PHILIPPINE ENGINEERING JOURNAL
PEJ 2011; Vol. 32, No. 2: 31-50

QUEZON CITY SOLID WASTE CONTROLLED DISPOSAL FACILITY: WASTE ANALYSIS AND CHARACTERIZATION STUDY

Ferdinand G. Manegdeg[a], Louernie D. Papa[b], Gabriel P. Pamintuan, Jr.[b], Nestor O. Rañeses[c], Adrian D. Alcayde[d] and Florencio C. Ballesteros, Jr.[d]

[a] Dept. of Mechanical Engineering, University of the Philippines Diliman
[b] Dept. of Mining, Metallurgy and Materials Engineering, University of the Philippines Diliman
[c] Dept. of Industrial Engineering and Operations Research, University of the Philippines Diliman,
[d] Dept. of Chemical Engineering, University of the Philippines Diliman

ABSTRACT

The objectives of the Waste Analysis and Characterization Study at the Quezon City Solid Waste Controlled Disposal Facility in Payatas are to design a waste analysis and characterization framework and to determine the types, amount, moisture content, bulk density and calorific value of the wastes delivered at the facility coming from the different sectors (households, commercial establishment, road networks, markets and institutions) of the four (4) districts of Quezon City.

The survey framework employed was designed for on-site final disposal waste characterization and analysis. The sampling design resulted to the generation of a total of 337 truck-trips using stratified random sampling comprising of 12.8% of the total number of trips per day during the daily official operation time from 05:00 to 22:00 hours as permitted by the facility.

The waste mass components are: paper (6.7%); food and kitchen waste (9%); textile, rubber and leather (5.8%); plastic (14.9%); garden / yard waste (13.6%); other combustible (1.3%); metals (0.7%); glass (0.3%); and other non-combustible (47.7%). The daily composition of wastes is relatively similar among the four districts of Quezon City. The average moisture content is 46%, the average bulk density is 142 kg/m^3, the average net calorific value is 2,697 kcal/kg and the chemical formula derived is $C_{641}H_{1760}O_{613}N_{11}S$. The results require a high temperature waste disposal system such as a pyrolyzer to dispose the mostly plastic materials, inorganic, non-recyclable and residuals; a systematic and expanded materials recovery facility to recycle the non-combustible such as glass and metals; and a sanitary landfill to cater for the biodegradable.

Correspondence to: Ferdinand Manegdeg, Department of Mechanical Engineering, University of the Philippines, Diliman, Quezon City, Philippines

Received: January 20, 2012
Accepted: May 15, 2012

1. INTRODUCTION

Quezon City, the Philippines, has a population of 2,679,450 persons as of 1 August 2007 (Information Management and Services Unit, 1998) with an average growth rate of 2.92 percent, for the period 2000-2007 (Information Management and Services Unit, 1998). Its population is the highest in the National Capital Region (NCR) and all the cities nationwide. It has attained the highest net income of PhP 2.65 billion and maintains a surplus of PhP 282 million for five straight years since 2004 (Quezon City Annual Report 2005-2006). Its home region, NCR, has a Gross Regional Domestic Product of PhP 244,154 per capita in 2008 (Philippine Statistical Yearbook 2008). Quezon City has a land area of 16,112 hectares, almost one-fourth of NCR and is the biggest among NCR's 17 local government units (Quezon City Planning and Development Office).

In 2003, the waste generation rate of Quezon City is 532,100 tons per year or an average of 0.63 kilograms per capita per day (Asian Development Bank, 2003), and with that rate, the calculated generation rate in 2007 is 619,500 tons per year or 1,700 tons per day. The municipal solid wastes are being dumped daily at the only disposal facility, the Quezon City Solid Waste Controlled Disposal Facility (QCSWCDF), formerly known as the Payatas Dumpsite.

The solid waste management (SWM) of the City is devolved in 1991 as mandated by Republic Act (RA) 7160 or the Local Government Code of the Philippines, and the responsibility of handling solid wastes is also delegated to the City by RA 9003 or the Ecological Solid Waste Management Act of 2000, which is implemented in 2002. In response, the Quezon City government created the Environmental Protection and Waste Management Department (EPWMD) in 2000 through City Ordinance No. SP 982, to manage the comprehensive SWM program of the city and oversee the implementation of solid waste programs and activities (Government-wide Performance Audit Report on Solid Waste Collection System of the Quezon City Government; and The Payatas Tragedy). Under the EPWMD, the disposal facility operation of QCSWCDF is relegated to the Payatas Operations Group (POG).

The need for a better technology of wastes disposal is vigorously demanded and hurriedly anticipated due to increasing population and economic growth rates, higher health standard requirements, more aggressive pollution reduction laws, urgent climate change challenges and the lack of waste disposal area in Metropolitan Manilà. Waste Analysis and Characterization Study (WACS) was conducted to provide the necessary information on the waste delivered to QCSWCDF. It was coordinated with the POG, EPWMD and the Office of the Mayor. The study was conducted in November 2009 using a method adopted from the Japanese Industrial Standards (JIS) and the American Society for Testing and Materials (ASTM) standards (American Society for Testing and Materials International, 1986, 1992, 2003, 2005; and JICA/MMDA, 1999). The information may be used in designing the most appropriate collection, transport, storage, treatment and disposal of waste that complies with existing pollution standards and further generates electricity out of the waste destruction.

1.1 Objectives

The objectives of the QCSWCDF Waste Analysis and Characterization Study are to design a waste analysis and characterization framework and to determine the types, amount, moisture content, bulk density and calorific value of the wastes delivered at the facility coming from the different sectors (households, commercial establishment, road networks, markets and institutions) of the four (4) districts of Quezon City. The results of the WACS will be used to identify the appropriate technologies for the destruction of the types of wastes obtained.

