Research Paper

An Integrated Approach to Solid Waste Management of Karachi
- Waste-to-Energy Option -

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Abstract

Solid Waste Management (SWM) is perhaps one of the most important element constituting the environmental health and sanitation of urban developing sector. The management system has several components which are integrated as well as interdependent thus the efficiency and effectiveness of the entire system is affected when any of its functional component fails or does not perform up to the level mark of operation.

Karachi Municipal Corporation (KMC) is responsible for the management of solid waste of the entire city. There is a need to adopt engineered approach in the redesigning of existing system. In most of the towns street sweeping operations have been mechanised and done by machinery operated by vehicles. Construction of Garbage Transfer Stations (GTS) at number of locations within the city will cut the cost of transportation of waste to disposal sites. Material processing, recovery of recyclables, compaction, volume reduction, and increase in density will enable transportation of waste to disposal sites/landfills via long vehicles (bulk transport), minimizing transport/traffic and environmental pollution related issues. Development of disposal sites into proper sanitary landfill sites is mandatory. The transportation mechanism is through garbage vehicles using either hauled or fixed container system employing crew for mechanical or manual loading. The number of garbage vehicles is inadequate and due to comparatively long haulage to disposal sites there are certain problems of frequent vehicular maintenance and high fuel costs.

Foreign investors have shown interest in enterprising in improvement schemes and proposed for operating Karachi solid waste management system. Waste to Energy option is being considered to provide a practical answer to be adopted to generate power and reduce waste load – a two prong solution for the increasing environmental problem.

The paper presents results and analyse of recent study into waste generation and characterisation probing into waste-to-energy option for Karachi City.

1 INTRODUCTION

The required infrastructure of Karachi Solid Waste Management is almost non-existent. In current scenario storage, collection and transfer & transportation of waste is being carried out in a very old and inefficient manner. Hence the mechanism of waste management and disposal in the city is very not up to any international standard.

In context to invitation to foreign collaboration and interest of international parties in improvement and upgrading of solid waste management of Karachi, Karachi Municipal Corporation (KMC) undertook a study to investigate into prospects of Waste to Energy option for Karachi metropolis. Generally Waste to Energy project has been successful in many cities of developed and as well as developing countries depending upon their waste management system and more on the characteristic composition of waste such as calorific / heat value contents.

The study project was based on carrying out comprehensive waste generation and compositional studies at different levels of i.e. at source (household), community bin, transfer stations and final disposal sites. Also the impact of income level or socioeconomic status on the waste characteristics was also analyzed. The independent group of consultants included representations both from academia and industry were; Sir Syed University of Engineering & Technology, Karachi and NAA Consulting (Pvt) Ltd.

Three (03) representative Towns of Karachi were selected; Saddar, Gulshan and Gulberg Town and the formal landfill site Surjani Town was selected as the disposal site. The informal dumping grounds / Temporary Garbage Transfer Stations (GTS) were Baloch Colony, Gulshan Iqbal and Korangi- Ibrahim Hyderi.

This paper encompasses the overview of SWM current practices and problems of Karachi City, the methodology and approach used for carrying the SWM studies in Karachi from June 20, 2013 to 26th July 2013. The physical analysis include determination of waste composition and segregation of garbage collected from households into different components; recyclable, organic fractions and inert as identified physically by manual sorting. The percentage weight composition was measured weight with bulk density measurements. For chemical analysis, samples were sent to laboratory (SGS Labs) for determination of chemical composition and calorific / heat content value. Solid waste management system in selected towns and project area (High, Medium & Low income level) localities was also observed.

Representative waste samples were collected and analyzed from source to disposal site for physical and chemical analysis results with evaluation & assessment of state of waste are presented in the paper. Waste characterization and investigation studies have been carried out earlier for Karachi metropolitan for prospects and options of deriving waste from energy with an improvement in waste management system through technical and financial assistance from international agencies support. However, these endeavors are yet to be materialized due to lack of institutional arrangements and unanimous collaborative action at local and provincial level amongst the concerned functional departments.

1.1 METHODOLOGY OF WASTE SAMPLING

Out of 18 Towns, 03 representative towns (Saddar, Gulshan and Gulberg) selected for the collection and analyses of samples, however it should be understood that the Waste Composition analysis involves determination of waste characterization at various sources and levels of waste management levels. Hence needs to be carried out accordingly in order to determine the impact on residual components of waste and change occurring in waste stream with the management processes; storage, collection, transfer & transport and at the ultimate point of disposal so that the mechanism and functional components of SWM could be planned, designed and implemented and the cost factor and viability of treatment processes associated such as composting, recovery and recycling of waste could be realistically determined. More importantly to decide the ultimate safe disposal of waste, composition of waste; physical, biological and chemical properties is significant in determining the waste disposal.

Laboratory Analysis

a) Moisture content
b) Organic and inorganic content
c) Nitrogen content
d) Carbon content
e) Calorific Value

2 WASTE GENERATION & COMPOSITIONAL STUDIES CONDUCTED JUNE-JULY, 2013

The section presents the observations made in the field regarding the waste generation characteristics; generation rate, weight composition – recyclables, organics & inert and the calorific / heat content present in waste and the variation in waste composition across the waste stream i.e. at door-to-door (household), collection and transfer; community bin, garbage transfer station and landfill. Also the impact of income level / socioeconomic status on waste generation and waste composition characteristics is highlighted.

2.1 Saddar Town Waste Compositional Studies

The variation in generation and characteristics of waste; describing its recyclables, organic fraction and inert material thereby specifying its heat / calorific value arising from high, medium and low income group residential areas of Saddar Town is shown in the Figure 2.1.

Figure 2.1: MSW Characteristics comparison for Income Level groups (Door to Door Collection) Saddar Town

	Door to door Saddar Town			Community Bin - Saddar Town			GTS AND LANDFILL SITE			
Saddar Town Recyclables	**High Income**	**Low High Income**	**Medium Income**	**High Income**	**Medium Income**	**Low Income**	**GTS Gulshan**	**GTS Korangi**	**GTS Baloch**	**Landfill**
Paper/C.B	14.44	14.81	5.58	4.6	3.79	4.02	1.98	0.53	0.51	2.6
PC	5.71	4.68	8.21	6.37	7.58	7.37	5.16	4.9	5	11.9
PET	2.39	5.32	1.15	0.38	0.45	0.48	0.38	0.55	0.57	0.3
METALS	0.81	0.68	1.25	0	0	0	0	0	0	0
GLASS	3.1	3.05	1.08	0.41	0.98	0	0.53	0.15	0.25	0.2
INERT	0.02	3.35	10.54	8.34	11.61	14.56	17.27	13.17	13.61	6.3
Diapers	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	7.6
Recyclable Value %	**26.35**	**28.53**	**16.19**	**11.76**	**12.8**	**11.87**	**8.06**	**7.67**	**6.32**	**14.95**

Figure 2.2: MSW Characteristics comparison for Income Level groups (Transfer stages) Saddar Town

A considerable reduction is observed in the recyclable contents of waste as shown in the tabulated representation given in Figure 2.2 reflecting the waste contents of different components at Transfer stage. The reduction of recyclables in waste stream from door to door stage to transfer stage is experienced in all income group levels.

