Appendices

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APPENDIX A

Glossary

Characterization - Characterization is the second step of an impact assessment and characterizes the magnitude of the potential impacts of each inventory flow to its corresponding environmental impact.

Classification - Classification if the first step of an impact assessment and is the process of assigning inventory outputs into specific environmental impact categories.

Environmental aspects - Elements of a business' products, actions, or activities that may interact with the environment.

Environmental loadings - Releases of pollutants to the environment, such as atmospheric and waterborne emissions and solid wastes.

Functional unit - The unit of comparison that assures that the products being compared provide an equivalent level of function or service.

Impact assessment - The assessment of the environmental consequences of energy and natural resource consumption and waste releases associated with an actual or proposed action.

Impact categories - Classifications of human health and environmental effects caused by a product throughout its life cycle.

Impact indicators - Impact indicators measure the potential for an impact to occur rather than directly quantifying the actual impact.

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Industrial system - A collection of operations that together perform some defined function.

Life cycle assessment - A cradle-to-grave approach for assessing industrial systems that evaluates all stages of a product's life. It provides a comprehensive view of the environmental aspects of the product or process.

Life cycle inventory - The identification and quantification of energy, resource usage, and environmental emissions for a particular product, process, or activity.

Normalization - Normalization is a technique for changing impact indicator values with differing units into a common, unitless format by dividing the value(s) by a selected reference quantity. This process increases the comparability of data among various impact categories.

Product life cycle - The life cycle of a product system begins with the acquisition of raw materials and includes bulk material processing, engineered materials production, manufacture and assembly, use, retirement, and disposal of residuals produced in each stage.

Sensitivity analysis - A systematic evaluation process for describing the effect of variations of inputs to a system on the output.

Stressors - A set of conditions that may lead to an environmental impact. For example, an increase in greenhouse gases may lead to global warming.

System flow diagram - A depiction of the inputs and outputs of a system and how they are connected.

Weighting - The act of assigning subjective value-based weighting factors to the different impact categories based on their perceived importance or relevance.

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APPENDIX B

Heavy metals removal process

Wastewater can be treated with physical, chemical, and biological process. Regardless of the type of treatment method, the treatment method, the treated water may require testing for physical, chemical, and biological contaminants to evaluate the effectiveness of the treatment method. The collection, analysis, and disposal of samples must be conducted according to prescribed or standard method. (Ingrid Ritchie, William Hayes, 1998)

Physical treatment

Physical treatment methods, including flocculation, separation, filtration, and adsorption are used to remove particulates.

Flocculation involves adding a chemical to the effluent to provide a binding site for small particles so they can increase in size and settle. The chemical addition must be occurred at a controlled rate accompanied by gentle mixing in a tank or basin to ensure contact and promoted growth of the floc.

Separation involves removing particulates and oil or other organic from the wastewater. Separators is included pits, chambers, and basins that is held the wastewater and allowed the contaminants to float to the surface or settle to the bottom.

Filtration is used to remove solids that can not be removed by flocculation or separation alone. Filtration involves passing the wastewater through a bed of granular material (such as sand, gravel, or anthracite) to remove particles, followed by periodic cleaning of the filter bed.

Adsorption involves passing the wastewater through a suitable material (activated carbon, activated alumina, or molecular sieves) that attracts and retains soluble contaminants.

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Chemical treatment

Precipitation involves adding a chemical (for example, alum, lime, ferrous sulfate, ferric chloride) at a controlled rate to the wastewater, followed by mixing and sedimentation to remove the precipitate that must be dewatered prior to disposal.

There are a number of technologies available for the heavy metal removal from a wastewater which are summarized in Table B-1. Chemical precipitation is most commonly employed for most of the metals (W. Wesley Eckenfelder, Jr. Boston, 2000).