1.2 Significance

The Waste Analysis and Characterization Study is normally conducted to aid in the planning of an integrated SWM system. The results also provide valuable data for setting-up goals and targets that can be integrated in the SWM plan. It will also be used in designing the most appropriate collection, transport, storage, treatment and disposal of waste with electricity generation out of the waste destruction and whose processes comply with existing pollution standards. A waste destruction, waste to energy facility whose technical characteristics such as capacity, power requirement, and thermal and pollution equipment specifications depend on WACS results. It will help determine the input materials and the amount of energy and pollution generated.

In order to address the locational jurisdiction of Quezon City and the appropriate technology for waste disposal with electricity generation for Quezon City in a statistically significant data, a waste analysis and characterization study is conducted on-site in QCSWCDF.

1.3 Quezon City Solid Waste Controlled Disposal Facility

The Quezon City Solid Waste Controlled Disposal Facility is the biggest and oldest operating dumpsite in Metropolitan Manila. It has been Quezon City's waste disposal facility for more than three decades. It has an accumulated 18.7 million m^3 (approximately 3.7×10^9 kg) since 2001 up to 2008 as shown in Table 1.1.

Table 1.1. Payatas dumpsite waste intake (Quezon City Controlled Disposal Facility).

Year	Waste Intake		Truck-Trips	
	Volume (m^3/year)	Weight (ton/day)	Number of Trips Per Year	Daily Average
2001	2,727,554	1,495	No Data	No Data
2002	2,522,848	1,382	No Data	No Data
2003	2,294,218	1,257	No Data	No Data
2004	2,393,287	1,308	160,876	440
2005	2,222,281	1,218	150,769	413
2006	2,230,518	1,222	152,571	418
2007	2,136,337	1,171	149,806	410
2008	2,142,951	1,171	150,044	410

The location is always a concern due to its nearness to La Mesa watershed (being the source of drinking water of Metropolitan Manila), to housing communities (home of many residents), and to the West Marikina fault line (perilous during earthquake) as shown in Figure 1.

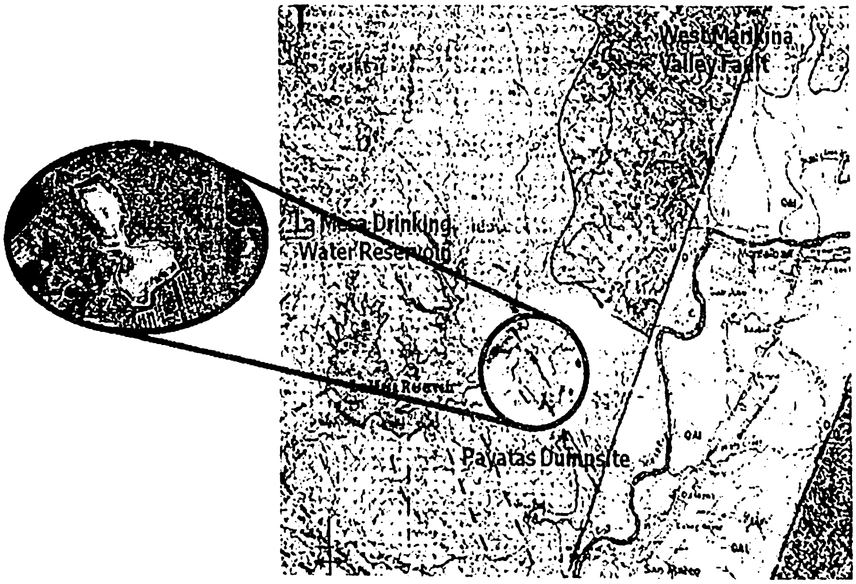

Figure 1. Location of QCSWCDF showing La Mesa watershed, West Marikina Valley fault line (Quezon City Planning and Development Office), and housing areas (Payatas Dumpsite Satellite Map).

In July 2000, it was a picture of chaos, danger and grief when a trash slide occurred and hundreds of people died (The Payatas Tragedy; and The Payatas Dumpsite from Tragedy to Triumph). Immediately after the trash slide, the dumpsite's closure was ordered but was later repealed by an executive order issued by the President to address the metropolitan-wide garbage collection problem. The reopening of the facility required monitoring guidelines which prompted the creation of the POG under the EPWMD.

1.4 Previous WACS in Metropolitan Manila

The Norconsult A.S. et. al (Norconsult), Japan International Cooperation Agency/Metropolitan Manila Development Authority (JICA/MMDA), Asian Development Bank (ADB), and Department of Science and Technology (DOST) performed WACS in Metropolitan Manila (Norconsult, 1982; JICA/MMDA, 1999; ADB, 2003; and DOST, 2009). All agencies used stratified random sampling which considered seasonal changes and generation sources.

Norconsult (1982) conducted WACS in Metropolitan Manila as part of a study to develop a SWM system. The study considered generation level of economic groups. A selected fully loaded vehicle which collected refuse from a generation source was brought into the sample processing site. The load was placed in a clean flat surface, mixed thoroughly and about 1 m^3 of refuse was obtained. After obtaining the representative samples, the wastes were separated into major components such as readily biodegradable (includes garbage, paper, wood, leaves and trees), readily combustible (includes textiles, plastics, rubber and leather) and mostly inert (includes metals, glass, dirt, ceramics, ash and stones). The moisture content and calorific value were determined for each component.

The Japan International Cooperation Agency/Metropolitan Manila Development Authority (JICA/MMDA, 1999) conducted waste characterization survey in 1997 to improve the SWM in Metropolitan Manila. Sampling took place in Parañaque, Makati and Quezon City, in April and June 1997, to determine the characteristics of the waste during dry and wet seasons. The number of samples collected at the source for the whole Metropolitan Manila was 3,402 including 1,134 samples from Quezon City. Representative samples were collected for a seven day sampling period from nine types of generation sources – household wastes from (1) high, (2) middle and (3) low income levels, commercial wastes from (4) restaurant and (5) other shops, (6) institutional wastes from government and state enterprises and private offices, (7) market wastes, (8) street sweeping waste and (9) river waste. All samples from each generator types were gathered, mixed and divided continuously in a procedure similar to coning and quartering until a volume of between 30 to 50 liters was reached. The wastes were separated as combustibles (kitchen waste, paper, textile, plastic, grass, wood, leather and rubber) and incombustibles (metal, glass, ceramic, stone and soil). Moisture content, specific gravity and calorific value were determined.