	Door to door Saddar Town			Community Bin - Saddar Town			GTS AND LANDFILL SITE			
Saddar Town Calorific Value Products	**High Income**	**Low High Income**	**Medium Income**	**High Income**	**Medium Income**	**Low Income**	**GTS Gulshan**	**GTS Korangi**	**GTS Baloch**	**Landfill**
Paper/C.B	14.44	14.81	5.58	4.6	3.79	4.02	1.98	0.53	0.51	2.6
PC	5.71	4.68	8.21	6.37	7.58	7.37	5.16	4.9	5	11.9
PET	2.39	5.32	1.15	0.38	0.45	0.48	0.38	0.55	0.57	0.3
TEXTILE	1.02	0.87	2.63	1.77	1.36	5.12	5.17	7	6.81	7.5
RUBBER	0.43	0.33	0	0.16	0.56	0.93	0.59	0.6	0.61	0.3
INERT	0.02	3.35	10.54	8.34	11.61	14.56	17.27	13.17	13.61	6.3
Diapers	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	7.6
Calorific Value %	**23.27**	**26.01**	**13.24**	**8.68**	**13.74**	**17.93**	**13.82**	**13.57**	**13.49**	**30.22**

Figure 2.3: Comparison of Calorific / Heat value of MSW across Waste Stream for Income Level groups in Saddar Town

Saddar Town - High income group (Door-to-Door Collection) is the Clifton area (UC 10 and UC 11) comprises of Bungalows of 500 to 2000 square yards. The rate of generation of waste is estimated to be 0.73 kg/person/day. Usually every household have 02 bins (01 in kitchen and 01 in open area) the

recyclable material consists of; paper, cardboard, plastic bags, PET, glass and metals), Calorific content items include; paper, cardboard, plastic bags, PET, textile, rubber and leather, *diapers were not initially included in the analysis (sampling and compositional analysis) at Household waste level*, Organic Fraction; mostly food remnants, kitchen waste, little yard waste. Yard waste is mainly collected on Monday; the diapers are included with inert material.

- Referring to Figure 2.2, the percentage of organic component is comparatively greater in High income area presumably due to open and vegetative area associated with the premises (gardens yielding yard/green) waste in addition to the normal content of organic waste. The recyclable material is high due to the use of packaging material (Plastic, Paper/cardboard, glass bottles etc).

Saddar Town - Medium Income group (Door-to-Door Collection) is representing High Medium Income and Low Medium Income Level groups as the demographic feature is almost same dwelling in apartments having similar socioeconomic stature. The area (UC 1 and UC 09) comprises of all residential apartments (02 beds to 06 bed size apartments). The rate of generation of waste is estimated to be 0.38 kg/person/day. The rate of generation of waste is low in comparison to High income group likely due to small area of occupancy or size of household and relatively less posh living standard. Households mostly use 01 bin or 01 plastic bag for the storage of all types of waste.

The percentage of organic fractions is comparatively high obtained during the door to door collection waste compositional studies. Diapers content weight is high however it is not included in waste composition and is remains in inert material at door to door collection analysis. The Figure 2.2 signifies that amongst recyclable materials paper/cardboard fraction is reduced almost to half in comparison to high income group which significantly affects calorific value of the waste. This also indicates that there is a high tendency of waste segregation and recovery being practiced at household level / door to door collection level.

It is further reflected from the waste analysis arising from the medium income level group that packaging material waste content is reduced to almost half in comparison to high income group featured by regular home-cooking yielding high organic fractions in waste stream.

Saddar Town - Low High Income group (Door-to-Door Collection) is identified in the Clifton area of UC 10 and UC 11 consisting of residential apartments (02 beds to 06 bed sized apartments). The rate of generation of waste is estimated around 0.45 kg/capita/day.

- The rate of generation of waste is comparatively lower than High income group; the percentage of organic material is comparatively is also on lower side in the category primarily due to devoid of open spaces in dwelling units such as; gardens, yards, etc. During the door to door waste compositional analysis, the diaper contents are segregated from the household recyclable and organic fractions and

included in inert material. It is further established during the social survey that the infant population is low in comparison to High Medium and Low Medium Income groups which produces significant quantities of the specific waste. The Calorific / Heat value reflected in Figure 2.3 is mainly due to paper/cardboard, plastic bags, PET, textile & rubber / leather. It is evident from the figure that the recyclable material, specifically PET fraction is doubled in comparison to quantities generated in high income groups imparting higher recyclable and calorific / heat values than high income group. The household mostly uses 01 bin for the storage of all types of waste. The life style and cooking habits reflects the change in recyclable material (food packaging) which is higher and organic fraction is low in comparison to High income group.

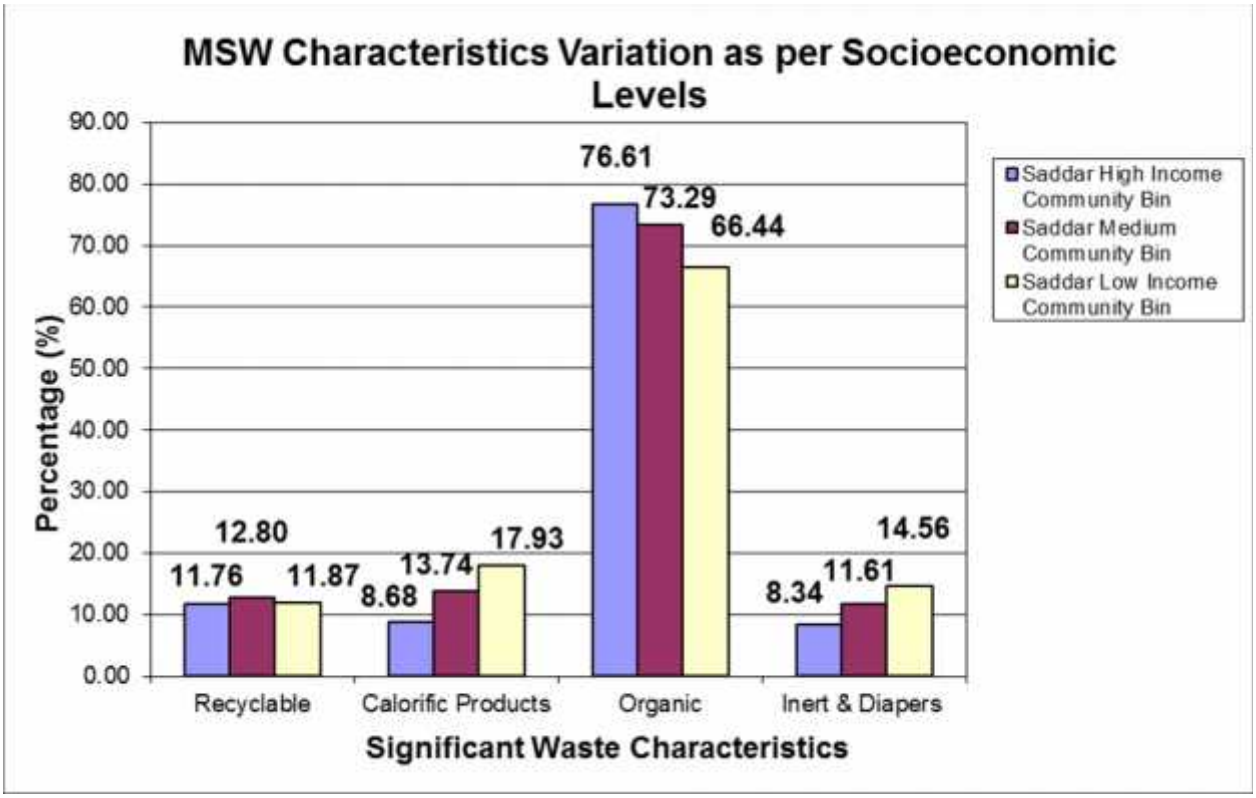

Figure 2.4: MSW Characteristics comparison in Income level groups (Community Bin) Saddar Town

Saddar Town - High Income group (Community Bin) are identified in Clifton area to be around 20 designated points where garbage is dumped indiscriminately, collected and transported. Only 20% of the total collection bins provided at these sites are demountable / hauled bins whereas remaining are open / fixed or yards along the road side.

Recyclables

- The comparison of recyclables in MSW waste arising from different categories of socio-economic level given in Figure 2.4 showing trend of collection from household to the community bins for high

income group suggests that the quantity of recyclable material is reduced significantly almost over 50%. The prime reason is engagement of informal staff which collects waste from door to door and sorts the recyclable material after collection and before discharging into the community bins. The second round of segregation and recovery is carried out by street scavengers that remove the leftover recyclables for sale in the informal market. The informal removal of recyclable at community bin or street level however does not remove the tetra pack waste and plastic bags which has no current recycling market (nearly 5%). The inert material increases from (3.02% to 8.54%) because of the two reasons additional loading of diapers (being considered in the inert category) and mixing of dirt material due to indiscriminate dumping of waste onto the un-metal ground.