Table B-1 Heavy metals removal technologies

Treatment process	**Heavy metals removal technologies**
Conventional precipitation	- Hydroxide - Sulfide - Carbonate - Co-precipitation
Enhanced precipitation	- Dimethyl thio carbonate - Diethyl thio carbamate - Trimercapto-s-triazine, trisodium salt
Other method	- Ion exchange - Adsorption
Recovery opportunities	- Ion exchange - Membranes - Electrolytic techniques

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APPENDIX C

Inventory of Electricity produced in Thailand

Exchanges per kWh (year 1999)

Inputs

Resource:		
Fuel oil	39.81	g
Diesel	2.69	g
Natural gas	111.43	g
Lignite	182.05	g

Outputs

Product:		
Electricity	1.00	kWh
Emission to air:		
CO	0.16	g
CO_2	0.71	kg
N_2O	22.15	mg
NO_x	2.27	mg
NMVOC	33.80	mg
CH_4	14.82	mg
Dust	0.12	g
SO_2	1.21	g
AS	6.87	μg
Cd	0.41	μg
Hg	0.02	μg
Ni	3.89	μg
Pb	22.00	μg
V	7.77	μg
Zn	34.40	μg

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APPENDIX D

Inventory of WWTP

Selected exchanges per functional unit (1 cubic meter)

Inputs

Energy and fossil resource:		
Energy	17.07	MJ
Diesel	13.70	g
Fuel oil	0.20	kg
Lignite	0.89	kg
Natural gas	0.55	kg
Gas/condensate	5.14	g
Raw material		
Cu	2.10	g
Pb	0.08	g
C	19.60	g
H	3.86	kg
N	0.48	g
Na	0.53	kg
O	0.16	kg
Fe	13.18	g
S	5.54	g
Cl	1.65	kg
Ca	65.62	g
Absorption water	1.78	kg
Cooling water	20.75	kg
Steam	0.22	kg
Nickel	15.28	g
Biomass	0.01	g

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Air	0.43	g
Al	0.01	g
Si	6.35	g

Outputs

Emission to air

CO_2	1.24	kg
CO	3.08	g
Dust (coarse)	0.60	g
Methane	6.19	g
N_2O	0.11	g
Non methane VOC	0.17	g
No_x	19.72	g
SO_2	6.23	g
Particulate	0.50	g
So_x	0.34	g
HC	1.68	g

Emission to water

Cu	0.29	g
Nickel	1.07	g
Lead	0.02	g
Gold	0.87	g
COD	0.01	g
SS	0.01	g
TOC	0.02	g
Cl	0.02	g

Emission to soil

Solid waste	0.32	g

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Mineral	0.13	g
Mixed industrial	0.01	g
Slag/ash	0.02	g
inert chemical	0.04	g
regulated chemical	0.01	g
Aluminum	0.37	g
Antimony	0.09	g
Arsenic	0.08	g
Barium	0.07	g
Beryllium	0.01	g
Bismuth	0.08	g
Calcium	51.62	g
Chloride	0.01	g
Copper	30.66	g
Iron	66.47	g
Lead	3.60	g
Magnesium	8.79	g
Manganese	0.43	g
Nickel	78.54	g
Tin	4.79	g
Zinc	0.87	g

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APPENDIX E

Estimation of Amount of Gas Emission

It is assumed that the organic wastes are stabilized completely and landfill is not provided device of air emission which is the significant impact to environment. Thus it can be calculated gases release, the corresponding expression by Eq 3.1 is defined in section 3.5.4 (G. Tchobanoglous et al., 1993).

The result of air emissions of treated wastewater 1 m^3 in landfill are determined by the weight of methane, carbon dioxide and ammonia. The detail of estimation of amount of gas produced in MSW landfill is focused in cardboard and plastic waste that is the high waste volume in WWTP.

Paper waste is derived from the used bag of chemical, resin and other parts of maintenance equipments and plastic materials are disposed. The detail of their percent by weight that used in this study is shown in Table E-1.

Table E-1 Typical data on ultimate analysis of the combustible components in municipal solid wastes modified from Table 4-8. (G. Tchobanoglous et al., 1997).

Component	Percent by weight (dry solid)					
	C	H	O	N	S	Ash
Cardboard	44	5.9	44.6	0.3	0.2	5
Plastic	60	7.2	22.8	0	0	10

An empirical formula is derived for the decomposable organic material. It is sssumed that the organic material can be described with a formula of the form $C_aH_bO_cN_d$; then the coefficients are estimated and calculated from the data in above table.