The Asian Development Bank (2003) performed waste characterization studies in key municipalities in Metropolitan Manila including Quezon City. Samples were obtained for seven days in April to May 2003 from seven generator types – (1) low-income residential, (2) middle-income residential, (3) high-income residential, (4) commercial, (5) markets, (6) industrial and (7) institutional. Approximately 60 representative samples each weighing 100 to 150 kg was obtained from vehicles randomly selected to collect specific types of waste. The procedure adopted for waste composition determination came from the Method for Determining the Composition of Unprocessed Solid Waste promulgated by the American Society for Testing and Materials (ASTM) Method D5231. The samples were sorted manually into different categories and the sorted materials were weighed. The moisture content was determined by air drying in seven days. The bulk density and generation rates were also determined.

The Department of Science and Technology (2009) conducted waste characterization study at the QCSWCDF in March 2009. Samples were obtained for seven days from dump·trucks which collect wastes from four generation sources – (1) residential, (2) commercial establishments, (3) institutions and (4) market areas. For each day, a dump truck collecting from one generation source was chosen to obtain a 1 m^3 sample that will be stored in a steel drum where the sample size was reduced by conical quartering for bulk density determination and for sorting or classification. The wastes were separated into biodegradable, recyclable (plastics, glass, paper and metals), residual (styrofoam, sando bags and laminates), inerts (ceramics, stones and dirt) and special wastes (hospital and hazardous wastes). The percentage composition, bulk density and volume of waste were calculated per day from each source.

The Norconsult study considered the composition and characteristics of wastes for the whole Metropolitan Manila area. The JICA/MMDA study considered on-site generation sources for their waste characterization which were not specific to the final disposal site. Norconsult, JICA/MMDA and ADB studies gathered their samples from generation sources. The DOST study performed waste characterization in Payatas dumpsite with a few samples.

2. MATERIALS AND METHODS

The methodology includes the design of survey framework (sampling design and protocol, survey instrument and field protocol); review of the method of municipal solid waste property determination; conduct of the survey (gather data, conduct laboratory analysis, encode data) and analysis of the data. A review of existing laws and regulations was included to provide the enabling framework for the type of waste and technology to be used.

2.1 Design of Survey Framework

The five functional elements of SWM are generation, storage, collection, treatment and disposal. Solid wastes are generated from different sources which are classified as residential, commercial, institutional, agricultural, residual and other types of wastes. During generation, the wastes are either segregated or in-situ recycled. The wastes are stored in waste bins, receptacles and other appropriate containers. Collection is done via house to house, curb side or other collection methods. The wastes can either be treated or go directly to disposal facilities. The solid waste is classified for materials recovery, biological reclamation and thermal reduction. Materials recovered include metals, glass, soil and others. Biological reclamation employs composting, biogasification and others. Thermal reduction deploys incineration, pyrolysis and refuse-derived fuel. The residue coming from the materials recovery, biological reclamation and thermal reduction goes to land disposal.

The study adopted the decision alternative for SWM from Tchobanoglous, et. al (1993), while the method and protocol were guided by the method done by the JICA/MMDA study (1999) and the protocol done by the ADB study (2003). The study was done for the wastes delivered at final disposal.

2.1.1 Sampling Design

The wastes come from different sectors (households, commercial establishments, road networks, markets and institutions) of the four districts (1, 2, 3 and 4) of Quezon City as shown in Figure 2 (Map of Quezon City, Philippines, URL www.quezoncity.gov.ph). Special wastes such as those coming from hospitals, street wastes and other wastes brought about by natural calamities are also sampled whenever applicable.

Figure 2. Map of Quezon City showing the boundaries of the four districts (Map of Quezon City, Philippines, URL www.quezoncity.gov.ph).

The garbage collection in Quezon City is divided into five collection areas with District 2 divided into 2A and 2B under five (5) different private contractors. The total contracted number of vehicles deployed is 230 and the vehicle distribution is shown in Table 2.1 (Government-wide Performance Audit Report on Solid Waste Collection System of the Quezon City Government, 2002).

Table 2.1. Distribution of the number of vehicles (Government-wide Performance Audit Report on Solid Waste Collection System of the Quezon City Government, 2002).

District	Number of Vehicles	Percentage (%)
1	47	21
2A	33	14
2B	44	19
3	50	22
4	56	24

Samples are obtained using stratified random sampling. Sampling is designed to account for the daily variation (different days of the week) and the geographic variation (different districts) because seasonal and geographic variations can have significant impacts on waste characteristics. The criteria used are origin of the wastes from the different districts, number of contractors, and the vehicle routes traveled where wastes are collected.

The sample size collected per day is calculated based on the average number of daily truck-trips provided by POG. The calculated sample size per day is 44 truck-trips comprising of at least an average of ten percent (10%) of the total number of trips per day during the daily official operation time from 05:00 to 22:00 hours as permitted by POG. A total of 337 truck-trips are sampled for eight (8) continuous days. The last day is conducted for validation.

2.1.2 Sampling Protocol

The samples from the tagged collection trucks were drawn before any activities such as material recovery are conducted. The representative samples were obtained using the coning and quartering method. The representative samples are collected and subjected to bulk density, mass composition and moisture content determination. The field supervisor ensures that the method and quality are properly followed.

Sample weight affects the variability of solid waste composition estimation. The recommended sample weight is between 91 to 140 kg (Klee, A.J., 1980) which was also the interval suggested by ASTM Method D5231-92. The sample weight between 91 to 140 kg was recommended by Klee (1980) since sample weights below 91 kg tend to increase sample variance rapidly while sample weights above 140 kg increase variance slowly.