Calorific Value Item

- There is not much significant increase in the heat content of waste observed owing to the recyclable contents of the waste.

Organic Waste Fraction

- From source the organic waste fraction increases from (68% to 76%), the reason is the recyclable and calorific value products decrease to almost 15% which has an overall impact on the increase in organic fraction. The organic fraction at the communal bin of high income area generally has 10% of yard waste.

Saddar Town - Medium Income group (Community Bin Transfer), there are 02-03 large size cement-concrete community bin designated per Union Council where the waste from nearby dwelling units is regularly dumped. Medium income group largely comprised of residential apartments rising from 04 to 07 floors high. Each apartment has privately hired sanitary staff which collect waste from door to door, sort, segregate and recover the recyclable at specific place within or outside the apartment / residential complex prior to disposal and transfer / transport using wheel barrows, hand driven carts to discharge the waste into the nearby community bins. The secondary sorting is carried out at the community bins where the scavengers collect and transfer the recyclables for transport to local recycling vendors on daily basis.

Organic Waste Fraction

The percentile value of organic waste at the source compared to the community bins in case of Saddar Town Medium income group is more or less the same.

Saddar Town - Low income group (Community Bin Transfer), has number of low income areas associated with Saddar Town such as; Dehli Colony, PNT Colony, Sheeren Jinnah Colony and others. Survey team in consultation with the administration of South Zone – DMC selected Sheeren Jinnah

Colony as representative locality for low income group category having a mix of 40-90 square yard residential units and generally the people residing in area are low bread earner.

The community bins in the area are low walled, open structure allowing indiscriminate dumping along the roadside. It is observed that due to lack of operational funds DMC-South fails to maintain the vehicular fleet, hence the lifting from low income residential areas is mostly neglected and due priority is given to high income, medium income areas. It was further observed during waste compositional studies that due to the reduction in the collection efficiency of waste lifting, the waste mounds are found in various spots cumulating garbage for up to few weeks which has deteriorated the aesthetics as well as affected the contents of waste.

Recyclables

- The change in recyclable contents for the socioeconomic variation as highlighted by the comparison of the graphs shown in Figure 2.4 and 2.2 obtained for the community bin transfer stage is significant. It is reported that at the community bin the composition of paper/cardboard material remains at 4% containing mainly tetra pack, plastic around 8% with no metal and glass. Inert material is high containing diapers around 14% and dirt. It is also observed that the plastic bags content is in the low income community bin is highest in comparison to the medium and high income residential area.

Calorific value Items

- The percentage of calorific value items is found to increase and exceed the recyclable content due to increase in textile fraction which is observed to be 5.12% at the community bin, plastic is 7.37% and the overall heat / calorific value item content of waste reaches almost 18%.

Organic Waste Fraction

- More than two-third of waste content is found to be organic in nature i.e. comprising of food, kitchen, vegetable / fruit and grass / leaves and degradable waste.

2.2 Gulshan Town Waste Compositional Studies Results

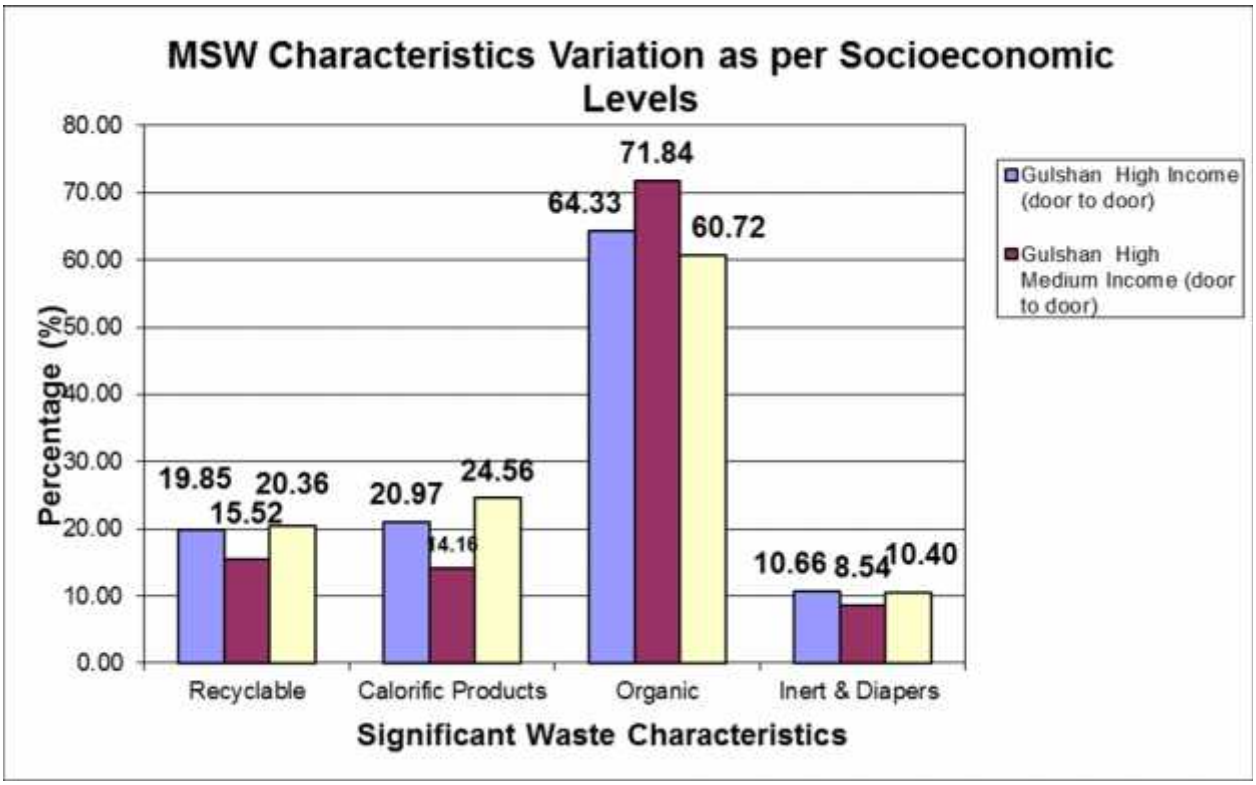

Figure 2.5: MSW Characteristics comparison in Income level groups (Door to Door Collection) Gulshan Town

	Door to door Gulshan Town			Community Bin - Gulshan Town			GTS AND LANDFILL SITE			
Gulshan Town Recyclables	**High Income**	**High Medium Income**	**Low Medium Income**	**High Income**	**Medium Income**	**Low Income**	**GTS Gulshan**	**GTS Korangi**	**GTS Baloch**	**Landfill**
Paper/C.B	11.01	8.07	6.5	4.54	2.47	2.53	1.98	0.53	0.51	2.6
PC	3.84	3.99	7.29	6.32	8.41	8.43	5.16	4.9	5	11.9
PET	2.58	1.58	4.95	0.35	0.49	0.48	0.38	0.55	0.57	0.3
METALS	0.24	0.33	0.16	0	0	0	0	0	0	0
GLASS	2.19	1.56	1.45	0	0	0	0.53	0.15	0.25	0.2
INERT	10.66	8.54	10.4	18.56	18.68	19.56	17.27	13.17	13.61	6.3
Diapers	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	7.6
Recyclable Value	**19.80%**	**15.52%**	**20.36**	**11.21%**	**11.37%**	**11.44%**	**8.06**	**7.67**	**6.32**	**14.95**

Figure 2.6 : MSW Characteristics recyclable variations observed for Income Levels & Transfer stages in Gulshan Town

