

K.Kumarasivam Young Environmentalist Award 2012

Internship Report:

Integrated Waste Management in Kaohsiung City

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Taiwan

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## 1.0 Introduction

The internship of KKEF Young Environmentalist 2012 took place in Kaohsiung City Gov R.O.C. Environmental Protection Bureau's Southern District Waste Management Plant which is constituted mainly by a four furnace Martin type incinerator and recycle transfer station. I was placed under care of the director of the waste management plant Dr. Hong-wen Yang and was assigned into operation and service unit to look into the management of the 49kMWh electricity generating incinerator. Besides, I also took the opportunity to visit other solutions of waste management such as Renwu Incineration Plant (operated by SITA Waste Services), Nanxing Project Seaside Landfill, Daliao Sanitary Landfill, Xiqingpu Sanitary Landfill and Xiqingpu Methane Gas Energy Harvesting Power Plant (operated by Veolia Environment). The 2-weeks experience in Kaohsiung City has exposed me to an integrated municipal waste management plan that starts from households where waste separation at source is practiced in line with the 'Keep Trash Off the Ground' policy started since 1995 making good use of every type of waste generated before ended up landfill. Compared to current waste management of Malaysia, the integrated waste management plan in Kaohsiung City looks more efficient in terms of energy recovery, economic beneficial and most importantly waste reduction.



Environment Protect Bureau Kaohsiung City Southern District Waste Management Plant, Taiwan

## 2.0 History of Waste Management in Taiwan

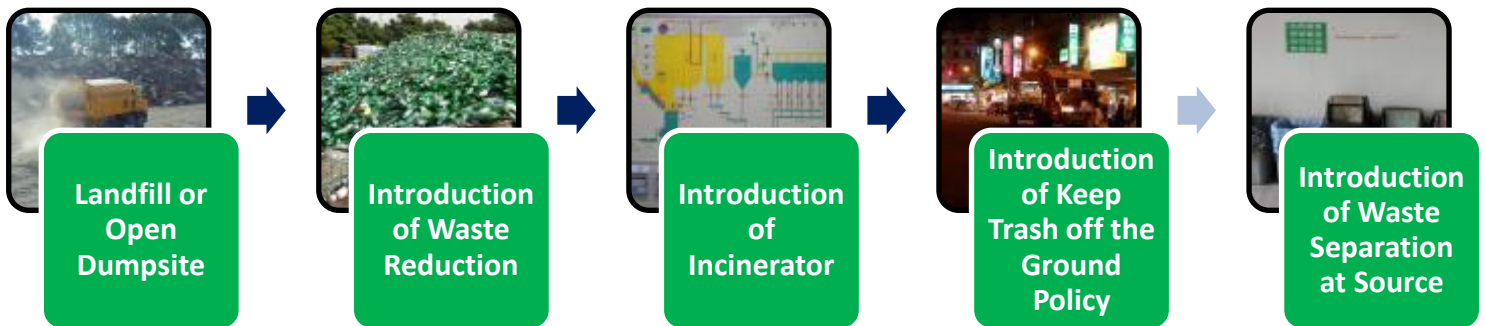


Figure 1: Waste Management Plan History

Similar to the context in Malaysia during the 80's and 90's, Taiwan's Municipal Solid Waste (MSW) ended up in landfill or dumpsite without treatment until year 1984 that Sanitary Landfills are being built.

By 1989 the Environmental Protection Bureau (EPB) and the Taiwan Ministry of Economic Affairs (MOEA) initiated the Joint Waste Reduction Task Force where waste minimization, resource reduction, recycling, and reuse programs were implemented. The Industrial Development Bureau (IDB) of the MOEA did fabulous job such as promoting extended producer responsibilities and sustainable materials management besides creating public awareness, sectorial-specific educational training courses and technical assistance in ensuring stakeholders to understand the importance of implementing waste minimization and resources reduction in industrial scale.

By 1990, 179 new landfills that had been built in six years came to the end of their lifespan, filled mainly by enterprise waste which greatly exceeds MSW. In year 1991 the first batch of waste to energy incinerators are being built. Today, 21 government-owned and three privately-owned electricity generating incinerators treat approximately 20,000 tons of MSW daily, generating 8000 MWh/day of electricity. All 150 incinerators in Taiwan are gradually being transformed into regional biomass energy centers.

By the end of 1995, the Joint Waste Reduction task force had established the National Center for Cleaner Production to provide deeper life-cycle analysis of Comprehensive Procurement Guidelines (CPG) to promote the use of materials recovered from unwanted solid waste. As a result, within seven years solid waste was reduced by 26,653 tons/year, CO<sub>2</sub> reduced by 58,186 tons/year, wastewater reduced by 1.3 million tons/year, and electricity conserved at 487,000 MWh/year. (Angelina Jao 2012)

In year 1995, ex-Taiwan President Chen Shui-Bian started 'Keep Trash Off the Ground' Policy in Taipei city without good response. The policy promotes waste storage at source or inside the premise without the need of transfer the waste from inside the premise to garbage bin outside of the premise in order to reduce point of source pollution. In year 1999 Kaohsiung City Government initiated the same program. Citizens are required to keep waste inside their premises before transferring the waste onto garbage truck that passes by at particular time of the day.

In year 2001, Kaohsiung City Government started the policy of household waste separation policy, hoping to imitate Taipei City's success in increasing waste management efficiency through waste separation. The household waste separation scheme classified waste into raw putrescible, cooked putrescible, recyclables and non-recyclables. In year 2005, 21,823 tons of raw and cooked putrescible were collected compared to 0 tons in year 2000. A total of 103,135 tons of recyclables are collected in 2005 tremendously outnumbered 38,375 tons in year 2000. In terms of waste generation per capita, the policy of household waste separation seems works well as it reduce from 1.029kg/capita in 2001 to 0.873kg/capita in 2011. (Environmental Protection Administration Executive Yuan R.O.C. (Taiwan) Environmental Statistic Bank 2013) Comparing year 2004 to year 2011 implementation of the waste separation policy has seen MSW collected dropped 38.4%, recyclables increased 96.6%, and most impressively, kitchen waste collected increased 171.1%. (Angelina Jao 2012)

After implementation of more environmental friendly measures, the remaining landfills are being shut down after reaching capacity while closed landfills are re-harvested for its energy potential and methane gas capture. Future byproducts of incinerators are more commonly used for land reclamation and road construction to substitute the uses of hardcore granites that are much more expensive and require rock mining.