In approximation, the sulfur and the ash are neglected, the percent composition and the moles of cardboard would be:

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Element	Percent	MW	Moles	Assume N=1
C	44	12	3.67 (44/12)	171.1
H	5.9	1	5.90 (5.9/1)	275.3
O	44.6	16	2.79 (44.6/16)	130.1
N	0.3	14	0.02 (0.3/14)	1.0

When the value for nitrogen is set equal to 1, the approximate formula for the solid wastes is shown as $C_{171.1}H_{275.3}O_{130.1}N$.

Their calculation is estimated the amount of methane and carbon dioxide by using of the formula followed Eq-3.1, as described below:

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

(Eq-3.1)

From first calculation table, the coefficients are

a = 171.1 b = 275.3 c = 130.1 d = 1

The resulting equation is shown on the following equation and table:

$$C_{171.1}H_{275.3}O_{130.1}N + 37.99H_2O \longrightarrow 87.08CH_4 + 84.03CO_2 + 17NH_3$$

Resulting	$C_{171.1}H_{275.3}O_{130.1}N$	H_2O	CH_4	CO_2	NH_3
Mole number	1	37.99	87.08	84.03	1
MW total	4424.0	683.75	1393.22	3697.53	17.00

Determine the weights of methane and carbon dioxide from the equation are derived in this step, which is calculated from molecular weight and waste weight of paper waste as conclude in table below:

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Paper landfill	T1	T3
Waste weight	8.48E-02	8.07E-03
CH4	2.67E-02	2.54E-03
CO2	7.08E-02	6.75E-03
NH3	3.26E-04	3.10E-05

Thus, the summary inventory of paper to landfill for WWTP is shown in Table E-2.

Table E-2 Summary of emission from paper waste on landfill.

Emission from paper landfill	T1	T3
CH4	2.67E-02	2.54E-03
CO2	7.08E-02	6.75E-03
NH3	3.26E-04	3.10E-05

For plastic waste, it can be calculated as same as paper waste and the result of equation is shown on the following equation and table:

$$C_{3.5}H_{5.1}O + 1.75H_2O \longrightarrow 2.14CH_4 + 1.37CO_2$$

Resulting	$C_{3.5}H_{5.1}O$	H_2O	CH_4	CO_2	NH_3
mole number	1	1.75	2.14	1.37	1
MW total	63.2	31.42	34.18	60.40	0.00

Determine the weights of methane and carbon dioxide from the equation are derived in this step, which is calculated from molecular weight and waste weight of plastic waste as conclude in table below:

Plastic landfill	T1	T2	T3	T4
PE	3.79E-01	6.17E-01	9.69E-02	2.63E+00
PP	6.73E-01	0.00E+00	5.65E-02	0.00E+00
Waste weight	1.05E+00	6.17E-01	1.53E-01	2.63E+00
CH4	5.69E-01	3.34E-01	8.30E-02	5.05E+00
CO2	1.01E+00	5.90E-01	1.47E-01	2.51E+00
NH3	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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Therefore, the summary inventory of plastic to landfill for WWTP is performed in Table E-3.

Table E-3 Summary of emission from plastic waste on landfill.

Emission from plastic landfill	T1	T2	T3	T4
CH4	5.69E-01	3.34E-01	8.30E-02	5.05E+00
CO2	1.01E+00	5.90E-01	1.47E-01	2.51E+00
NH3	0.00E+00	0.00E+00	0.00E+00	0.00E+00

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APPENDIX F

Sensitivity analysis

Sensitivity analysis of this study is used for the highest contribution to WWTP, which is resources use especially on gold recovery process (T3) and batch treatment and neutralization process (T4).

For gold recovery process (T3), the major raw materials use in this system are considered for 2 types as gold inlet wastewater and gold resin usage. From Fig. F-1, it can be seen that the gold inlet wastewater is significant subject for T3, which is most sensitive to the total environmental impact. While gold resin usage does not be sensitive to the changes as shown in Fig. F-2.