	Door to door Gulshan Town			Community Bin - Gulshan Town			GTS AND LANDFILL SITE			
Gulshan Town Calorific Value Products	**High Income**	**High Medium Income**	**Low Medium Income**	**High Income**	**Medium Income**	**Low Income**	**GTS Gulshan**	**GTS Korangi**	**GTS Baloch**	**Landfill**
Paper/C.B	11.01	8.07	6.5	4.54	2.47	2.53	1.98	0.53	0.51	2.6
PC	3.84	3.99	7.29	6.32	8.41	8.43	5.16	4.9	5	11.9
PET	2.58	1.58	4.95	0.35	0.49	0.48	0.38	0.55	0.57	0.3
TEXTILE	3.54	0.41	5.56	1.79	4.57	3.85	5.17	7	6.81	7.5
RUBBER	0	0.11	0.26	0.24	0.16	0.2	0.59	0.6	0.61	0.3
INERT	10.66	8.54	10.4	18.56	18.68	19.56	17.27	13.17	13.61	6.3
Diapers	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	7.6
Calorific Value %	**20.97**	**14.16%**	**24.56%**	**13.24%**	**16.10%**	**15.49%**	**13.82**	**13.57**	**13.49**	**30.22**

Figure 2.7 : Variation in Calorific/Heat values of MSW observed at different Transfer Levels in Gulshan Town

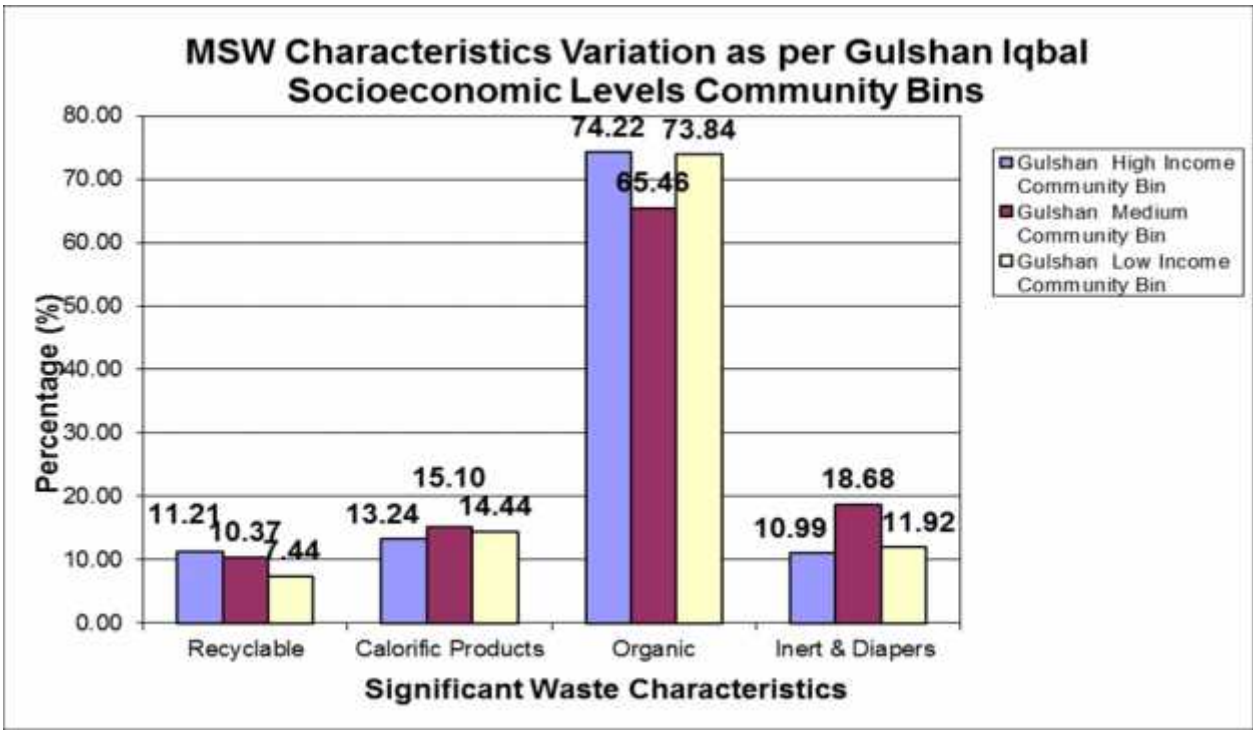

Figure 2.8: MSW Characteristics Variation observed in Income level groups (Community Bin) Gulshan Town

2.3 Gulberg Town Waste Compositional Studies Results

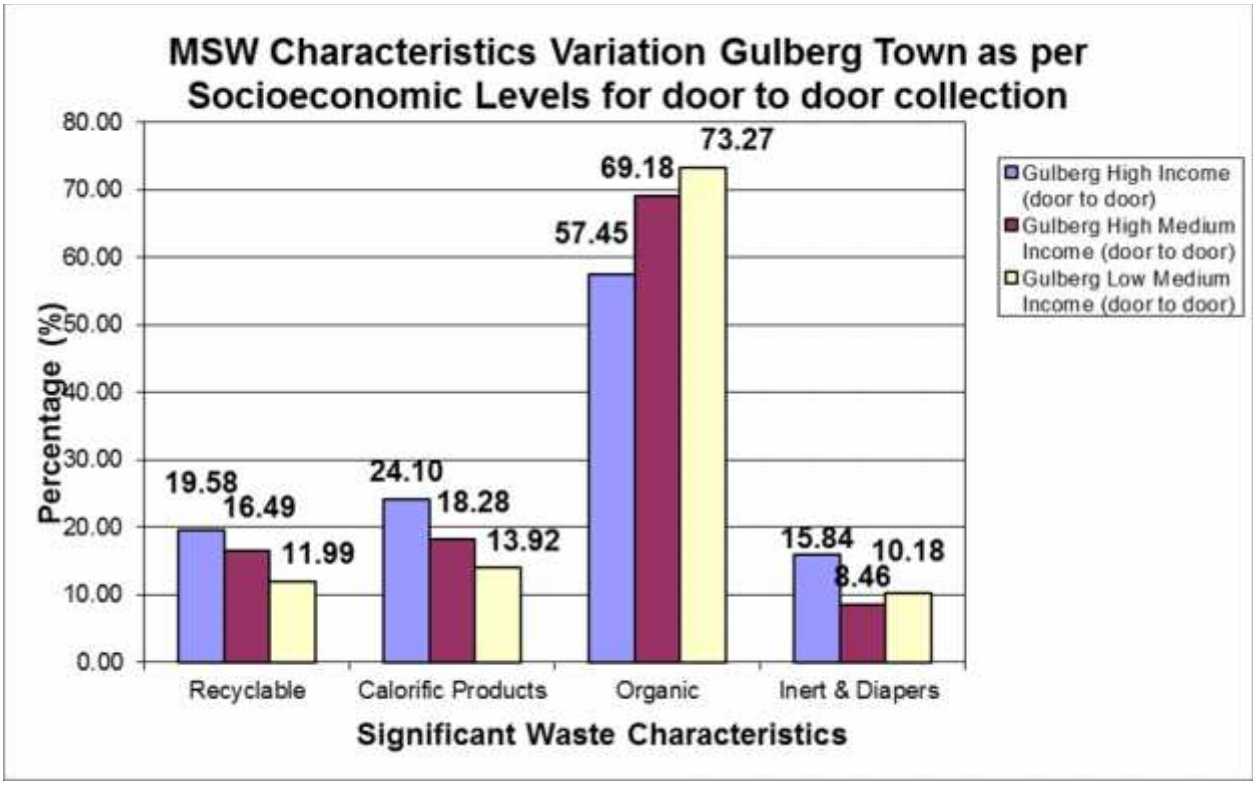

Figure 2.9: MSW Characteristics Variation in Income level groups (Door to Door Collection) Gulberg Town

	Door to door Gulberg Town			Community Bin - Gulberg Town			GTS AND LANDFILL SITE			
GulbergTown Recyclables	**High Income**	**High Medium Income**	**Low Medium Income**	**High Income**	**Medium Income**	**Low Income**	**GTS Gulshan**	**GTS Korangi**	**GTS Baloch**	**Landfill**
Paper/C.B	9.38	6.81	2.76	2.34	1.32	1.6	1.98	0.53	0.51	2.6
PC	6.78	5.83	5.03	6.02	6.51	5	5.16	4.9	5	11.9
PET	2.28	2.33	2.28	0.33	0.49	0.5	0.38	0.55	0.57	0.3
METALS	0.49	0.42	0.29	0.07	0	0.11	0	0	0	0
GLASS	0.65	1.1	1.62	0	0	0.83	0.53	0.15	0.25	0.2
INERT	15.84	8.49	10.18	24.78	18.17	22.72	17.27	13.17	13.61	6.3
Diapers	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	7.6
Recyclable Value	**25.24%**	**16.49%**	**11.99%**	**8.75%**	**8.32**	**12.73**	**8.06**	**7.67**	**6.32**	**14.95**