2.1.3 Field Protocol

Trucks coming from the various districts as represented by the five different contractors are tagged by the site team leader at the gate using purposive random sampling, i.e., for each round of tagging, each contractor is represented. The tagged vehicle proceed to the working area to unload the waste. The wastes are mixed using front-end loader after which the samples are taken. The protocol is quality assured by the field supervisor.

Pre-weighed trash bags with composition label are prepared prior to manually sorting the wastes per composition. The wastes are hand sorted and placed in their respective composition labeled trash bags. After sorting is completed, each component is weighed and properly recorded. Double checking the process is part of the quality assurance provided by the field supervisor. The field supervisor is required to check the weight and the data entered in the survey instrument. The weighing scales were calibrated prior to deployment.

In all the activities in the field, the safety officer ensures that all sorters are trained on safety procedures and are wearing gloves, aprons and boots and follow safety procedures strictly.

2.1.4 Survey Instrument

The survey instrument requires gathering of vehicle information (plate number, body number, type and size), name of contractor, where the vehicle originated, number of households served by the truck, collection route, time and date, waste categories, waste volume, composition and respective weights, temperature, time duration, and survey personnel. The instrument has data capacity for at least eight days.

2.2 Waste Property Determination

The municipal solid waste properties are bulk density, composition and moisture content. The waste bulk density is determined using ASTM Method 1159E (2003). The composition determination is based on the JICA/MMDA method (1999). The moisture content of the solid sample is determined using gravimetric method.

2.2.1 Bulk Density Determination

The bulk density in kg/m^3 is determined by weighing the mass of waste on the special container with a volume of 1 m^3. A minimum of three (3) trials is done until the difference in the measured weight is ± 5 kg. The bulk density is the ratio of the mass of the sample in kg to that of the volume of the container in m^3 as calculated using Equation 1:

$$\text{Bulk Density (kg/m}^3) = M_{sample} / V_{container} \qquad \text{Equation 1}$$

2.2.2 Composition Determination

For the composition determination, a specified volume of waste totaling one (1) cubic meter is sorted and separated according to components. Each component is weighed and the percentage by weight is calculated. The mass composition is the ratio of the mass of the waste component in kg to that of the mass of the sample in kg as calculated using Equation 2 where the mass composition is expressed in percentage:

$$\text{Mass Composition (\%)} = 100M_{component} / M_{sample} \qquad \text{Equation 2}$$

The waste components are classified into paper, food and kitchen waste, textile, leather and rubber, film and hard plastic, garden/yard waste, other combustible, metals, glass, and other non-combustible as shown in Table 2.2.

Table 2.2. Waste categories.

Category	Particulars
Paper	White paper, newspaper, cartons, folders, cardboard, yellow paper
Food and kitchen waste	Swill, innards, vegetables, fruits, peelings
Textile, leather and rubber	Tires, slippers, rubber mats, rubber shoes, clothing, seat covers, shoes, canvass sheets, feathers
Plastic, film	Polypropylene sacks, plastic cups, other film plastic
Plastic, hard	Shampoo containers, other hard plastic
Garden and yard waste	Leaves, garden, fruit peels, coconut husks
Other Combustible	Styrofoam, foam, plywood, wood chips, lumber, tree branches, coconut shells, diapers, hair
Metals	GI sheets, aluminum cans, tin cans, metal wire
Glass	Glass bottles, broken glasses
Other Non-combustible	Filling materials*, bricks, ceramics, miscellaneous (grit, street sweepings),

*Some trucks are filled with soil for covering material.

2.2.3 Moisture Content Determination

The moisture content of the samples is determined using gravimetric method. Solid waste of known weight is dried in an oven at 103 ± 2 °C for three (3) hours. The dried weight of the sample is then measured. The process of drying was repeated until constant weight is obtained. The moisture content is the ratio of the difference between the initial and final weights of the sample in kg to that of the initial weight of the sample in kg as calculated using Equation 3 where the moisture content is expressed in percentage:

$$\text{Moisture Content (\%)} = 100[W_{initial} - W_{final}] / W_{initial} \qquad \text{Equation 3}$$

2.3 Actual Survey

The actual survey was conducted continuously from 9 to 16 November 2009. The collection and characterization were conducted for seven (7) days for the actual data and one (1) day for validation. During the field survey, there were a minimum of 17 technical project staff involved consisting of site team leaders, field supervisors, vehicle data controllers, chemists, quality controllers, environmental consultants, safety officers and ten (10) waste sorters or "*paleros*" per shift of ten hours. The sorters were hired from the sorters of POG. The actual flow of activities is depicted in Figure 3.

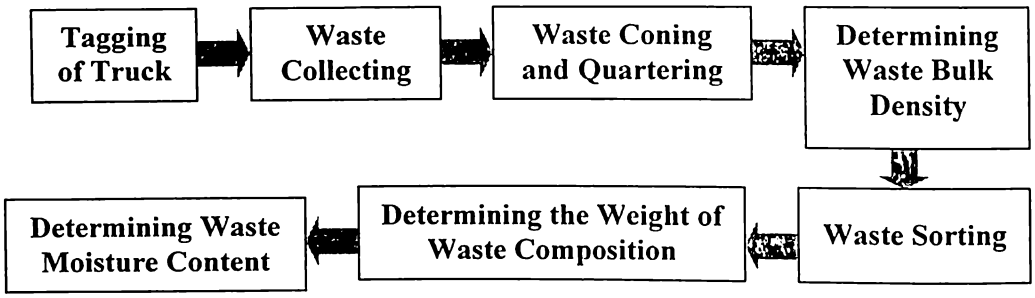

Figure 3. Actual flowchart of WACS process.

The trucks were tagged randomly. Samples from the tagged trucks were taken by getting wastes from the front, middle and rear portions of the trucks. Samples were obtained after the trucks have unloaded the wastes. Scavengers were not allowed to get anything until the sampling has been completed. The representative solid waste samples were obtained using the coning and quartering method. The samples obtained per day were brought to the field laboratory and subjected to bulk density and weight composition determination. The bulk density of the waste sample was obtained using Equation 1. The wastes were classified according to composition. The percent composition was calculated using Equation 2.

