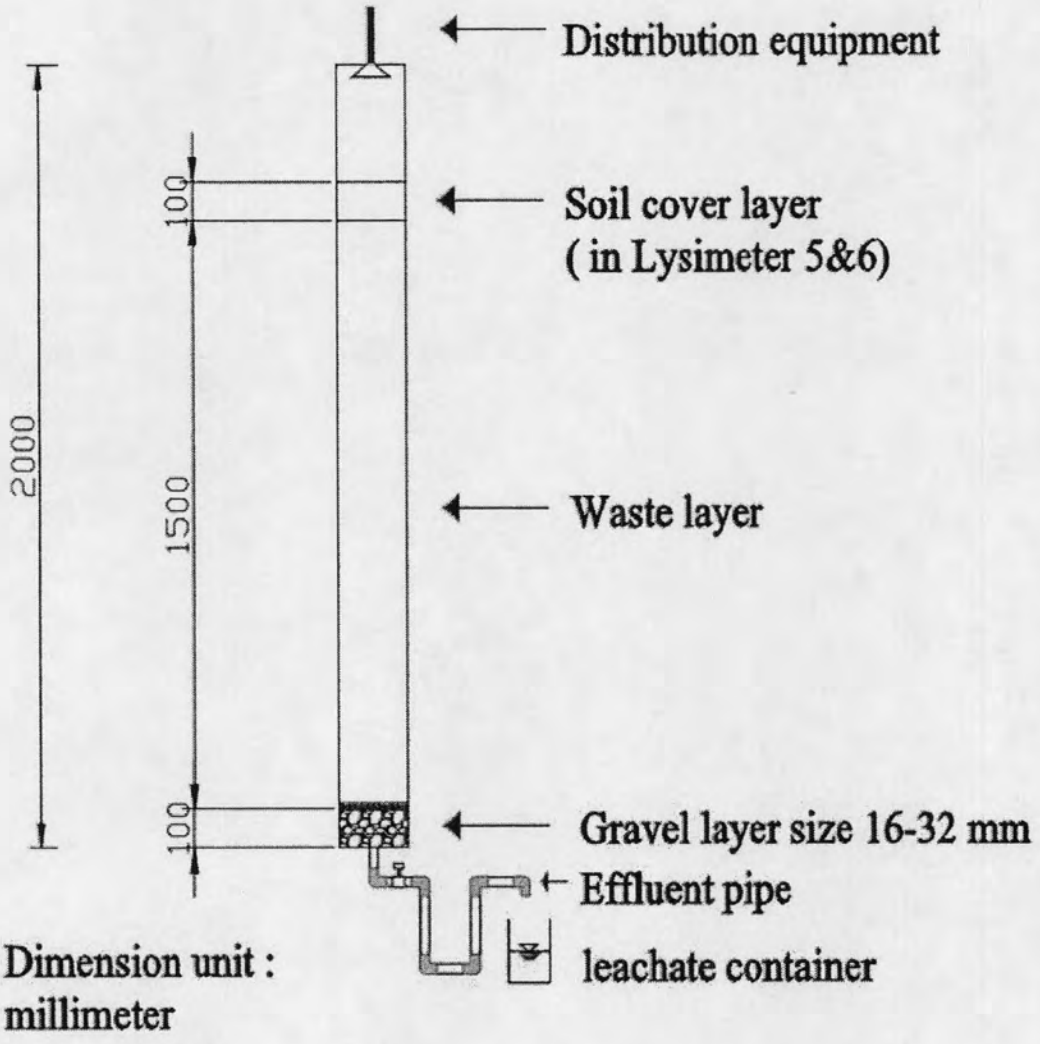


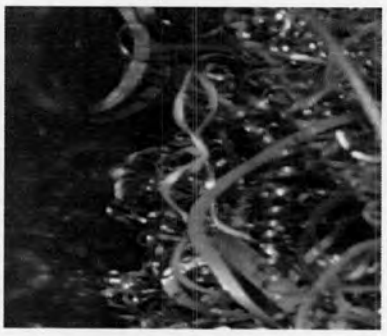
Figure 3.3 Cross-section of a lysimeter

Table 3.3 Compositions of the C&D lysimeters

C&D Component	% composition by weight in Lysimeter No. 3	% composition by weight in Lysimeter No. 4
Concrete	60.6	60.6
Gypsum board	21.8	21.8
Roofing	2.80	2.80
Steel bar	0.70	0.70
CCA-treated wood	-	6.70
Untreated wood	14.1	7.40

(a) Wood

(b) Gypsum board



(c) Steel bar

(d) Concrete

(e) Roofing

(f) Waste mixed

Figure 3.4 C&D waste components in Lysimeter Nos. 3 and 4

The waste compositions of wood used in the MSW lysimeters (Lysimeter Nos. 5 and 6) simulated the waste compositions of the Chiang Mai Municipality in 2004, according to the data collected by the Pollution Control Department (see Table 3.4) (PCD, 2004). Wood is estimated at 1-5% of the total Chiang Mai city waste stream depend on each areas. The CCA-treated wood waste was estimated at 2% of the total wood stream in order to simulate the worst case that CCA-chemical might be contaminated to the waste stream. Each component of waste was chopped into 4-cm by 4-cm pieces whenever possible before mixing the

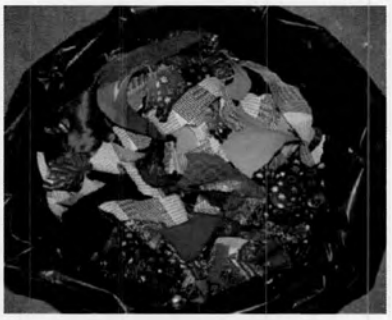
percentage ratios described in Table 3.4. The waste components placed in the MSW lysimeters are shown in Figure 3.5. An overall view of the all the lysimeters is presented in Figure 3.6.