Figure 2.10 : MSW Characteristics variations observed for Income Levels & Transfer stages in Gublerg Town

	Door to door Gulberg Town			Community Bin - Gulberg Town			GTS AND LANDFILL SITE			
Gulberg Town Calorific Value Products	**High Income**	**High Medium Incom**	**Low Medium Incomw**	**High Income**	**Medium Income**	**Low Income**	**GTS Gulshan**	**GTS Korangi**	**GTS Baloch**	**Landfill**
Paper/C.B	9.38	6.81	2.76	2.34	6.81	1.6	1.98	0.53	0.51	2.6
PC	6.78	5.83	5.03	6.02	5.83	5	5.16	4.9	5	11.9
PET	2.28	2.33	2.28	0.33	2.33	0.5	0.38	0.55	0.57	0.3
TEXTILE	3.49	2.98	2.63	3.4	4.59	4.68	5.17	7	6.81	7.5
RUBBER	2.17	0.32	1.21	0.66	0	0.66	0.59	0.6	0.61	0.3
INERT	15.84	8.46	10.18	24.78	18.17	22.72	17.27	13.17	13.61	6.3
Diapers	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	with inert	7.6
Calorific Value %	**19.58%**	**18.28%**	**13.92%**	**12.75%**	**11.59%**	**12.44%**	**13.82**	**13.57**	**13.49**	**30.22**

Figure 2.11: Variation in Calorific/Heat values of MSW observed at different Transfer Levels in Gulberg Town

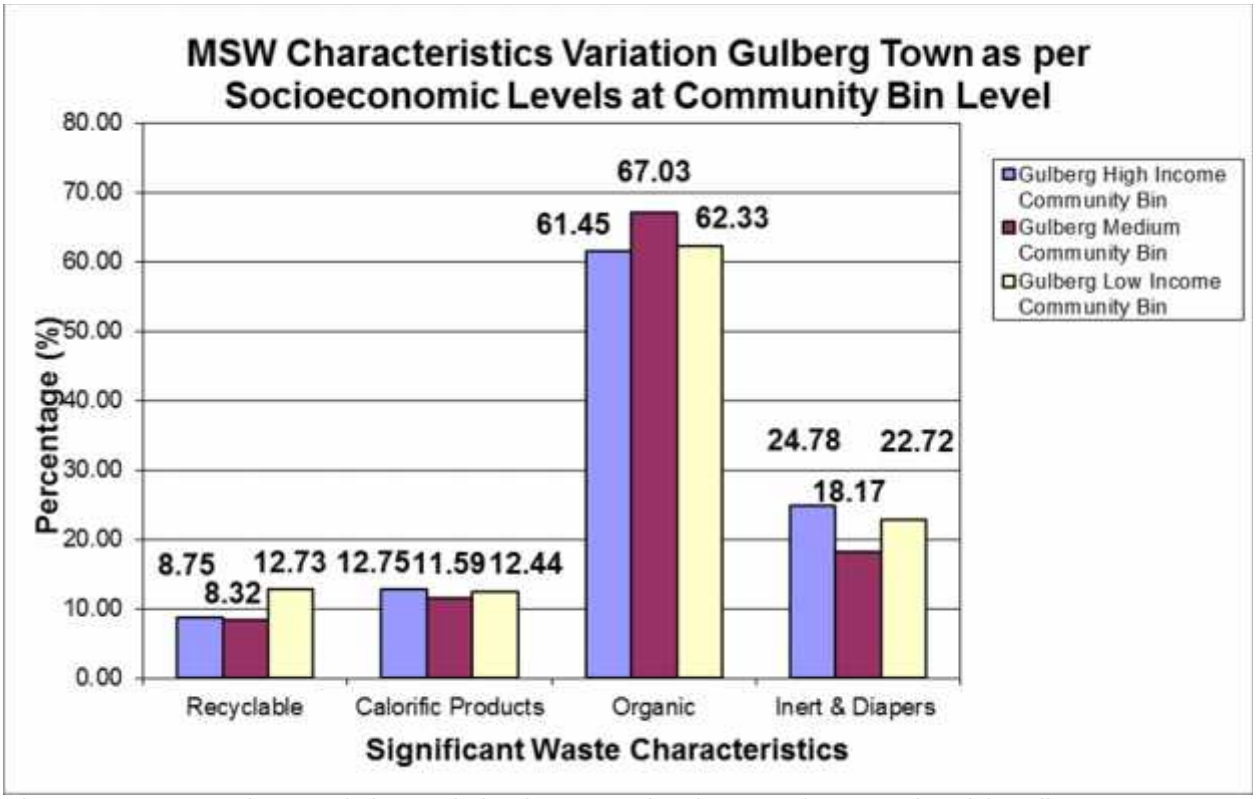

Figure 2.12: MSW Characteristics Variation in Income level groups (Community Bin) Gulberg Town

2.4 Garbage Transfer Stations Waste Compositional Results

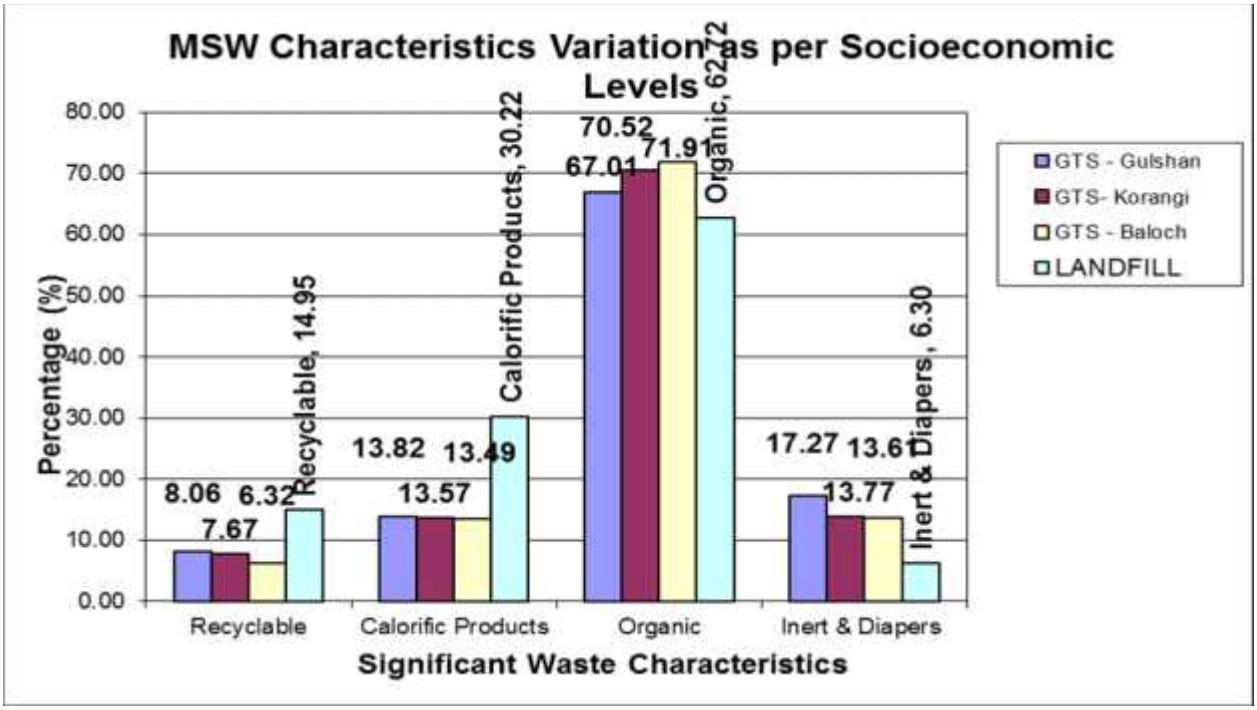

Figure 1.13 : Comparison of Variation in MSW Characteristics at Garbage Transfer Stations (GTS) and Landfill

Garbage Transfer Stations

There is no specifically designed and constructed nor formally recognized Garbage Transfer Stations (GTS) established in Karachi metropolis. However DMCs and Towns have selectively adopted or designated temporary stations for centralized discharge and onward transfer and bulk transport of waste to final burial grounds and dumpsite. It is observed during the study project that are 03 actively functioning GTS which are receiving waste in sufficient quantities on daily basis. It is further noted that their service / coverage area was considerable large to yield good representative sampling of waste for the study and analytical purpose. The transfer and transport of waste to disposal sites is made in two ways; either through GTS or directly through collection from the community bins depending upon the localities and their distances from the disposal site – Surjani Landfill. The GTS is currently servicing 30% load capacity of the collected waste i.e. transferring this volume of waste to Surjani Landfill while the rest 70% goes directly through directly collection & transfer method to the designated landfill.