The representative samples were brought to the laboratory for moisture determination. Upon arrival of the samples, the chemist pre-weighed the samples, placed in an oven and determined the dry weight of the samples. The moisture content for each sample was calculated using Equation 3.

The site team leader checked and validated the entries while the project leader checked the entries randomly. The data obtained were recorded manually in designated logbooks in the field and in the laboratory. The data were then recorded electronically in a pre-designed computer template to determine the composition percentages and charts.

The data obtained were analyzed for statistical and environmental significance from which conclusions and recommendations were formulated.

3. RESULTS AND DISCUSSION

The results of the WACS and previous WACS as well as laws, ordinances and regulations related to solid wastes are analyzed.

3.1 Distribution of Samples

The samples were obtained from the trucks chosen at random. A total of 337 solid waste samples were obtained for the seven-day WACS and one-day validation conducted, representing 12.8% of the total trucks of 2,627 that delivered during the QCSWCDF official operation time from 05:00 to 22:00 hours. However, the samples represented 9.7% if those trucks that delivered outside of official operation time as reported by POG are considered. The number of trucks sampled per day and the total number of trucks are given in Table 3.1. The calculation of the population size was based on the number of trucks observed during the survey which reflected the official operation time of QCSWCDF. On the first day of survey, three tagged dump trucks failed to proceed to the WACS area for no apparent reasons which were later corrected by guiding the drivers.

Table 3.1. Number of trucks sampled.

Day	District 1	District 2A	District 2B	District 3	District 4	Special Wastes from All Districts	Number of Trucks Sampled	Number of Trucks on Official Operation Time	POG Reported Number of Trucks
1	9	5	7	8	4	2	35	377	444
2	7	10	9	9	9	4	48	380	482
3	8	9	9	4	12	2	44	389	480
4	6	9	14	4	8	3	44	346	465
5	5	10	6	10	7	1	39	377	478
6	5	8	10	6	13	2	44	329	469
7	7	2	5	8	12	9	43	170	208
8	2	12	7	8	8	3	40	259	440
Total	49	65	67	57	73	26	337	2627	3466
%	4.5	19.3	19.9	17	21.7	7.7	100	12.8	9.7

The contracted services for collection of solid wastes correspond to the five districts of Quezon City. Private trucks coming from all districts are those from commercial establishments, government institutions and private sources which are tagged as special delivered wastes. Dispatching of additional trucks is based on the amount of wastes still to be picked up for each cell assignment to complete the collection requirement for the day.

Table 3.1 shows that a total of 39% of the sampled trucks came from District 2 which has 58% of the total population of Quezon City. This is followed by District 4 with almost 22% of the total sampled trucks at 16% of the total population. The data correlates that the number of trucks dispatched in the districts is directly proportional to the size of population in the districts and hence to waste generators.

3.2 Waste Composition

The average waste composition (in percent) generated in the four districts of Quezon City is presented in Table 3.2. The average composition for the four districts shows that the wastes are composed mostly of inorganic, plastics, garden and yard waste, food and kitchen waste, and paper.

Table 3.2. Waste composition.

Composition	Percentage (%)
Paper	6.7
Food and Kitchen Waste	9.0
Textile, Leather and Rubber	5.8
Plastic, Film	13.3
Plastic, Hard	1.6
Garden and Yard Waste	13.6
Other Combustible	1.3
Metals	0.7
Glass	0.3
Other Non-Combustible	47.7

The same top five types of waste can also be observed in the average 8-day composition for each district. The waste composition per district in more detail is shown in Figure 4. The average daily compositions for the different districts do not differ much in terms of components and relative percentages. However, for special delivered wastes, the difference on the inorganic is 12% less compared to the 47% in the regular wastes.

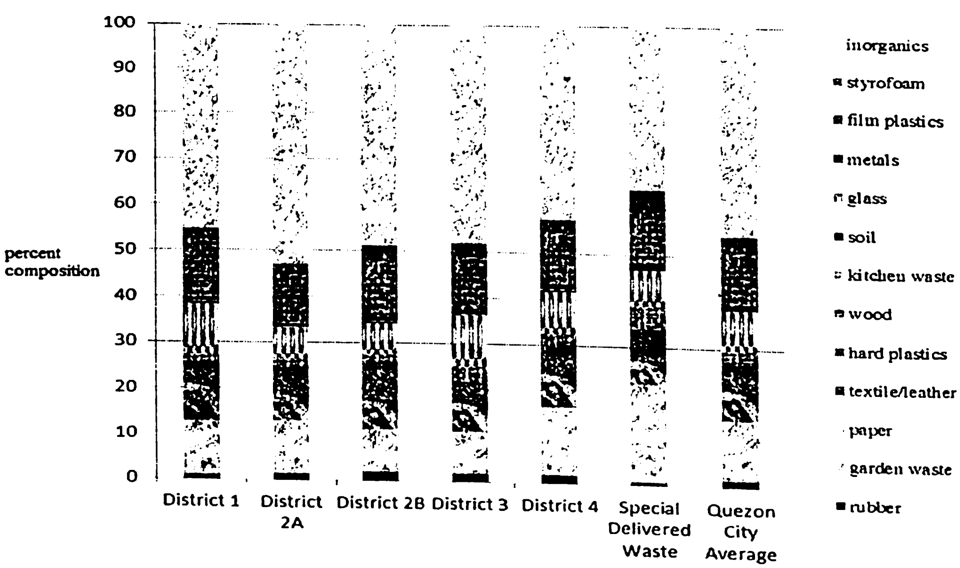

Figure 4. Waste Composition in Quezon City

3.3 Bulk Density Calculation

The waste has low density. The lowest value obtained was 55 kg/m^3 while the highest value was 241 kg/m^3. The average minimum and the average maximum were 74 and 219 kg/m^3, respectively. The calculated average bulk density was 142 kg/m^3. The computed average bulk density per day is given in Table 3.3.