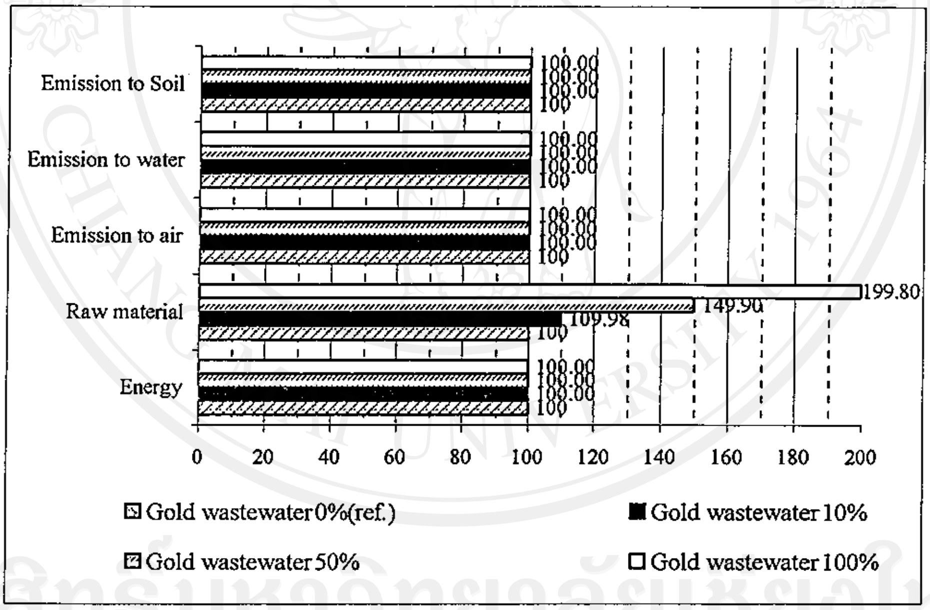

Figure F-1 Gold inlet water changes to the over all ELU by sensitivity analysis.

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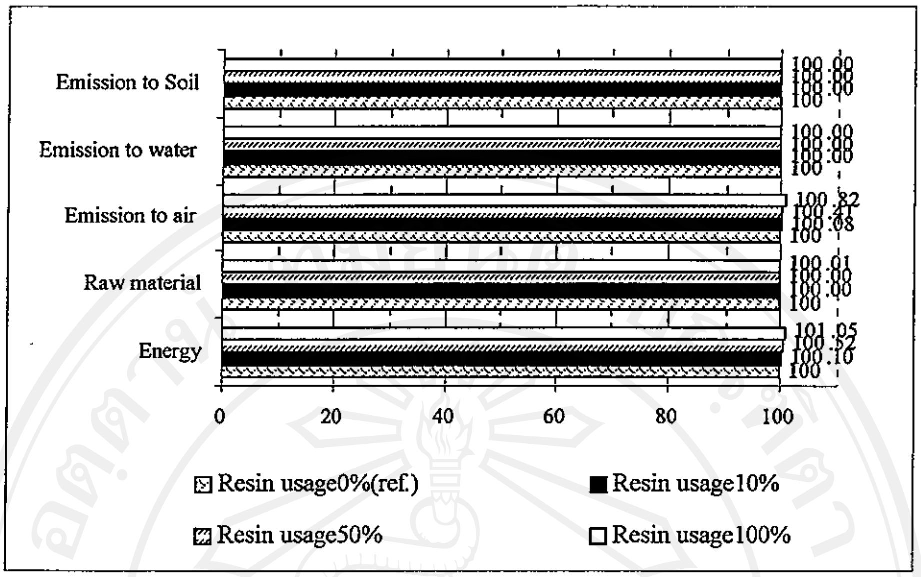

Figure F-2 Gold resin usage changes to the overall ELU by sensitivity analysis.

For batch treatment and neutralization process (T4), They have been selected the major of raw material that might be generated high ELU i.e., electricity usage, chemical transportation, waste transportation, sludge generation, HCl production and NaOH production and then trialed on sensitivity analysis. The results are shown the most significant subject to T4 that are sludge generation, NaOH production and Chemical transportation, respectively, as illustrated in Fig. F-3 to Fig. F-7.