GTS Gulshan Iqbal

It is a temporary waste handling and storage facility situated close to the Lyari River bed in UC No. 05 jurisdiction of Gulshan Iqbal. The same site is being used by almost 40% of Gulshan Town area for storing its waste as temporary grounds and is also served by Baloch Colony GTS which serves nearby few areas bins which are lifted and directly transported to the landfill site. The waste is lifted within a day with the help of large garbage lift tripper trucks which are filled by front end loader. The entire setup is not

neither well-planned nor a designed, constructed face. All activity is being carried out on an uneven and earthen ground the dirt and other inert material mixes with the waste and deteriorates its quality. At GTS site, waste lying over 24 hours is at the mercy of scavengers who are free to sort / segregate and recover/remove almost all the recyclable material available in the waste dump. The comparison of the Gulshan Town waste characteristics at the community bin and at the Gulshan Town GTS significantly shows the difference.

- **Recyclable from High Income Community Bin to GTS Gulshan Level (8.75% to 8.06%)**
- **Calorific Value Items from High Income Community Bin to GTS Gulshan increased from (12.15% to 13.82%) which does not include the % of diapers which is mixed and taken with inert material**
- **Organic Waste composition has been changed from 61.45% to 67.02%**

While taking the field observations, waste samples from all income groups; low, medium and high income categories were collectively discharged at the temporary facility and composite samples. In total, 12 samples were prepared gathered over a period of 12 days, on continuous basis. The sample size approximately 1% by weight of the total was drawn. The samples which were collected from the very moment after discharged by vehicles at GTS were observed to have rich recyclable and calorific value contents but after a day (24 hours) of retention the composition of waste deteriorated due to scavenging activity at the GTS site. The observed change in the percentage weight contents of the items are given below.

Recyclables

- The recyclable content in municipal waste arising from high income communal bin level is reduced to the GTS level as a change is observed from 8.75% to 8.06%. The marked or notable change is in the paper/cardboard material which reduces from (4.60% to 2.0%). The main reason informal sector is active in scavenging in transfer stage from community bin to GTS hence the waste composition is likely to vary and recyclable content is to reduce considerably. Inert material increases from (8.34% to 17.34%) is likely due to two reasons; additional loading of diapers and mixing of dirt material due to indiscriminate dumping of waste onto the un-metal ground. The main reason of dropping down of recyclable material item wise is the excessive sorting practices at GTS.

Calorific Value Items

- A certain rise in the percentage of calorific value items is observed from high income group Gulshan Town community bin in comparison to that at the Gulshan temporary GTS. It is noted that the recyclables has increased from 12.15% to 13.82%, owing to increase in inclusion of textile content

from 1.77% to 5.17%. Inert material increases from (8.54% to 17.24%) again likely due to either additional loading of diapers which have not been included in other waste contents and mixing of inert material due to indiscriminate dumping of waste onto the un-metal ground.

Organic Material

- Organic Waste composition has changed from 61.45% to 67.02%. The contents and the quality have changed with mixing of dirt and small plastic waste is observed. Such quality of waste is not useful and difficult to manage for the composting and gains weight for handling and transportation.

Waste Generation Rates

It is estimated that in Saddar Town the waste generation rate is (0.38 to 0.73 kg/capita/day) for low to high income category. Gulshan Town the waste generation rate is (0.53 to 0.953 kg/capita/day) low to high income category. Gulberg Town the waste generation rate is (0.37 to 0.70 kg/capita/day) low to high income category.

2.5 Landfill Site Waste Compositional Results

General Conditions Landfill Site

At the dumping site the waste characterization / compositional studies at only 01 designated site selected as the Surjani Landfill Site for a prescribed 12 days continuous period.

During the sampling period it was observed that on an average about 2500 tons/day of waste is being hauled from various Towns of Karachi to the designated site. The main towns which are transporting and discharging their waste at Surjani Landfill site are; Gulshan, Gulberg, Saddar, Nazimabad, North Nazimabad, Shah Faisal, Jamshed, North Karachi and Liaquatabad, and the cantonment areas are; Cantonment Board Clifton / DHA, Cantonment Board Faisal, other areas.

At the landfill site it was observed that vehicles having different configurations, types and capacities are arriving with waste loads having small to large waste (weight/volume) load capacities (2.5 to 32 tons). The second variation observed is the change in waste composition arising from various locations representing different stages / levels of collection of waste management in Karachi being hauled to Landfill Site.

Table 2-1 reviews the different levels of collection, transfer and transportation of waste at various stages of waste management in Karachi.

Table 2-1: Mechanism of Waste Collection and Transportation from Various Municipal Areas of Karachi culminating at Surjani Landfill Site

Towns	**Waste Collection and Transportation mechanism to the landfill site**	**Assessment**
Gulberg Town and 30% part of Gulshan Town	Scavengers involved at door to door collection brings the leftover waste to the demountable / roll arm containers / community bins after sorting which is being collected mechanically by garbage vehicles transported directly to the landfill site	The waste reaching the landfill site from Gulberg Town undergoes two-stage sorting; 1st stage occurs at door to door collection by informal collection services and 2nd stage sorting during the transferring / filling of waste from informal waste-picking carts to the community bins / roll arm containers. It is observed at the landfill site that the quality of waste is intact and has gathered not much of the dirt material enabling further processing.
Saddar	High income group of Saddar Town UC No.10 & 11 of Clifton residential area generates high quantities and contents of waste however the waste is not transported to the Surjani Landfill site. The waste arising from medium / low income group is hauled to the Surjani Landfill site.	In the middle and low income area of Saddar Town the private sanitary staff collects waste using the wheel barrows and transports the same to the larger waste collection points / community bins made of cement concrete structure. The two-stage sorting of waste took place at the source and at the bin. The waste from the community bins are removed by tripper trucks using the front end loaders and hauled to the landfill site. The quality of waste reaching landfill site form collection points is good enough to be used for further processing where cement concrete bins are intact and surface is lined.
Shahfaisal Town, 40% of Gulshan Town, Jamshed Town using the Temporary Garbage Transfer Station	The towns management are transferring and hauling waste to the Surjani Landfill via temporary garbage transfer station which is almost 30% of the total collection in the jurisdiction.	The waste hauled from GTS to the landfill site is perhaps the most contaminated with dirt and of low recyclable contents. It is due to the reason that it undergoes a repeated cycle of sorting, segregation and recovery exercise, at source, at the community bin at the temporary GTS..
Nazimabad, North Nazimabad, Liaquatabad & other areas (unspecified)	An ordinary type of collection system exists in these areas and waste is generally discharged at the community bin from source after door to door collection or voluntary drop by residents at the communal bin. Waste is lifted from the community bin by front end loader and hauled to the landfill site in tripper trucks.	Tripper trucks directly discharge the waste at landfill site. The waste arising from these areas have already undergone two-stage recovery.
DHA, Cantonment Board Clifton, Faisal and similar agencies	Such areas have been outsourced to private operators for the collection of waste from source by the cantonment agencies. The private operators deploy small tripper trucks and small compactors trucks with crew which collects waste from door to door, sort the waste and transports the disposable load to the landfill site.	This type of operations involves one-stage sorting that takes place at the time of door to door collection by private operator's staff, the quality of waste reaches to the landfill site is very fresh and good and has good potential for further processing. Also to certain extent the recyclable contents are higher than the other areas and the calorific value is also good due to one-stage sorting, secondly the waste characteristics are also good owing to its origin being from very high income group category.