Table 3.3. Average bulk density.

Day	Average Bulk Density, kg/m^3
1	126
2	151
3	125
4	158
5	147
6	151
7	125
8	151
Average	142

3.4 Quantity of Waste Received

The total amount of waste received at QCSWCDF was calculated based on the total number of truck-trips with the corresponding volume capacity per truck and the estimated bulk density since the truck weighing scale on-site is not operational. Table 3.4 shows the total number of trips during the official operation time, the corresponding volume and the calculated tonnage based on the average daily bulk density value. The QCSWCDF receives an average of 663 tons of waste per day. Table 3.4 also shows the total number of trips as reported by POG, the corresponding volume and the calculated tonnage based on the average daily bulk density value. The facility receives an average of 881 tons of waste per day with a minimum of 341 tons and a maximum of 1,496 tons.

Table 3.4. Estimated quantity of waste received at QCSWCDF.

Day	Observed Trips on Official Operation Time			POG Reported Trips		
	Number of Trips	Volume (m^3)	Average Quantity per Day (ton)	Number of Trips	Volume (m^3)	Average Quantity per Day (ton)
1	377	5148	649	444	6209	782
2	380	5386	813	482	6877	1038
3	389	5311	664	480	6747	843
4	346	4884	772	465	6620	1046
5	377	5390	792	478	6909	1016
6	329	4686	706	469	6641	1003
7	170	2594	324	208	3181	398
8	259	3938	595	440	6460	975
Average	328	4667	663	433	6206	881

3.5 Moisture Content

The calculated moisture content using Equation 2 is tabulated in Table 3.5. The maximum value measured is 68% while the minimum value is 24%. The average moisture content is 46%.

Table 3.5. Moisture content.

Day	Moisture Content, %		
	Minimum	Maximum	Average
1	24	69	38
2	21	67	45
3	25	70	49
4	21	67	45
5	26	68	48
6	23	70	41
7	30	67	51
8	25	69	51
Average	24	68	46

3.6 Calculated Values of Selected Waste Properties

The calorific value and the chemical formula of the waste were calculated based on the measured percent composition and moisture content. Table 3.6 shows the calculated values.

Table 3.6. Calculated and measured values for selected waste properties.

Parameters	Calculated Values	Measured Values
Moisture Content, %		46
Bulk Density, kg/m^3		142
Calorific Value, kcal/kg	2,697	
Chemical Formula	$C_{641}H_{1760}O_{613}N_{11}S$	

3.7 WACS Results

The results of previous WACS together with the results of this study are shown in Table 3.7. Biodegradable wastes include food and kitchen waste and garden and yard waste. Combustibles include paper, plastics, styrofoam, textile, rubber and tires, and other organics. Non-combustibles include soil and other filling materials, and non-combustible recyclables that include metal, screenings, glass and foils. Classification of wastes into biodegradable, combustibles and non-combustibles will aid in determining the proper waste treatment technologies to be used. This study did not consider hazardous and hospital wastes as a separate category.

Table 3.7. WACS Results.

WACS	Norconsult[1] A.S. (Metropolitan Manila)	JICA[2] (Quezon City household average)		ADB[3] (Quezon City)	DOST[4] (QCSWCDF)	This Study[5] (QCSWCD)
Sampling method	sampling of vehicles collecting from generation sources	sampling on-site of generation sources		sampling of vehicles collecting from generation sources	sampling of vehicles dumping on the disposal facility	sampling of vehicles dumping on the disposal facility
Date	1982	April 1997	June 1997	April to May 2003	March 2009	November 2009
Number of Samples	-	1,134	1,134	approx. 60	28	337
Biodegradable	39.5	59.86	50.46	39.9	47.4	22.6
Combustible	30.4	30.26	39.86	50.3	35.6	28.7
Non-combustible	29.1	9.87	9.68	9.4	5.2	48.7
Hospital and Hazardous waste	1.0	-	-	0.4	11.8	-
Moisture Content, %	42.6	45.06	44.55	67	-	46
Density, kg/m^3	-	160	180	218	186	142
Net Calorific value, kcal/kg	1,468.5	1,429	1,984	-	-	2,697

- means no data [1]Norconsult A.S. et. Al, 1982 [2]JICA/MMDA, 1999 [3]Asian Development Bank, 2003
[4]Department of Science and Technology, 2009 [5]Hazardous and hospital wastes were not considered as a separate category.

3.8 Discussion

Several factors affect the creation and implementation of an effective SWM system. Base on available waste treatment technologies, solid waste can be classified for materials recovery, biological reclamation and thermal reduction. International and local existing laws, ordinances and regulations regarding solid wastes and waste treatment technologies will be a major factor in assessing the environmental impact of a solid waste management system or treatment technologies. Lastly, public perception can adversely affect the solid waste management system as it has the final judgment on its implementation.

With the creation of the RA 9003, a formalized set of rules and regulations for solid waste management was implemented – devolving the responsibility of handling municipal solid wastes to the local government units (LGUs), mandating the creation of a 10-year National Solid Waste Management framework to be followed by the LGUs and establishing the National Solid Waste Management Commission. This law also mandates waste diversion through reuse, recycling and composting or biological reclamation and other materials recovery activities and started the national movement on the growth and development of SWM.

Due to the high calorific value calculated for the QCSWCDF wastes, thermal reduction with energy recovery is a promising and advantageous waste treatment technology. However, thermal reduction treatment methods, commonly referred to as incineration, faced a major setback with the implementation of RA 8749 or the Philippine Clean Air Act of 1999 as it bans the incineration of municipal, biomedical, and hazardous wastes, which process emits poisonous and toxic fumes.