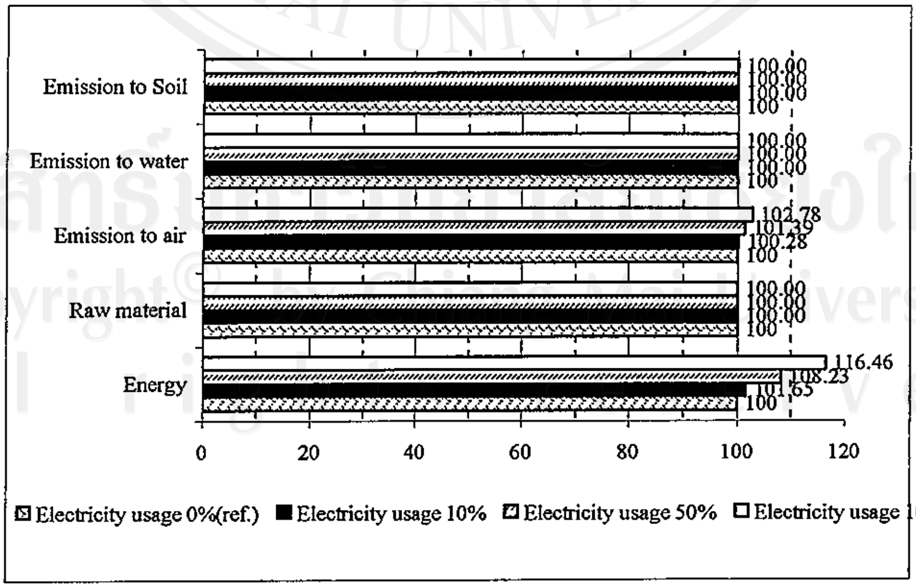

Figure F-3 Electrical usage changes to the overall ELU by sensitivity analysis.

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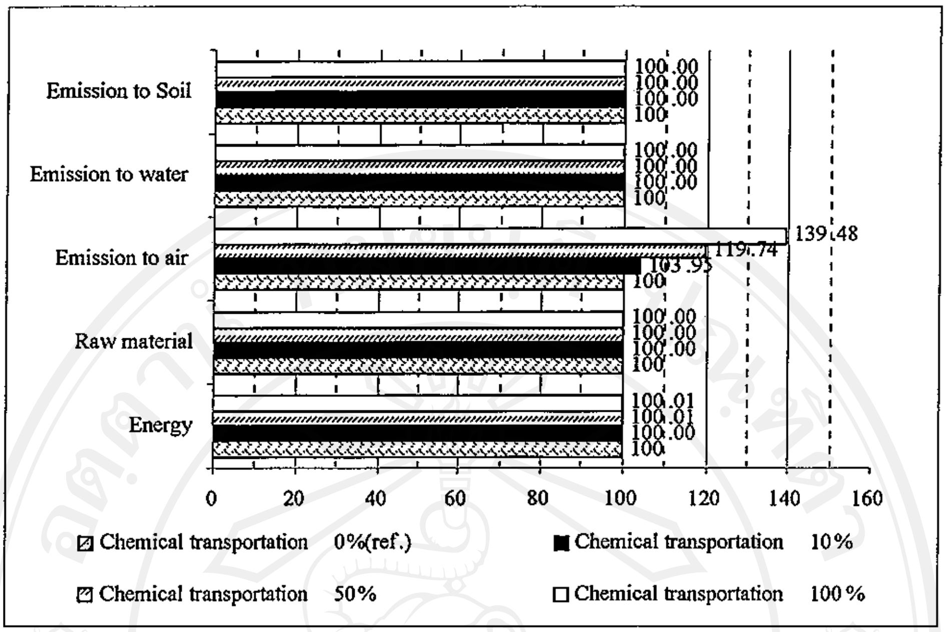

Figure F-4 Chemical transportation changes to the overall ELU by sensitivity analysis.