Table 1-2: Physical Analytical Results of Landfill

Sample Number	Waste Source	Dated	Total Quanitity (Kg)	Total % of Organic Waste	Total %age of Recyclable (Paper, CB, Plastic, PET, Metals and Glass)	Total % of Waste with High Calorific Value (Plastic/PET, Rubber, Textile & Diapers)	Inert
Sample 01(a) by weight	Vehicle 01-Mix waste from Liquatabad No 09, Vehicle 02-UC # 09, Vehicle 03-Gulberg GTS, Vehicle 04-Gulshan Iqbal UC -11, Liaquatabad-Saadatullah, Golimar Bara Market, Petal Padha	13-Jul-13	**954**				
by percentages (%)			%ages	**71.87**	**12.28**	**23.42**	**4.72**
Sample 02 (a) by weight		14-Jul-13	**1006**				
by percentages (%)			%ages	**58.81**	**15.02**	**35.43**	**5.77**
Sample 3(a) by weight	Vehicle 01-Nazimabad, Vehicle 02- Vehicle 03-Gulshan Iqbal and Vehicle 04- Gulberg GTS	15-Jul-13	**1030**				
by percentages (%)			%ages	**67.06**	**12.71**	**26.87**	**6.02**
Sample 3(b) by weight		15-Jul-13	**1007**				
by percentages (%)			%ages	**68.50**	**12.94**	**25.84**	**5.66**
Sample 4(a)	Vehicle 01- Nazimabad Block B (Board Office, Vehicle 02- Liquatabad UC#02, Vehicle 03-Gulshan Gulistane Jauher Cantonment Area, Vehicle 04-Gulberg GTS	16-Jul-13	**1006**				
by percentages (%)			%ages	**64.66**	**14.36**	**28.48**	**6.86**
Sample 4(b)		16-Jul-13	**1069**				
by percentages (%)			%ages	**61.47**	**13.14**	**30.95**	**7.30**
Sample 5(a)	Vehicle 01- Gulshan Iqbal UC05 GTS, Vehiclle 02-CBF- Model Colony Katchra Kundi	17-Jul-13	**1255**				
by percentages (%)			%ages	**62.98**	**14.08**	**29.85**	**7.09**
		17-Jul-13	**1259**				
			%ages	**66.76**	**12.63**	**25.66**	**7.39**
Sample 6(a)	Vehicle 01- New Karachi, Vehicle 02- CBF-Jauhar, Vehicle 03 N.Nazimabad	18-Jul-13	**1256**				
by percentages (%)			%ages	**63.60**	**13.87**	**29.67**	**6.69**
Sample 6(B)			**157**				
by percentages (%)			%ages	**62.42**	**8.66**	**32.48**	**5.10**
Sample 7(a)	Vehicle 01- Gulshan e Jamal CBF, Vehicle 02-CBF Shahrahe-Faisal	20-Jul-13	**1259**				
by percentages (%)			%ages	**62.74**	**15.79**	**30.37**	**6.51**
Sample 7(B)	Vehicle 01- Nazimabad UC#09, Vehicle 02- GTS Gulberg Town	20-Jul-13	**1252**				
by percentages (%)			%ages	**60.22**	**16.47**	**31.74**	**7.83**
Sample 8(a)	Vehicle 01- Gulberg Town, Vehicle 02- Saddar Cant Station	22-Jul-13	**1261**				
by percentages (%)			%ages	**60.22**	**18.99**	**33.55**	**6.03**
Sample 8(B)			**1256**				
by percentages (%)			%ages	**65.39**	**15.29**	**28.91**	**5.49**
Sample 9(a)	Vehicle 01- Liaquatabad UC 01, Vehicle 02- Saddar Cant Station, Vehicle 03- North Nazimabad 2K Stop and Vehicle 04- New Karachi UP Modh	23-Jul-13	**1275**				
by percentages (%)			%ages	**62.95**	**17.42**	**31.00**	**5.73**
Sample 9(b)			**1253**				
by percentages (%)			%ages	**68.97**	**13.15**	**24.64**	**6.23**
Sample 10 (a)	Vehicle 01- Saddar Town Bath Island, Vehicle 02-Liaquatabad UC#09, Vehicle 03- North Karachi UC # 11 & 08	24-Jul-13	**1000**				
by percentages (%)			%ages	**62.76**	**16.71**	**30.04**	**5.70**
Sample 10 (b)			**1004**				
by percentages (%)			%ages	**62.90**	**14.23**	**29.23**	**7.77**
Sample 11 (a)	Vehicle 01- Saddar Town Eid Gah UC#06, Vehicle 02-Gulberg Town UC#08, Vehicle 03- Liaquatabad UC#02	25-Jul-13	**1007**				
by percentages (%)			%ages	**63.40**	**15.90**	**30.64**	**5.86**
Sample 11(b)			**1011**				
by percentages (%)			%ages	**57.93**	**18.76**	**35.59**	**6.33**
Sample 12 (a)	Vehicle 01- Saddar Town Bath Island, Vehicle 02-North Karachi, Vehicle 03-UP Modh, Vehicle 04- 5M	26-Jul-13	**1015**				
by percentages (%)			%ages	**59.86**	**18.39**	**33.78**	**6.31**
Sample 12 (b)			**1022**				
by percentages (%)			%ages	**56.95**	**18.04**	**36.74**	**6.26**
AVERAGE VALUES ITEMS WISE			**23.6**	**63.29**	**14.95**	**30.22**	**6.30**
				Organic %	**Recyclables %**	**Calorific Items %**	**Inert %**

Waste Compositional study at the Landfill site:
The study conducted at the GTS and the subsequent analysis carried out concluded that owing to the prevailing practices of collection, transfer and transport from community bins to GTS and to landfill site with the waste repeatedly undergoing sorting and recovery of recyclable items the change in composition is significant. It is estimated that the waste composition can change up to 30% (cumulative of all percentage weight contents) in terms of its recyclable contents which have undergone 3-cycles or stages of sorting and recovery affecting the composition turning up at landfill significantly particularly in context to its calorific or heat value contents.

However practicing a different management system in which door to door collection just allowing one-stage sorting & recovery of recyclables can produce a rich content recyclable as well as organic fraction for both composting and waste to energy options prior to ultimate disposal of waste (landfill). This has been experienced in cantonment areas of Karachi and is working successfully.

The sample for determining the physical waste composition as well as for chemical analysis, a representative sampling of waste material arising at landfill site from various locations of Karachi having different levels of transfer and sorting & recovery stages was rather a difficult task but was carefully and intelligently handled by obtaining a proper mix, blending the different wastes into representative and appropriate scaled proportions so as to ensure that waste samples prepared are true representative having the components in a proportions as being dumped at the landfill site. Keeping all the constraints and requirements, 22 samples were prepared for the waste compositional study at the landfill site programmed to identify garbage vehicles for tapping waste selectively. Out of 22 samples, 06 samples were blended with the GTS waste to ensure that waste arising from GTS should also be contributed in the sampling regime. Hence directly and indirectly hauled waste composition scenarios both were included in the sampling for compositional analysis.

WASTE COMPOSITIONAL ANALYSIS AT LANDFILL SITE

Recyclables

Table 2-3: Recyclable Items weight percent – Waste Compositional Studies at Landfill Site

Recyclable Item	Saddar Town High Income Door to Door (%)	Saddar Town High Income Community Bin (%)	Temporary storage at GTS (%)	Surjani Site Landfill Site (%)	Comments
Paper/Cardboard	14.42	4.60	0.51	2.60	
Plastic Bags	5.71	6.37	5.0	11.90	
PET	2.39	0.38	0.57	0.30	
Metals	0.81	0	0	0	
Glass	3.10	0.41	0.25	0.20	
Percent Recyclable contents	26.35	11.76	6.32	14.95	Increase in quantity and no. of plastic bags,

It is observed that variation in the recyclable content of waste is gradually decreasing from across the transfer stages as the waste progress towards the disposal site from its source. However an increase in the content is observed at the disposal site which is understandably due to the gathering of unwanted plastic bags and other contaminated plastic waste that is added to it as a residual.