Furthermore, it requires the phase out of existing incinerators dealing with bio-medical wastes by July 2003. This was later clarified with the issuance of the Department of Environment and Natural Resources (DENR) Memorandum Circular No. 5 (12 July 2002) which states that RA 8749 . . . "does not prohibit incineration of wastes except those burning process that emit 'poisonous' fumes" . . . This now provides a legal framework for the use of . . . "any type of thermal treatment technology, whether burn or non-burn as defined in Department Administrative Order (DAO) 2000-81, that meets the emission standards of stationary sources as listed in Section 19 of RA 8749 and complies with all other relevant provisions of RA 8749 and other applicable laws of the Republic is allowed to be operated in the country . . .".

The waste composition results show that there are still recoverable in the wastes being dumped in the controlled dumpsite facility. A Materials Recovery Facility is necessary to further reduce the wastes for final disposal. In addition, there are a lot of fines like soil materials in the wastes that can be used as cover material in lieu of the daily soil cover being used by the facility. These methods are in line with the waste diversion mandate given by RA 9003.

It is noticeable that the amount of biodegradable waste decreased reflects the intense collection of biodegradable waste by the barangay local government unit and some subdivision owners and more of a reflection of the changes in behavior of the populace in terms of biodegradable waste disposal. In market places, there are also segregation procedures practiced. Households also practice segregation due to barangay ordinance and biodegradable waste only collection day. A few commercial establishments (especially big grocery stores) already established a "no plastic use" or "bring your own bag" day.

The biodegradable waste is treated and utilized by composting for fertilizers and by sanitary landfill for biogas retrieval. The waste is also high in moisture content, high in garden and kitchen waste that a significant volume of leachate can be generated. Provision for leachate collection and treatment should be installed so as to reduce the risk of contaminating the groundwater, the Marikina River downstream and reduce contact to the people and residents in the area. Guidelines on controlled dumpsite and sanitary landfill provided by RA 9003 should carefully be followed.

The presence of the gas extraction and flaring facility will only address the gas produced by the biodegradable waste in Payatas. However, residuals which constitute the bulk of the waste should be addressed by thermal reduction to lengthen the lifespan of the landfill.

A high percentage of combustible such as paper (6.7%), textile, rubber and leather (5.8%), plastics (14.9%) and other combustibles (1.3%) were measured. A technology to dispose the wastes at high temperature like a pyrolyzer type of equipment (International Environmental Solutions Corporation) that complies with environmental regulations set by RA 8749 is worth considering. The synthetic gas produced can be used to generate electricity. The inert produced will greatly reduce the initial volume of waste that otherwise would have been disposed of in landfill. In addition, thermal reduction may address the problems posted by hazardous and hospital wastes which are not supposed to be dumped in landfills. For ease in waste handling, a shredding machine should be included. Likewise, pollution control devices should be installed.

Although the Ecological Solid Waste Management Act of 2000 was a comprehensive law encompassing solid wastes, laws relating to hospital and hazardous wastes are general and non-comprehensive. Hospital wastes are regulated by the RA 4226 or Hospital Licensure Act (1965) and the Department of Health Department Circular No. 152-C series of 1993. These laws do not provide a standardized set of rules and guidelines for treatment of hospital wastes that should be followed by every hospital in the country. RA 6969 or the Toxic Substances and Hazardous and

Nuclear Wastes Control Act of 1990 had provisions for managing hazardous waste but these are not standardized and broad in scope. Specific laws regarding hospital and hazardous waste need to be implemented. These laws should provide a comprehensive management plan for the collection, segregation, treatment and proper disposal of special wastes.

The low bulk density measured (142 kg/m^3) necessitates the use of a compactor truck for collection to maximize the collection of solid waste and reduce the number of trucks necessary for collecting and transporting wastes. A baling system for storage will further enhance efficiency of solid waste management scheme. Also, the estimate on the amount of waste being received by the facility should be examined. Validation through regular bulk density measurement should be done to get a good estimate on the actual volume of wastes accumulated in the facility and the use of weighing scale on-site is crucial.

An attempt was made to confirm the results of the composition of the 7 days WACS with the day-8 validation run. However, there were large discrepancies between the values. The same is observed in comparing day-1 and day-8 average daily composition values. However, the bulk density and moisture content for the day-1, the average 7 days WACS and the day-8 validation run values are in congruence. This shows that indeed municipal solid waste composition varies significantly as regards to time. In this light, it is essential that WACS be conducted regularly to account for the heterogeneity of the solid waste being disposed in QCSWCDF.

As available area for sanitary landfills diminishes and the high cost of frequent building of sanitary landfills and transporting at farther locations, policies to promote waste reduction and thermal disposal will become more critical and urgent.

4. CONCLUSIONS AND RECOMMENDATIONS

The WACS conducted provides valuable data for SWM plan. The data generated and the experience observed also necessitates suitable recommendation for waste destruction with energy generation.

4.1 Conclusions

A waste analysis and characterization framework was designed to determine the types and amount of waste delivered at the facility. The results were compared to previous studies and based on limited available materials, a disposal technology is suggested.

1. The sampling design resulted to a total of 337 truck-trips using stratified random sampling that considered seasonal and geographic variations, origin of the wastes from the different districts, number of contractors, and the vehicle routes traveled. The number of vehicles sampled comprised of 12.8% of the total number of trips during the official operation time of QCSWCDF from 05:00 to 22:00 each day as permitted by POG. The survey lasted for eight (8) continuous days with the last day conducted for validation.
2. The waste components are: paper (6.7%), food and kitchen waste (9%), textile, leather and rubber (5.8%), plastic (14.9%), garden and yard waste (13.6%), other combustible (1.3%), metals (0.7%), glass (0.3%), and other non-combustible (47.7%). The daily composition of wastes is similar among the four districts of Quezon City.
3. The average moisture content is 46%. The average bulk density is 142 kg/m^3. The average net calorific value is 2,697 kcal/kg. The chemical formula derived is $C_{641}H_{1760}O_{613}N_{11}S$.

4. The results require a high temperature waste disposal system such as a pyrolyzer to dispose the mostly plastic materials, inorganic, non-recyclable and residuals (28.7%); a materials recovery facility to recycle the non-combustible such as glass and metals; and sanitary landfill to cater for the biodegradable (22.6%).