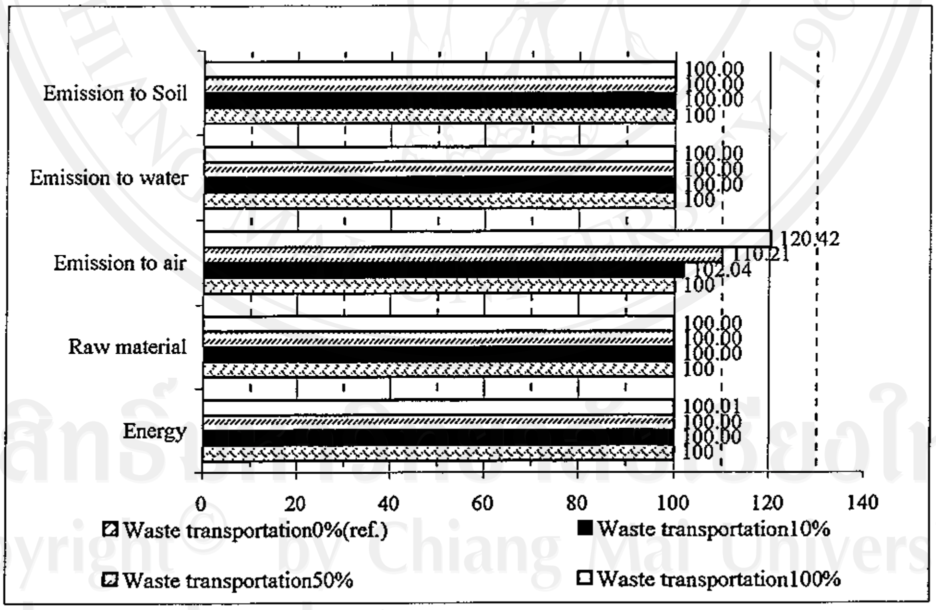

Figure F-5 Waste transportation changes to the overall ELU by sensitivity analysis.

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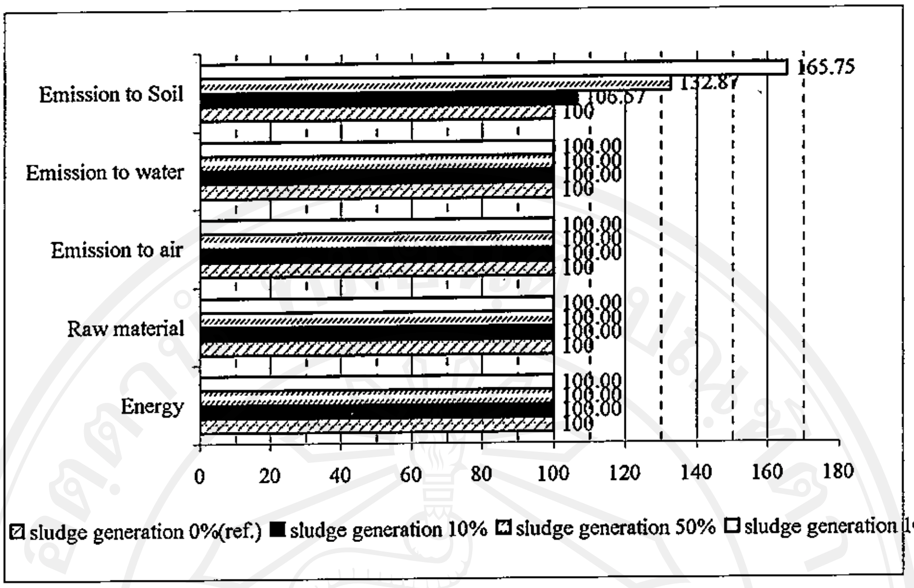

Figure F-6 Sludge generation changes to the overall ELU by sensitivity analysis.

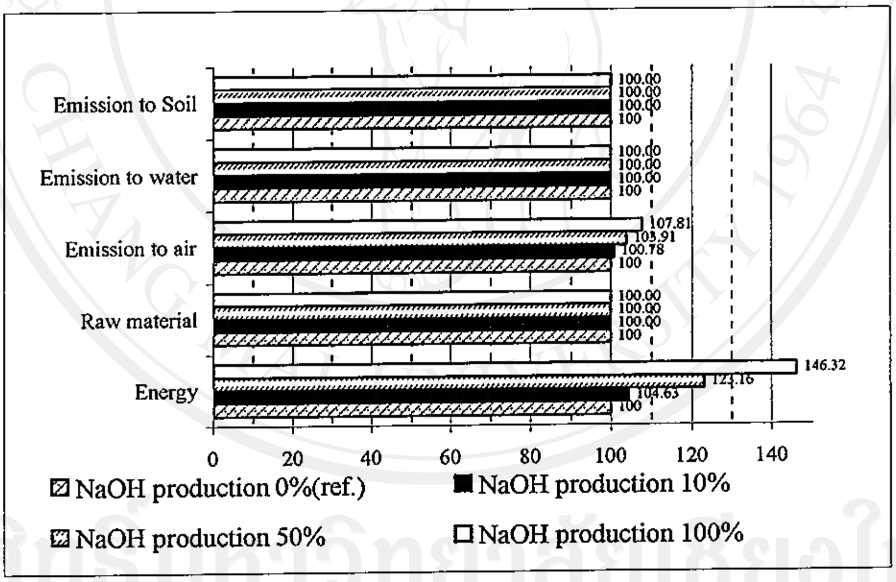

Figure F-7 NaOH usage changes to the overall ELU by sensitivity analysis.