## **2.1 How did Taiwan managed to succeed in waste minimization and waste management efficiency**

### Stakeholders Willingness

The main reason behind the success of waste minimization program is the strong willingness from the citizens, NGOs and all stakeholders involved as explained by Minister Stephen Shu-Hung Shen. According to the minister working with NGOs to build consensus is important to influence the people to understand the importance of adjusting their daily behavior to protect the environment and the economy.

### Government Initiatives

A 4-in-1 Resource Recycling System is being developed by EPB where the first of the four steps saw community-based NGOs being organized to promote waste separation at source. Next, a private recycling industry and the purchasing of recyclables from communities are being developed. The third step saw Municipal Garbage Collection Teams separate and collect MSW and recyclables, and provide a preset portion of the proceeds from the sale of resources to participating organizations and workers. In the fourth step a Recycling Management Fund was established. The EPB sets fees to not only manufacturers but also importers to pay compulsory into the Recycling Management Fund which supports program costs (including actual collection and recycling work, subsidies for education, auditing, and certifications). In past years, the Fund has managed an average "collection, disposal and treatment fee" (CDTF) of \$208.5 million/year. By 1995, MOEA also co-sponsored nearly 80 R&D industrial waste reduction projects. Financial incentives were also used to help industries engage in SMM at a faster rate.

## Law Enforcement

Waste Disposal Act and the Resource Recycling Act are 2 main enforce legislation in waste management. Since 2000, specific industries have been required to use the EPB's user-friendly online waste tracking and reporting system, the Industrial Waste Control Report System (IWCRS), to report waste within 24 of it being shipped, received, or completely treated. The Waste Disposal Act stipulates that all garbage trucks must pass specifications and maintenance tests, and have permits for transportation and disposal, as well as GPS tracking systems, transmitting the truck's location every 30 seconds to the IWCRS. In 2010, 432 suspected violations were discovered, and 58 citations were issued. The IWCRS is the most visited website of all Taiwanese government websites – approximately half a million businesses, nearly all major industrial waste generators, use the reporting system.

On Dec. 30, 2011, the EPB brought its Illegal Dumping Management System online to create a database of dump sites around using GPS satellites to discover unreported sites. Database auditing and mining assist inspectors in discovering violations, which trigger on-site inspections of waste generators. Stiff fines and penalties are stipulated for corporations and individuals who violate the law, including up to NT\$15 million (\$500,000) in fines and three years to life imprisonment. The EPA mandates over 10,000 on-site inspections annually, but acknowledges that more inspectors are needed, and has implemented an education, training, and certification system to address any possible false reporting.

The Waste Disposal Act requires 25,861 generators, 4963 transporters, and 865 TSDFs to make online reports on the IWCRS, although over 466,000 firms now use the system. These generators represent 22% of the total generators on the island, and generate 80% of the waste annually. The remaining 20% of waste are generated by small-quantity generators. As of 2011, 80% of industrial waste and 90% of medical wastes have been properly disposed.

### Benefits of Technology

The EPA's system allows generators to self-audit moreover enabling parent companies to control over reported data of its subsidiaries. On top of that, reporting functions are robust, including statistical analysis of temporary storage, permitted quantities, disposal quantity trends, GPS tracking inquiries, as well as automated alert systems.

The IWCRS also permits waste disposal facilities to track quantities as well as condition of post-treatment materials for possible reuse. All waste is accounted for and properly treated. The system audits waste manifests against permits for disposal, treatment, and recycling. Illegal dumping is now nearly under control, with a shrinking number of cases being pursued by the EPA.



### 3.0 Current Integrated Waste Management Practice in Kaohsiung City

Current Waste Management Practice in Kaohsiung City adopts the principle of the following Waste Hierarchy (Figure 2) that stress on importance of waste reduction at source as first priority in minimizing waste generation and reducing unnecessary energy lost in waste treatment, in line with principals of Organization for Economic Co-operation and Development's (OECD) Sustainable Material Management and United Nations Environment Program's (UNEP) Sustainable Resources Management.

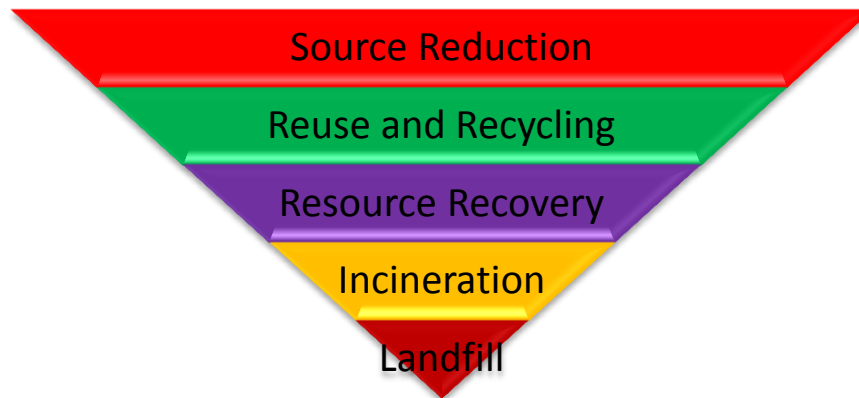


Figure 3: Waste Hierarchy

According to a July report issued by Taiwan's Environmental Protection Administration (EPA) in year 2012, the country's rate of properly-treated municipal solid waste (MSW) has reached 99.99%, MSW recycling is over 40%, and enterprise waste recycling is at 84%. Latest figures show nearly 3 million tons of recycled materials across 33 regulated categories nationwide, an increase of nearly 34,200 tons from the previous year thanks to current practice of efficient waste management plan (Angelina Jao 2012).

Taiwan's solid waste management policies have transformed from earlier 'end-of-pipe treatment' to the current 'zero-waste' mechanisms, and rates continue to improve by strategically progressing through step-by-step measures for source reduction and resource recycling and reuse. However, successful achievements in waste minimization and recycling are resulting in insufficient combustible material or in other words over-supply of incineration capacity. Private operators which won contracts based on low bids are

seeking other feedstock to replace high-calorific waste like plastic and tyres that are being recycled out of the waste stream.