4.2 Recommendations

The recommendation is focused on the frequency of WACS and the appropriate waste management technology for the type of waste composition observed.

1. It is recommended that regular WACS be conducted to account for seasonal variations and technology changes.

   It is expected that the results will differ if the sampling activity was done over a longer period to include both wet and dry seasons. Volume and composition differs during these days.

   The composition variations will impact on waste collection, design of wastes management, processing, and disposal systems. For example, the revolutionizing trend in the communications and technology industry and its related Business Process Outsourcing is expected to affect solid waste composition since more electronic wastes will be generated. Quezon City embarked on expansion of its communications, information and technology industry by providing incentive programs and infrastructure developments.

2. The use of appropriate waste management technology to reduce and dispose the waste is also passionately recommended.

   A high temperature pyrolyzer under no air (or very minimal) environment, converts the waste into inert materials, reduces the volume of waste by a tenth, generates synthetic gas for electricity generation and is complementary to the existing gas collection system.

   On the other hand, policies supporting composting as an alternative treatment technology will affect composition as such technology utilizes the organic fraction in solid wastes.

   An expanded and systematic materials recovery and shredding facility is also recommended to efficiently and safely recover recyclable and prepare residuals for proper disposal.

   Better collection technology with on site separation is recommended due to the heterogeneous nature of the waste. Heavy duty compactor equipment is also recommended due to the low density property of the waste.

   These recommendations need enabling laws and regulations to implement.

5. REFERENCES

1. 2005-2006 Quezon City Annual Report. URL http://www.quezoncity.gov.ph/images/AnnualReport/annualreport0506.pdf.
2. Asian Development Bank, 2003. Metro Manila Solid Waste Management Project (Technical Assistance 3848) Final Report. AEA Technology, plc.
3. American Society for Testing and Materials International, 1992. ASTM D 5231-92 Standard Test Method for Determination of the Composition of Unprocessed Municipal Solid Waste.
4. American Society for Testing and Materials International, 2003. Standard Test Method for Apparent Density, Bulk Factor, and Pourability of Plastic Materials, Documents No. ASTM D 1895-96, Reapproved 2003.
5. American Society for Testing and Materials International, 1986. Standard Test Method for Determining Bulk Density of Solid Waste Fractions, Documents No. ASTM E1. 109-86.
6. American Society for Testing and Materials International, 2005. Standard Test Method for Laboratory Determination of Water (Moisture) Content of Soil and Rock by Mass, Documents No. ASTM D 2216-05.
7. Department of Science and Technology, 2009. Waste Characterization Study in Payatas Controlled Dumpsite.
8. Government-wide Performance Audit Report on Solid Waste Collection System of the Quezon City Government, 2002. URL http://www.coa.gov.ph/GWSPA/ 2001-2002/SWM/QC-SWM01-02.htm.
9. Information Management and Services Unit, 1998. The Philippine Statistical Yearbook. Manila: NSCB Publications.
10. Integrated Solid Waste Management Engineering Principles and Management Issues, 1993. New York: McGraw-Hill.
11. Japan International Cooperation Agency / Metropolitan Manila Development Authority, 1999. The study on Solid Waste Management for Metro Manila in the Republic of the Philippines. Final Report. PCI Kokusai Kogyo Co. Ltd. Metro Manila, Philippines.
12. Klee, A.J., 1980. Quantitative Decision Making, Design & Management for Resource Recovery Series, Volume 3. Ann Arbor Science, Ann Arbor, Michigan.
13. International Environmental Solutions Corporation. URL http://www.wastetopower.com/advanced_pyrolysis_systems.htm
14. Map of Quezon City, Philippines. URL www.quezoncity.gov.ph.
15. National Solid Waste Management Commission Secretariat as of 2nd Quarter 2009.
16. Norconsult A.S. et. al, 1982. Metro Manila Solid Waste Management Study.
17. Payatas Dumpsite Satellite Map. URL http://www.wikimapia.org/#lat= 14.7158459&lon=121.1069083&z=17&l=0&m=b.
18. Philippine Statistical Yearbook 2008. National Statistical Coordination Board.
19. Quezon City Controlled Disposal Facility. URL http://www.cv.titech.ac.jp/~jsps/Payatas%20pdf/1_2Louie_Sabarter%20pdf.pdf.
20. Quezon City Planning and Development Office.
21. Tchobanoglous, G., Theisen, H. and Vigil, S., 1993. Integrated Solid Waste Management Engineering Principles and Management Issues. New York: McGraw-Hill.
22. The Payatas Tragedy. URL http://www.gmanews.tv/story/144132/The-Payatas-tragedy.
23. The Payatas Dumpsite from Tragedy to Triumph. URL www.quezon city.gov.ph.

ACKNOWLEDGMENT

The Project Team deeply appreciates the Quezon City government most especially to Mayor Feliciano R. Belmonte, for granting the conduct of the WACS at Payatas. The support of the Environmental Protection and Waste Management Department and the Payatas Operations Group is exemplary for their presentation of vital historical and operational information on the facility and for their generous help extended during the collection and sorting of the wastes.

The Team greatly appreciates with gratitude the Waste to Energy (Asia Pacific) Pty., Ltd. for commissioning and funding the study especially to Mr. Robert M. Rutherford, Mr. Hamish Doley and Mr. Hermilo F. Echavez.

Credit is generously given to the U.P. Environmental Engineering Graduate Program and UP Engineering Research and Development Foundation, Inc. Innovation and Project Development Program for providing their expertise in the field of SWM.

Acknowledgment is made to all individuals especially to Dr. Leopoldo V. Abis, Mr. Alexander Santos, Engr. Rafael R. Angangco, Ms. Melody Campton and Ms. Gilda Asuncion C. Manegdeg and agencies too numerous to mention for providing useful information, constructive criticism, timely coordination and frequent encouragement and to Engr. Ashley S. Baliong for her efforts in the final revision of this paper.