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APPENDIX G

Jar Test Procedure

Jar testing, to determine the proper coagulant dosage, is continued to be one of the most effective tools available to WWTP operators. Finished wastewater quality, all depend on the proper application of chemicals to the wastewater entering the treatment plant. It is illustrated in Fig. G-1, which is six position stirring apparatus and electronic motor control system offering regulated variable speeds of all paddles simultaneously with the exact speed displayed on a digital readout. Lab equipment for jar test is included bench type pH Meter, that is preferable with temperature compensation as shown in Figure, colorimeter, spectrophotometer.

The method of jar test operation can be explained as follow;

1) First the jar test operation, wastewater must be checked pH and keep some sample for finding heavy metal concentration for inlet wastewater.

2) Using the 1000 mL graduated cylinder then add wastewater to be coagulated to each of the jar test beakers.

3) Prepared chemical stock solution add to each beaker with vary increasing amounts.

4) After dosing each beaker, operate the stirrer at high rpm for approximately 1 minute.

5) Then, slow to the rpm which matches the turbulence created in your flocculators and allow to stir for 30 minutes while observing the floc formation.

6) At the end of the 30 minutes turn the stirrer off and allow to settle. Because there are 2 hours of settling time in this plant, at the end of 1 hour most of the settling will be complete.

7) Observe the results and sampling wastewater for analysis.

The jar test result is monitored and recorded for checking. It is noted that a coagulant underfeed will be caused the sample to appear cloudy, with little or no floc and almost no settling. A coagulant overfeed will form dense floc, however, it will appear fragile and fluffy; when the stirrer is turned off, it will not settle well. Floc

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formed by an overfeed is false floc which is very light and will carry to the filter. This is one of the most common treatment problems. A good floc will appear heavy and tight, not too dense, with spaces of bright, clear water between the particles and will begin to settle as soon as the stirrer is turned off. (Phipps & Bird, Inc. 2003)

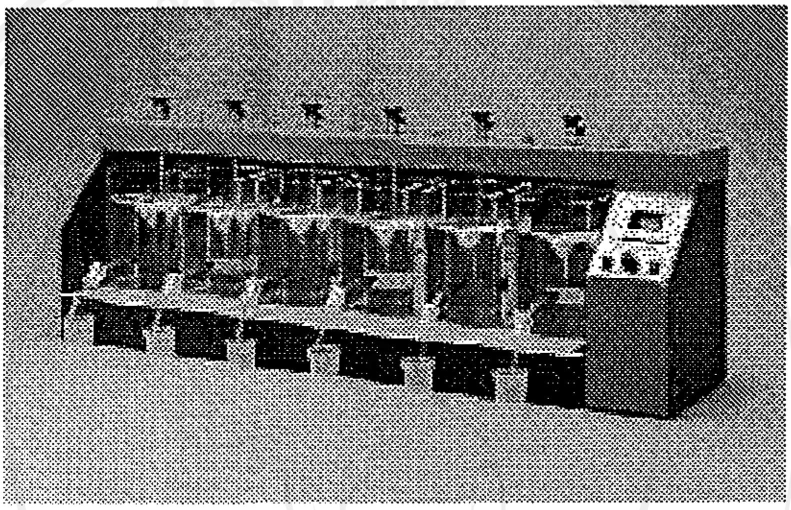

Figure G-1 The six-paddle model of jar test

Conducting the jar test and important information obtained, jar testing traditionally has been done on a routine basis in most WWTP to control the coagulant dose. Much more information, however, can be obtained with only a small modification in the conventional method of jar testing. It is the quickest and most economical way to obtain good reliable data on the many variables which affect the treatment process. These include:

- Determination of most effective coagulant.
- Determination of optimum coagulation pH for the various coagulants.
- Evaluation of most effective polymers.
- Optimum point of application of polymers in treatment train.
- Optimum sequence of application of coagulants, polymers and pH adjustment chemicals.
- Evaluating results of sludge recycle.

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