### 3.1 Waste Generation at Source

Consumerism is the key player at this level. The more the people consume, the more unwanted waste are being generated. In this era, standard of living and propaganda of comfortable life has led to generation of worthless trash that degrades the environment. To date no perfect measures has been found to tackle waste generated. Consequently correcting the right attitude of consumerism getting needed things rather than wanted things could greatly reduce waste at this level.

### 3.2 Waste Separation at Source

Waste separation comes into action to sort generated waste into raw putrescible, cooked putrescible, recyclables and non-recyclables. This has not only reduces energy wasted in separating the waste later but also categorized waste according to their potential value. Raw putrescible are composted into natural fertilizer while cooked putrescible will be used as animal feeding. Recyclables will be sent to material recovery facilities to be converted into products that could be reused while non-recyclables will be sent into the waste to energy incinerator, burned and turn heat energy into electricity.



Figure 4: Waste separation at source garbage bins

### 3.3 Keep Trash Off the Ground Policy

Under this policy, citizens are not allowed to temporarily keep waste in garbage bin outside of premises nor throw garbage on the ground else penalty will be given. Generated and separated waste must be kept inside the premise to prevent point of source pollution outside premises.

### 3.4 Waste Collection

Waste collection in Kaohsiung City is made up by garbage truck (compactor) that collects non-recyclables with putrescible bin at the back of the truck and garbage truck that collect recyclables. Separated and stored waste are transferred when garbage truck that projects music pass by according to a fixed time schedule. Routine pick up for non-recyclables are on 3 times daily basis mostly from evening till night while recyclables pick-up truck runs every two days and rest on Sunday. Unlike to scenario in Malaysia, waste management company workers are not responsible to pick up garbage bag from outside of one house to another but only to make sure the citizens transferred correct content or type of waste onto the garbage truck.



Figure 5: Garbage truck pass by scheduled road side while citizens brought out their waste and throw into the truck

### **3.5 Transfer Station or Waste Management Plant**

The collected wastes are being transferred to a transfer station before each type of waste is being sent to designated destination. A waste management plant might be equipped with facility of transfer station as well.

### **3.6 Waste Handling Facilities**

#### **3.6.1 Waste to Energy Incinerator**

In the city of Kaohsiung, there are 3 waste management plants which all waste from city of Kaohsiung would be sent for incineration to generate heat energy that will subsequently generate electricity, namely Central District Waste Management Plant, Renwu Waste Management Plant and Southern District Waste Management Plant. Non-recyclables would end up being incinerated to generate electricity. The power of electricity generated largely depends on the caloric value of the waste. Wet wastes are hard to be burned.

#### **3.6.2 Agricultural and Poultry Farm or Composting Facility**

Raw putrescible is being collected in larger bins while cooked putrescible is being loaded straight into big trailer. Both type of waste are then being sold and transported to composting facility and farms respectively.

#### **3.6.3 Waste Recovery Center**

Recyclables are unloaded and temporarily stored in recyclables storage center inside waste management plant before the responsible material recovery center contractors bought them away to turn them into new products.

### **3.7 Final Disposal or Reuse**

Leachates from waste are collected, circulated and treated by leachate treatment system or sent to central sewage treatment plant before being discharged into water systems. The by-products such as ashes from incinerator are being solidified before being sent to sanitary landfill or used in land reclamation or road construction.