Table 3.4 Composition of the MSW lysimeters

MSW component	% composition by wet weight
Food waste	52.9
Paper	10.8
Plastic	14.8
Glass	9.41
Metal	2.06
Rubber and leather	0.88
Cloth	2.55
Garden waste	1.18
Stone and ceramics	2.06
Miscellaneous total	1.37
Wood	2.00
% moisture content	53.5%

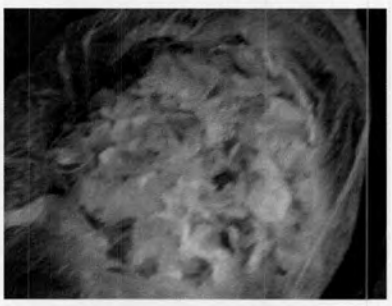
The moisture content of each component was predetermined and the results are shown in Table 3.5. After mixing the waste, the moisture content of the mixed waste was adjusted to 53.5% to mimic the actual moisture content of the waste being simulated. The waste was mixed and filled with compaction to a density of 600 kg/m^3 for every 25-cm layer of waste in order to get the same composition and density in both lysimeters. A ten-centimeter layer of soil was used to cover the waste in order to simulate actual landfill situations.

(a) Rubber and leather



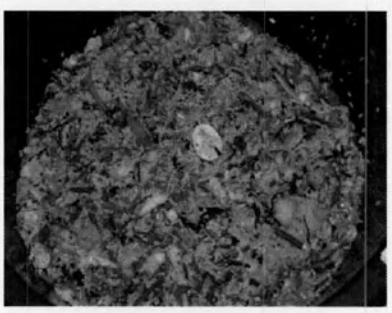
(b) Cloth

(c) Glass



(d) Miscellaneous

(e) Garden waste



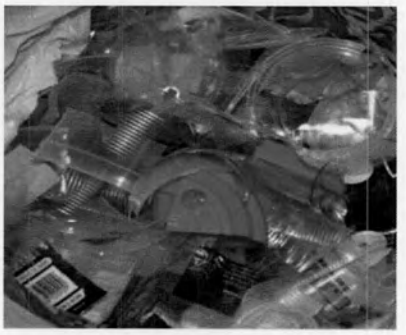
(f) Food waste

Figure 3.5 Waste components in Lysimeter Nos. 5 and 6

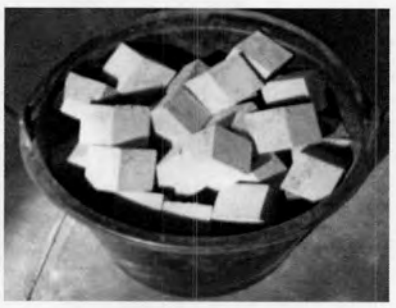
(g) Metal

(h) Stone and ceramics

(i) Paper



(j) Plastic



(k) CCA-treated wood

(l) Untreated wood

(m) Waste mixed

Figure 3.5 Waste components in Lysimeter Nos. 5 and 6 (continued)

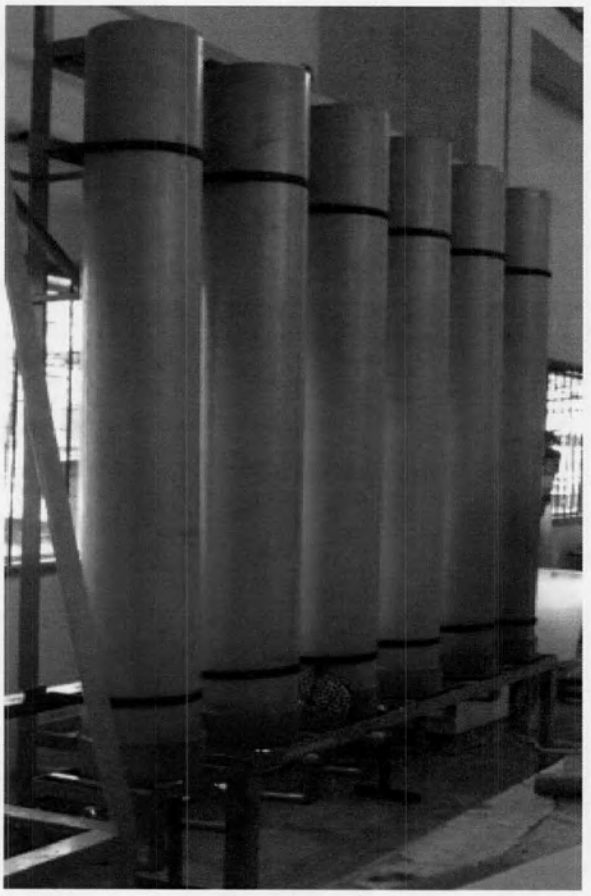


Figure 3.6 An overall view of the six lysimeters

Table 3.5 Moisture content of each component

MSW component	% Moisture content
Food waste	72.77
Paper	5.56
Plastic	1.09
Glass	0.15
Metal	1.2
Rubber and leather	0.53
Cloth	4.54
Garden waste	10.48
Stone and ceramics	0.6
Miscellaneous total	1.72
Wood	8.62