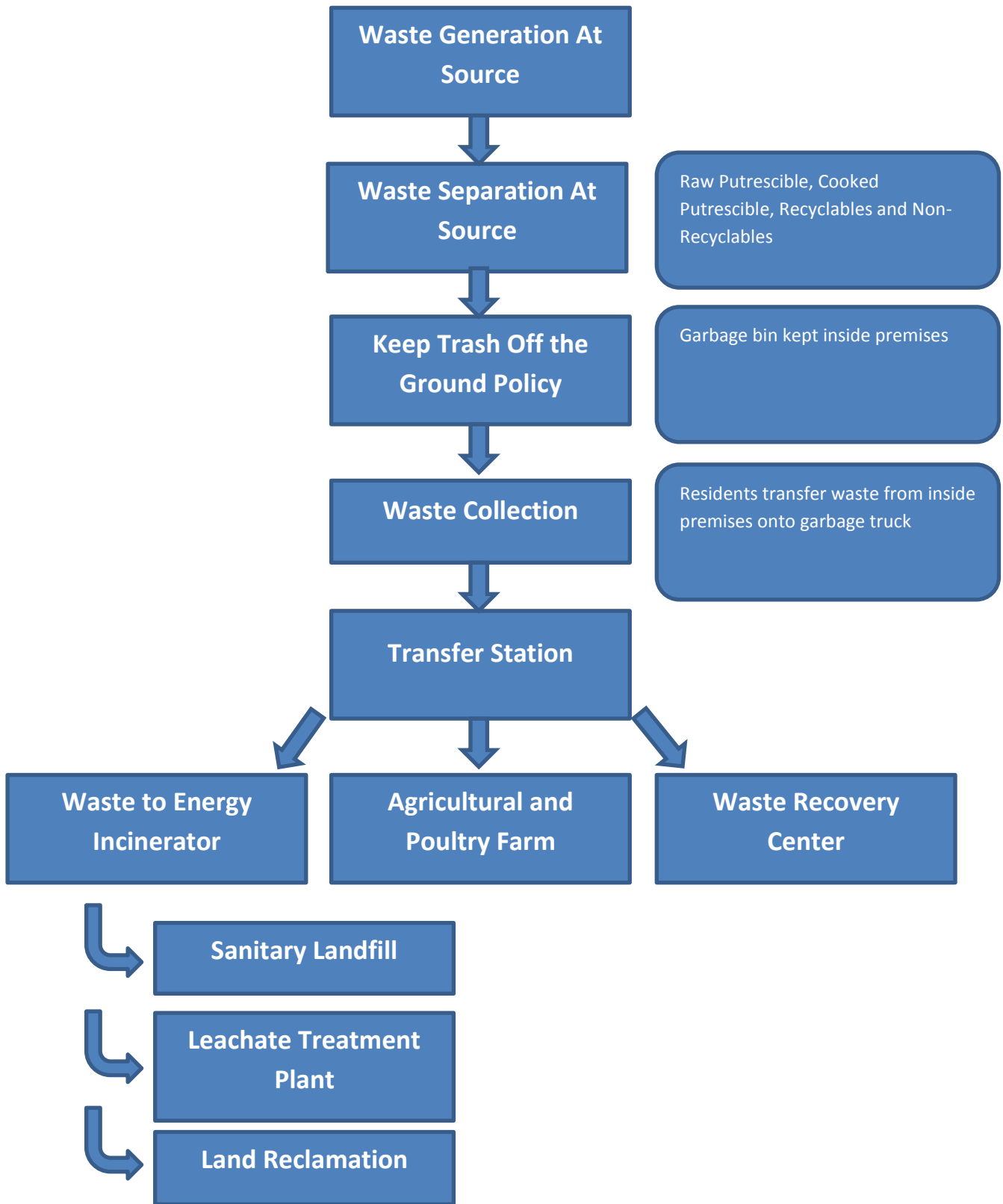


Figure 6: Integrated Waste Management Flow

#### 4.0 Kaohsiung City Gov R.O.C. Environmental Protection Bureau Southern District Waste Management Plant

Over the period of internship, I was being led by Mr. Chan Kai Bu from Operation Unit and Mr. Wong Xin Zhong from Service Unit to look into the operation of the waste management plant from the moment waste entered the plant and burnt residue of waste or leachate leave the plant.

#### 4.1 Plant Location

The waste management plant is being built in Xiaogang Industrial Area which is regarded as the busiest industrial zone in Taiwan where big manufacturer such as Chinese Steel Corporation (CSC) and oil refining company for instance Chinese Petroleum Corporation (CPC) operates.



Figure 7: Location of Southern District Waste Management Plant in Xiaogang Industrial Area

## 4.2 Plant Facilities

The waste management plant is made up of the Plant Section (plant building where 4 Martin type 450 t/ 24 h/ furnace is located, the administration building, recyclables center, transfer station of raw and cooked putrescible, refuse truck garage, car wash, refuse weighing bridge and 2 guard house), Plantation Section and Mutual Beneficial Facilities (Swimming pool heated by incinerator, table tennis room, pool room, musical auditorium, lecture hall and community center)

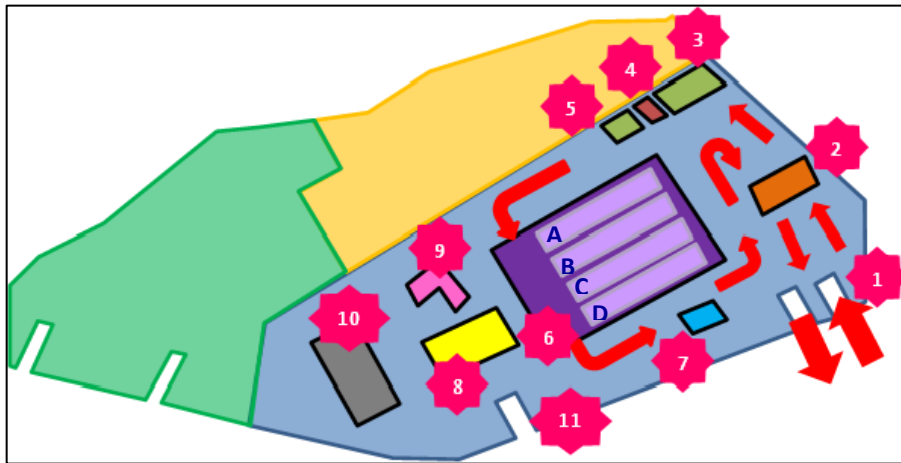
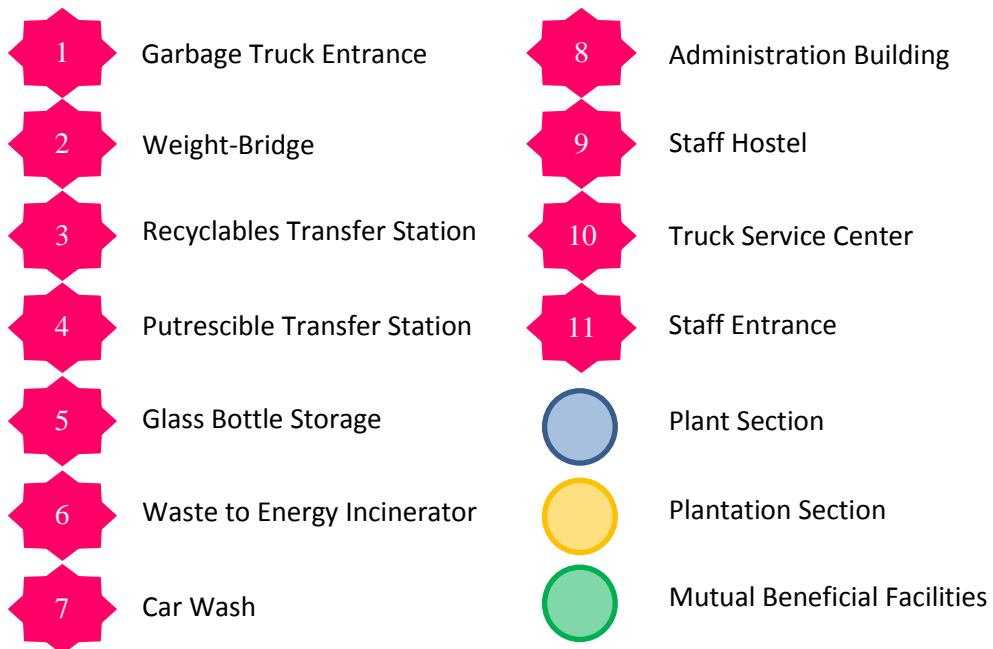


Figure 8: Sectorial Plan of Southern District Waste Management Plant



### 4.3 Operation in Waste Management Plant

There are 4 process involved: Waste reception and energy generation, Treatment of Toxic gas from burnt waste, Treatment of Leachate/Waste Water, Odour Prevention and Treatment of Ash and Fly Ash.

#### 4.3.1 Waste reception and energy generation

##### Weight-bridge

Municipal solid waste entered waste management plant through weight-bridge (measured up to 40 tons) that takes down the weight of garbage truck. There are 4 officers on duty, each operating and monitoring 1 weight-bridge (2 incoming and 2 outgoing). The trained and experienced officers screens the type of waste transported by registered company and all hazardous waste, not flammable objects for instance electrical waste, metals, solidified ashes and inorganic sludge will not be permitted to enter the plant. Charges are imposed based on truck sizes that enter the plant. Detail information on rules and regulations of trucks and waste permitted to enter the plant are recorded in the following official Environmental Protection Bureau Southern District Waste Management Plant website at <http://sip.kcg.gov.tw/pg> .



Figure 9: Weight-bridge



## Dumping Area

Garbage trucks that had unloaded recyclables will enter the waste to energy incinerator and first reach dumping area where garbage trucks dispose all remaining waste into refuse bunker through 18 bunking gates while bulky waste would be sent into bulky waste shears to break large chunk of waste into smaller pieces. Waste in 30m deep refuse bunker (Volume = 21600m<sup>3</sup>) would be mixed thoroughly by using 3 refuse cranes to reach an even value of refuse heat before being picked up and dropped into charging port that sends the waste into furnace for incineration. There are 2 sets of drainage injection system that collect leachate from refuse bunker to spray leachate into burning furnace or sent for treatment in Kaohsiung Central Waste Water Treatment Plant.



Figure 10: Dumping Area



Figure 11: Garbage truck unloading waste into refuse bunker.



Figure 12: Refuse Bunker



Figure 13: Refuse Crane Lifter



Figure 14: Refuse Crane Lifter pick up waste and feed into the stoker

## **Incinerator**

The waste on charging hopper is then pushed into the stoker. The to-and-fro movements of the grate slowly push the waste forward. The waste will pass the drying zone, combusting zone, and post-combustion zone to ensure total burned. Air required for incineration is provided by 4 sets of secondary air fan (each fan attach to 1 furnace) and steam air preheater.



Figure 15: Grates inside furnace, maintenance is being done to clean up the furnace.

## **Waste Heat Recovery Boiler**

Burnt waste generates heated gas that flows into waste heat recovery boiler; heat up water from water feeder tank with de-aerator to change its form to steam gas.

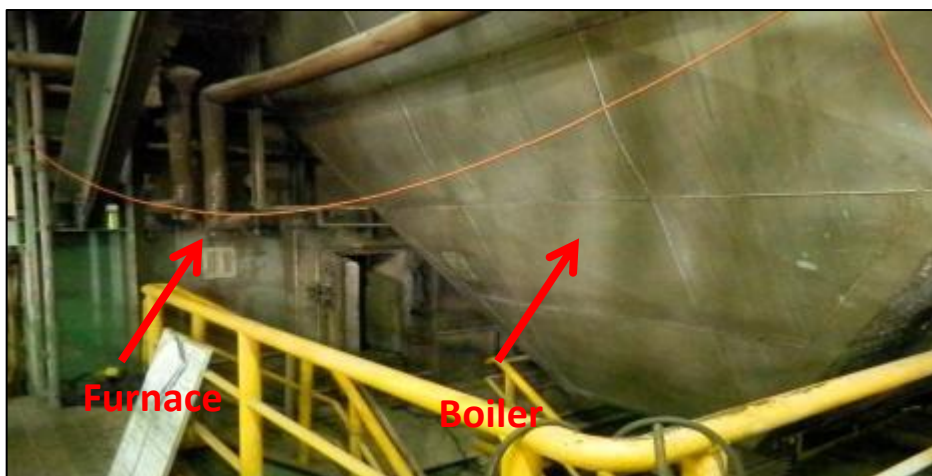


Figure 16: Furnace and Waste Heat Recovery Boiler

### **Condensing type turbine generator**

Heated steam gas then enter condensing type turbine generator and pushes turbine to generate kinetic energy that turns into electricity.



Figure 17: Condensing type turbine generator

### **4.3.2 Treatment of Toxic gas from burnt waste**

#### **Ammonia Oxide Removal System**

2 sets of ammonia oxides removal system sprayed ammonia spirit into the high-temperature furnace reducing ammonia oxides to nitrogen. Gases in the furnace then enter the semi-dry scrubber.

#### **Semi-dry Scrubber**

The atomizer above the scrubber will spurt out slaked lime paste and interact with acid gases like sulfur oxide and chlorine hydride in the heat to produce solid fly ash.

#### **Bag-filter**

The produced solid fly ash is sprayed with activated carbon when exiting scrubber to absorb heavy metals and dioxin pollutants before flowing into bag-filter precipitator that will separate and collect the particulate pollutants in the heat and dispose of heavy metals at the same time.



Figure 18: Bag filter

### **Induced Draft Fan**

Filtered flue gas is then ventilated by induced draft fan, heated by flue gas re-heater before going through the stacks and emits into the atmosphere.

### **4.3.3 Treatment of Leachate/Waste Water**

Platform washing, staff living, car washing, make up water tank, boiler and laboratory produce organic and inorganic waste water that is treated by onsite waste water treatment system which includes physical treatment , chemical treatment, biological treatment, three-phase treatment, and residual treatment. After a series of procedures like chemical coagulation, precipitation, biological treatment, sand filtration, and disinfection, the waste water can be recycled and reused.

Leachate from the refuse bunker are designed to be sprayed into the incinerator for direct combustion and carburetion to reach the goal of zero waste discharge from the plant however addition of leachate into the furnace chamber is suspected to have reduce heat value and reduce incineration efficiency moreover the flowing channel of leachate from refuse bunker into furnace is blocked after 10 years or operation thus leachate is now collected and sent to Kaohsiung Central Waste Water Treatment Plant for further treatment.



Figure 19: Waste Water/Leachate Treatment Plant

#### **4.3.4 Odour Prevention**

A sealed negative pressure design is adopted by the waste management plant to prevent odor from spreading. 4 sets of primary air fan drew air from refuse bunker into 4 furnace to provide air for high temperature combustion while a de-odour equipment functions during shut down of plant to eliminate bad odour into the atmosphere. The dumping area is also rinsed with water and spread with deodorant. Besides, car wash facility cleans up the garbage trucks to prevent undesirable smell and effluent from spreading out of the plant.

#### **4.3.5 Treatment of Ash and Fly Ash**

##### **Slag Extractor**

After waste incineration, the ash (residue of waste burnt from furnace) is collected by slag extractor, metallic material magnet and stored in slag bunker before being delivered to be weighed and buried at the landfill or used in road construction without prior treatment.