3.2.2 Operation and monitoring of the lysimeters

- **Rainfall simulation**

In order to simulate rainfall, distilled water (pH 7±0.2) in an amount equal to the daily rainfall in Chiang Mai province from May 1, 2005 to October 31, 2005 (see Table 3.6) was fed once a day into every lysimeter.

Table 3.6 Daily rainfall data (mm) between May-October 2005 in Chiang Mai province from the Meteorological Department, under the Ministry of Information and Communication Technology of Thailand.

Date	Rainfall (mm)					
	May	June	July	August	September	October
1	0.0	18.7	0.0	11.8	28.3	0.0
2	26.8	23.5	0.2	T	7.3	0.0
3	0.0	16.4	0.0	0.0	34.3	15.6
4	0.0	2.8	T	4.9	T	0.0
5	T	7.2	8.1	0.0	50.0	0.0
6	3.6	20.7	0.0	2.8	6.5	0.0
7	8.1	0.1	0.0	4.9	12.7	1.0
8	20.4	0.2	0.0	4.5	9.3	3.5
9	T	3.3	1.5	0.4	5.3	0.0
10	0.0	4.3	0.0	0.0	41.0	0.0
11	0.0	0.0	0.0	0.8	53.2	0.0
12	0.0	T	47.7	38.5	2.9	0.0
13	0.0	9.2	2.3	13.1	0.0	2.3
14	0.0	0.0	33.6	9.8	9.3	1.1
15	0.0	17.4	3.2	0.0	4.4	0.0
16	0.0	0.3	0.1	2.4	T	0.0
17	0.0	6.5	0.0	11.1	0.9	0.0
18	0.0	T	0.0	2.4	50.0	0.0
19	0.0	19.7	4.8	0.1	69.1	17.6
20	T	7.4	19.9	0.9	T	0.0
21	1.3	18.8	2.0	7.2	T	0.0
22	0.0	0.0	27.1	3.5	0.0	0.0
23	0.0	12.6	0.0	5.0	3.3	0.0
24	1.9	0.0	15.4	0.0	T	2.7
25	0.0	T	7.6	0.6	0.0	0.0
26	0.0	T	5.6	0.0	0.0	2.4
27	2.4	2.0	0.0	12.3	15.7	0.7
28	0.0	2.4	0.0	6.8	12.4	8.3
29	11.0	0.0	0.0	0.0	18.2	60.3
30	28.8	0.0	T	0.1	2.2	39.7
31	0.4	-	0.0	11.3	-	36.8
Total	104.7	193.5	179.1	155.2	436.3	192.0

Note: T = Rainfall amount less than 0.1 mm

3.2.3 Sampling and analysis

The quantity of leachate generated from each lysimeter was measured daily. The leachate characteristics were analyzed weekly, except for the last month, during which time they were analyzed once every ten days. The parameters and analytical methods are shown in Table 3.7. Quality control measures, i.e. a method blank, spikes and replication, were employed in order to satisfy the recommended minimum criteria for acceptable data quality.

Table 3.7 Monitoring parameters and analytical methods used in the lysimeter tests

Parameters	Method/Analysis instrument
• pH	pH meter (pH 315i/set)
• Conductivity	Conductivity meter (Cond 330i/set)
• Oxidation-reduction potential (ORP)	ORP meter (WTW pH315i)
• Total organic carbon	TOC analyzer (analytikjena Model. Micro N/C) : TOC Combustion Technique, AWWA(1995)
• Dissolved organic carbon	TOC analyzer (analytikjena Model. Micro N/C) : TOC Combustion Technique, AWWA(1995)
• Volatile fatty acid	Distillation Method, AWWA(1995)
• Total alkalinity	Direct Titration, AWWA(1995)

Table 3.7 Monitoring parameters and analytical methods used in the lysimeter tests (continued)

Parameters	Method/Analysis instrument
• Heavy metal	
– Sample digestion	US EPA SW 846 method 3010
– Arsenic	Hydride Generation Technique: Atomic Absorption spectrophotometer, Model. GBC Avanta Model HG 3000
– Chromium	Flame Technique: Atomic Absorption spectrophotometer, Model. GBC Avanta Model HG 3000
– Copper	Flame Technique: Atomic Absorption spectrophotometer, Model. GBC Avanta Model HG 3000

3.3 Statistical Analyses

A one-way ANOVA at 95% confidence intervals was used to compare the results between the groups of samples.