##### **Fly Ash Silo and Solidification**

On the other hand the fly ash collected at the waste heat recycling furnace, semi-dry scrubber and bag filter precipitator are needed to go through the solidification treatment, weighed and is sent to and buried at the sanitary landfill or seaside land reclamation

project. The duration of incineration process drastically reduces the volume to be buried. Meanwhile, the solidification treatment stabilized fly ash movement from causing second-hand public hazard.



Figure 20: Magnetic Separator



Figure 21: Fly ash being solidified



Figure 22: Solidified fly ash being collected

#### **4.4 Significance of Southern District Waste Management Plant**

The plant enables energy recovery of waste heat & metals through technologies of cogeneration and magnetic separation to generate electricity and recycle metals. Waste incineration produces high-temperature waste heat that passes a series of heat exchange courses in the super heater, evaporator and economizer in heat recovery boiler. Each heat recovery boiler is able to generate high-temperature steam up to 400°C that supplies heat energy to plant facilities and the warm-water swimming pool of mutual beneficial facilities besides producing huge amount of electricity by steam turbine generator. Estimated 20% of the electricity generated supplies the demand of the plant (5MWh) while another 80% is being sold to Tai Power Company. With regard to the recovery of waste metals, the slag produced after incineration will be delivered to the vibration slag conveyor while magnetic separator will sieve out waste metals from the slag and reuse the metals.

#### **4.5 Public acceptance of Waste to Energy Incinerator**

The public could not accept the concept of incinerator at the beginning. However the government of Kaohsiung City came to agreement with the citizens to build the Waste to Energy Incinerator with compensations to citizens staying within 1km radius perimeter from the plant and building of a Mutual Beneficial Facility which include swimming pool and community center that does not apply charges to residents staying within 1km radius in addition a small ecological garden that attracts nesting of birds and several species of amphibians.

Besides, live updated air pollutants and dioxin level could be seen from outside of the plant as well as inside the administration building lobby while season index could be checked from official website (<http://sip.kcg.gov.tw/po/o01-1>) of the plant or Environmental Protection Bureau official website (<http://www.epa.gov.tw>). Table 1 presents the air pollutant and dioxin level of year 2012 that is way under standard limit. Besides, the citizens could be assured that the plant always operates its incineration at 800°C for at least 30 minutes to ensure complete incineration and reduce formation of dioxins. This is further confirmed by literature review of a report of dioxin reduction by



Kobylecki R.P. et al 2001. Consequently, the citizens are contended and feel safe thus has no objection on the incinerator.

Table 1: Air Pollutants emitted from plant during 2012

Duration	Opacity (%)	Sox (ppm)	Nox (ppm)	HCl (ppm)	CO (ppm)	Pb (mg/Nm3)	Cd (mg/Nm3)	Hg (mg/Nm3)	Dioxin (ng-TEQ/Nm3)
Standard limit	10.00	80.0	180.0	40.0	120.0	0.2000	0.0200	0.0500	0.100
Jan-Mar 2012	2.47	2.0	75.0	2.0	6.0	0.0138	ND	0.0066	NA
Apr-Jun 2012	2.74	5.0	78.0	17.0	7.0	0.1505	0.0025	0.0148	0.064
Jul-Sep 2012	3.69	3.0	103.0	ND	2.0	ND	ND	0.0017	0.064
Oct-Dec 2012	3.53	5.0	100.0	4.0	6.0	0.1383	0.0021	0.0141	0.048

Source: Environmental Protection Bureau Southern District Waste Management Plant

#### 4.6 Future Plan

In near future, the plant is planning to sell the heated steam gas directly to nearby industrial plants namely Chinese Steel Corporation (CSC) and Chinese Petroleum Corporation (CPC) for their operations due to higher profit compared to generate electricity that is sold to Tai Power Corporation. Moreover, industrial plants that need heated steam gas for their daily operation will not need to set up boiler or facing boiler maintenance which saves a part of their budget.

#### 5.0 Renwu Waste Management Plant

I was given the opportunity to visit Renwu Waste Management Plant, a sister plant of Southern District Waste Management Plant which is equipped with same facilities, both built by the government except that Renwu Waste Management Plant is operated by SITA Waste Services Ltd from Hong Kong (tendered for 20 years) and contains only 3 furnaces thus it could only handle 1350 tons of waste per day compared to 1800 tons of waste per day in Southern District Waste Management Plant. There are also less staffs appointed, at ratio of 1:4 comparing Renwu Waste Management Plant to Southern District Waste Management Plant which is run by the government.



Figure 23: Renwu Waste Management Plant



Figure 24: Updated Pollutants Reading

## 6.0 Kaohsiung City Green Initiatives

The city of Kaohsiung is full of green initiatives that enable sustainable development.

### 6.1 Nanxing Seaside Land Reclamation

On 29 Nov 2012, I was being brought to Nanxing Seaside Land Reclamation Site where construction waste, slag or bottom ash and solidified fly ash from incinerator is being sent to reclaim the seaside. Continued from finished phase in 2000, currently the land

reclamation process is towards the end of second phase. Completed area has become a secondary forest that attracts migrant birds thus has become a man-made habitat besides its own purpose as recreational park.

Besides reclamation, there is another attraction in the site where unused tyres are being used to protect the coastline from serious corrosion. This has given tyres a reuse value and solution however doubt has been raised that degradation of tyres in sea water would release polycyclic aromatic hydrocarbons (PAHs) that might be toxic that potentially pose threat to marine ecosystem as studies has shown that measures are needed to be taken against PAH. (CIRS 2012, Mahyar Sakari et al 2010, Tomohiko Isube 2005)



Figure 25: Reclaimed land that has grown into secondary forest and recreational park.



Figure 26: Land reclamation by solidified fly ash in phase 2 of the project.



Figure 27: Coastal erosion in few months.



Figure 28: Unwanted tyres are being used to protect the coastline.

## 6.2 Renewable Energy

### 6.2.1 Solar Power

In Southern District Waste Management Plant, the water heater system in staff hostel is powered by electricity converted by solar panel installed at roof top.



Figure 29: Solar panel at rooftop of staff hostel.

Besides, most of the lamp posts beside the road in Kaohsiung City are powered by solar panel installed at each unit.



Figure 30: Solar powered lamp post in Chung San University, Kaohsiung.

### 6.2.2 Wind Turbine

I took the opportunity to visit Cijin Island Wind Turbine Park during one of the weekend. The electricity generated by spinning turbine could light up the park for four and a half hour at night.



Figure 31: Cijin Island Wind Turbine Park

### 6.3 Energy Recovery

Buried waste contains potential energy that still could be harvested and utilized to generate electricity.

#### 6.3.1 Methane Harvesting from closed landfill

During the internship, I was being brought to visit Xiqingpu Sanitary Landfill methane to electricity plant operated by Veolia Environment upon request to Dr Hong-wen Yang. After Xiqingpu Sanitary Landfill's closure on 30 June 1999, the methane gas to energy mobile plant with capacity of 5448 kWh electricity generation converting methane gas at 3400 SCMH ( $\text{m}^3/\text{hr}$ , 1atm,  $25^\circ\text{C}$ ) is being built in April 2000 and officially started its operation since May 2000. Made up of 129 wells and 12 collection station, this power plant utilize 4 electric generator convert approximately 25.5k thousand cubic meter's volume of methane gas annually to provide electricity to 7000 households at the same reducing methane gas emission at 15,100 tons per year. The electricity generation efficiency of methane gas is estimated at 0.223kg/kWh while estimated carbon dioxide emission reduction efficiency is at 5.073kg/kWh. Monthly gas sampling results has showed that methane constituted 45-60% while carbon dioxide's composition dominates another 40-55% and oxygen could hardly be found at 0%.



Figure 32: Methane Gas Power Plant Overview



Figure 33: Methane Gas Power Plant

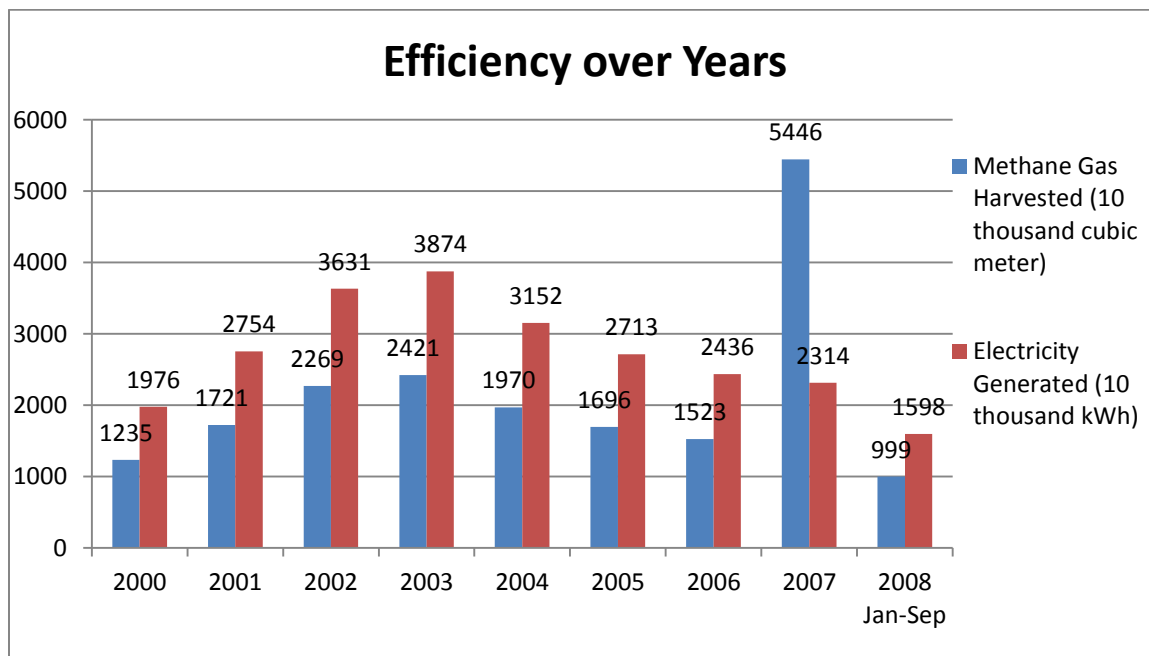


Figure 34: Methane Gas Harvested and Electricity Generated over years have successfully reduced estimated 54519 tons methane gas emission as well as 1440 thousand tons carbon dioxide emission.

Besides being site of methane to energy power plant, closed Xiqingpu Sanitary Landfill is designed to become a recreational park that offers man made ecosystem at the same time create awareness to public the concept and importance of environment protection. In all the power plant has effective prevent fire from happening in Xiqingpu SL, reduce VOCs threat, increase local quality of air index, reuse waste and also green energy comply to no-nuclear energy policy as well as environment management.

### 6.3.2 Waste to Energy Project from closed landfill

I was also being introduced to closed Xiqingpu Sanitary Landfill where old waste are being dug out for incineration and also to make up the volume of waste that are needed by waste management plant due to the fact that household waste separation at source has greatly reduce the amount of combustible waste.



Figure 35: Part of closed Xiqingpu Sanitary Landfill that is re-excavated.

Daliao Sanitary Landfill is another site that I've visit. Serving the public since 80's, Daliao Sanitary Landfill is built with double layer of HDPE liner at its bottom, completed with leachate collection piping and methane gas extraction when incinerators are not introduced. Now, Daliao Sanitary Landfill only accepts bottom ash or construction waste or solid waste that is not fit to be incinerated while some of its old waste is being excavated to be sent for incineration or further treatment.



Figure 36: Daliao Sanitary Landfill



## 6.4 Carbon Emission Reduction

### 6.4.1 Public Transportation

The population of Kaohsiung city has grown 1% over 6 years since 2.73mil in year 2001 to 2.76mil in year 2006 then to 2.78mil in 2012. (City Population 2013) In order to solve the problem of rapid urbanization and high population density, various type of high efficiency public transportation is being provided by the government of Kaohsiung city.

#### 6.4.1.1 Mass Rapid Transit

After working hours and over the weekend during the 2 week stay in Kaohsiung city, I travelled around the city to look into the local transportation system. Mass Rapid Transit in Kaohsiung city connects county of Gangshan at far north to Xiaogang at south and Siziwan from west to Daliao county in the east. Senior residents enjoy 10% discount all the time and upon reaching every station, the passengers are informed by 4 languages (English, Chinese, Tai Dialect and Hakka Dialect). (Attachment)



Figure 35: MRT

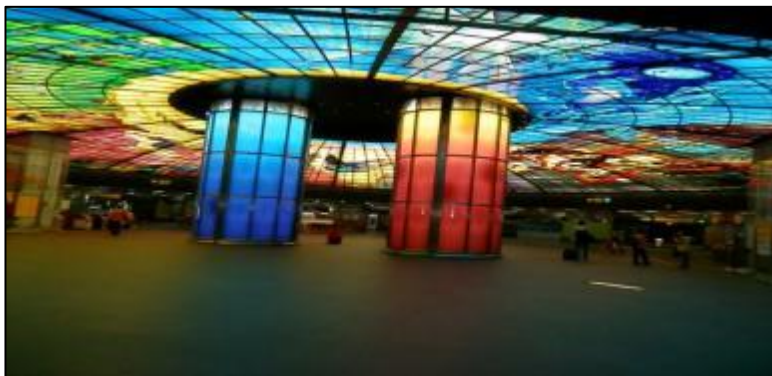


Figure 36: MRT Formosa Boulevard Station: The Dome of Light

#### 6.4.1.2 Bus

Public bus connects places where MRT not reach. A further 10% discount privilege would be presented to passenger to hop on the bus within 2 hours of coming off from the MRT to encourage usage of public transportation. Each bus stop is installed with schedule of bus arrival.



Figure 37: Bus schedule and map at every station.



Figure 38: Bus

#### 6.4.1.3 Bicycle

The government of Kaohsiung offer bicycle rental service all over the city to reduce carbon emission by motor vehicle. Families could be seen riding bicycle around the city over the weekend. The MRT also offer carriage which accommodate cyclist.



Figure 39: Various kinds of bicycle for rental

#### 6.4.2 Methane Harvesting from closed landfill

Please refer to Section 5.3.1.

### 6.5 International Commitment

The city of Kaohsiung is active in international environmental commitment.

#### 6.5.1 ICLEI

Kaohsiung city is a member of ICLEI – Local Governments for Sustainability which is an international association of local and metropolitan governments dedicated to sustainable development promoting local action for global sustainability and supports cities to become sustainable, resilient, resource-efficient, bio-diverse, low-carbon; builds smart infrastructures and develops green urban economy which membership covers 12 mega-cities, 100 super-cities and urban regions, 450 large cities, 450 small and medium-sized cities and towns in 84 countries dedicated to sustainable development. For instance, Greater London Authority and 10 other cities in UK, Tokyo Metropolitan Government and 21 other cities in Japan, Seoul Metropolitan City and 41 other cities in South Korea, Bangkok Metropolitan Administration and Phuket in Thailand and Surabaya Metropolitan City together with 6 other cities in Indonesia.

## 7.0 Conclusion

The Internship in Kaohsiung city has not only exposed myself to the waste to energy incinerator that is not popular nor a standard choice of waste management in Malaysia but also enabled me to look into the reality and effectiveness of integrated waste management which makes use of every type of waste for instance from raw or cooked putrescible to recyclables to non-recyclables and slag in addition solidified fly ash that has been proposed in Malaysia for a long time but all efforts seems to be in vain.

The scenario in Kaohsiung City has advised us to start waste separation at source in Malaysia as the first step of integrated waste management before any plan of building incinerator to reduce risk of waste shortage in the future as this is a main problem faced by every incinerator in Taiwan now. Most of the incinerators are running at approximately 50-75% capacity due to waste shortage over the years since 2009. Besides that, waste separation enables identification of each type of waste re-use value for instance raw putrescible that could be sold as compost while cooked putrescible could be used as livestock feed.

We might need to look into need of incinerators in Malaysia in near future since sanitary landfill or traditional dumpsite is never a good resort for waste management. The ability of waste incineration to generate electricity has been proven by the Southern District Waste Management Plant over 13 years of operation since 1999 on top of that gaining huge profit annually. The biggest concern from the public is the pollutants emitted particularly dioxins as well as lead (Pb) and mercury (Hg) are within standard that could be accepted. As discussed in Section 3.6.1 and Section 4.5 examples in Kaohsiung city might suggest that the Malaysian public can be rest assured that toxic gas generated during incineration is treated before being emitted and high temperature over a period of time greatly reduces production of dioxin. However the carbon emission from incineration needs further testing to ensure its contribution to green-house effect is under an acceptable level.

As discussed in Section 2.1, stakeholders' willingness, government initiatives, law enforcements and benefits of technology are main factor succeeding integrated waste management in Taiwan. For years the Malaysian Government tried to promote integrated waste management which ended up in failure largely due to lack of support from public and stakeholders besides law enforcements perhaps case study of Taiwan might be ideal example to pursue.

This internship has opened my eyes to the importance of public awareness and cooperation as the most determining factor to successful of waste separation at source in Kaohsiung City especially after more than 10 years since 90s their government has been putting in hard efforts including incorporating environmental education into school education. Besides, the government shall understand public needs through discussions during implementation of proposed projects. Negotiation might be needed for instance setting up Southern District Waste Management Plant was initially objected by public, however after the government explained to public about its importance and built mutual beneficial community center moreover paying compensation, the public accepted the proposal in addition supporting the government's policy of waste separation at source and "Keep Trash Off the Ground" policy.

We Malaysians might not be ready yet for waste separation at source due to the lack of knowledge and support however I believe that by promoting awareness nationwide and educate schooling young generations, the government can firmly start the policy like "No Plastic Bag Day" campaign in Penang and Selangor and enforce legislation to let the public know the intention of the government in settling waste problem and improve current situation by better practice.

As Malaysia is now marching progressively towards Wawasan 2020 aiming to become a more developed country, an integrated waste management approach must be started to prepare the public towards next level of globalized challenge which is to protect and sustain the environment, enable social growth at the same time allow adequate resources allocation that permit economic development. In other words, we must not neglect value

of potential waste and reducing waste together with proper management such as incinerator could not only solve the issue of landfill sitting in Malaysia but also could have reduce the impact of methane emission which causes series of impacts including global warming, climate change, melt of ice berg and rising sea level etc. Think before we consume as well as think before we throw can best guarantee our future generation a better world.

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