Calorific Value Items

Table 2-4: Calorific value Items weight percent – Waste Compositional Studies at Landfill Site

Calorific Value Item	Saddar Town High Income Door to Door (%)	Saddar Town High Income Community Bin (%)	Temporary storage at GTS (%)	Surjani Site Landfill Site (%)	Comments
Paper/Cardboard	14.42	4.60	0.51	2.60	
Plastic Bags	5.71	6.37	5.0	11.90	
PET	2.39	0.38	0.57	0.30	
Textile	1.02	1.77	6.81	7.50	
Rubber	0.43	0.16	0.61	0.30	
Diapers	Included in inert material	Included in inert material	Included in inert material	7.6	
Inert	3.02	8.34	13.61	6.30	
Percent Calorific Value contents	23.27	8.68	13.49	30.22	Increase of plastic bags, textile and diapers from source to disposal site

It is noted that calorific value items correspondingly decreases with the recyclable content however diapers / nappies which are not initially accounted in the weight measures and kept segregated during the waste compositional studies remained included in as inert material would substantially add to the heat / calorific value content of waste ultimately arising at the landfill. The quantitative assessment shows that almost 8% of waste is added to the landfill waste as specific disposal diapers waste which is a material of high heat content. The other components imparting significant calorific / heat content to the waste arising at landfill is 12% of plastic bags and 7.5% of textile waste.

Organic Materials

The landfill site is receiving almost 2/3rd of MSW collected as organic waste content which can be further divided into two streams. Stream one constitutes of fresh organic waste; remains of vegetables and fruits which accounts up to 17% is rich in organic content that can be subsequently processed or directly used as fodder for cattle. Such quality organic waste is obtained when it is transferred and transported without contamination within a day to the disposal site. It is further estimated that almost 50% of that is fairly digestible material however due to contamination with plastics and paper its quality gets deteriorated despite that the organic fraction available at the landfill site is substantially significant.

2.6 Chemical Analysis Results of Waste from Generation Source to Landfill Site

Services of one of the most reputable and reliable analytical laboratory services were hired to undertake the sampling and analyses of the waste chemical composition and heat / calorific content estimation. Samples were collected as per defined methodology and sampling regime and transferred / transferred to the laboratory premises. Table 2.5 summarizes the results and the calorific / heat values are independently shown in Figure 2.14 and 2.15 specifying the stages of collection and transfers across the waste stream. It is to be noted that the waste samples analyzed do not have diapers included i.e. values are to be adjusted on higher side / increased considering the quantum of diapers if as included at landfill site by 8% by weight content.

Table 2-6: Summary of Chemical Analysis Results by SGS Laboratory see appendix C

Sample No.	Waste Collected From	Total Moisture (%)	Gross Calorific Values (K.cal/kg)	Organic Carbon Total (TOC) %	Carbon (%)	Hydrogen (%)	Nitrogen (%)
Sample No. 1	Door to Door Clifton Block 7 Saddar Town	94.08	3644	Not Tested	37.21	5.28	1.331
Sample No. 2	Fresh Dischaged at Gulshan GTS	61.65	4056	Not Tested	38.17	5.25	1.456
Sample No. 3	Fresh Dischaged at Gulshan GTS	60.44	4274	Not Tested	41.15	6.09	1.437
Sample No. 4	Door to Door medium income Block 16 F.B Area	91.13	Not Tested	35.78	42.88	6.12	1.444
Sample No. 5	Door to Door High income Block 6 , F.B Area	90.74	Not Tested	40.77	45.1	6.26	1.397
Sample No. 6	Sample from Baloch GTS	61.39	3566	Not Tested	35.72	4.86	1.339
Sample No. 7	Door to Door High Income Gulberg Tomn	62.98	4505	Not Tested	44.35	6.05	1.403
Sample No. 8 Landfill Site	Nazimabad Block B (Board Office, Liquatabad UC#02, -Gulshan Gulistane Jauher Cantonment Area, Gulberg GTS	70.66	3363	26.94	34.26	4.44	1.75
Sample No. 9 Landfill Site	Nazimabad Block B (Board Office, Liquatabad UC#02, -Gulshan Gulistane Jauher Cantonment Area, Gulberg GTS	85.7	4508	33.61	45.57	6.05	1.871
Sample No. 5 (A) Landfill Site	Gulshan Iqbal UC05 GTS, CBF-Model Colony Katchra Kundi	93.34	4386	34.48	43.89	6.25	1.42
Sample No. 5 (B) Landfill Site	Gulshan Iqbal UC05 GTS, CBF-Model Colony Katchra Kundi	95.76	4450	34.56	44.76	6.64	1.561
Sample No. 6 (A) Landfill Site	New Karachi, CBF-Jauhar, Vehicle 03 N.Nazimabad	85.54	4473	29.85	40.29	5.92	0.264
Sample No. 6 (B) Landfill Site	New Karachi, CBF-Jauhar, Vehicle 03 N.Nazimabad	91.35	4107	41.23	44.56	6.5	0.265
Sample No. 8 (A) Landfill Site	Gulberg Town, Saddar Cant Station	73.92	3970	35.72	39.75	5.47	6.098
Sample No. 8 (B) Landfill Site	Gulberg Town, Saddar Cant Station	69.38	3805	36.62	39.62	5.3	7.738
Sample No. 11 Landfill Site	Saddar Town Eid Gah UC#06, Gulberg Town UC#08, Liaquatabad UC#02	70.82	4090	36.85	40.9	5.85	1.92

3 CONCLUSION

It is established that Karachi's municipal solid waste undergoes segregation, sorting and itemized separation of recyclable items from the very source i.e. household level. Individuals are involved in direct selling of recyclable/resalable materials directly to the waste collectors who pay visit to homes. The informal collectors and middle dealers sell these recyclables as 'commodity' to recyclers for recycling. Another stream of recyclable material is separating out from MSW waste stream is at the transfer stage from household to community bin and street level where much of the recyclables are being removed by the waste collection service providers, street scavengers who sell them to recycling industry through middle dealers. Finally, least separation of some of the waste items mostly metals takes place at the dump sites through open burning which is a cause of environmental deterioration and degrading air and water quality particularly at the dumping grounds.

The variation in waste (generation rate and composition) is a highly variable characteristic observed depending upon the waste producer income and living life style as well as waste management; collection, handling (segregation, sorting, separation) practices at source, and different transfer levels; community bins, garbage transfer station and disposal sites by formal and informal sector (in-house, private collection, street scavenging, middle dealers). The three main components of the municipal solid waste branching out and showing variations at different transfer stages are; organic fractions, recyclables and inert. The waste stream originating from the sources mainly; households / dwelling units, shops & markets, streets & roads, institutional and public places, open places, etc. experience significant variation in composition of waste composition particularly in terms of recyclables which get substantially reduced as it reaches to the final dumping place. Organic fractions are also reduced and inert are increased. Comparison of previous data of Karachi with the present finding indicates that waste composition has remained more of less similar and the variations are in conformity following the previous trends observed as in socioeconomic levels as well as across the transfer stages of waste from source (generation) to the disposal. Waste generation rates have however increased to some noticeable extent which is a sign of affluence and shift in life style of the citizens of Karachi. In context to waste to energy option for Karachi, it may be suggested that feasibility lies both at establishing Waste to Energy plant at GTS or Landfill with the current waste management practices, however if the collection mechanism is improved and the number of recovery of unaccounted calorific / heat value items such as diapers, tetra-pack containers, etc. is contributed in the waste fed into the waste to energy system then a substantial / feasible operation of the system on sustainable grounds is envisaged.

Recommendations An independent Waste to Energy study for Karachi should be undertaken to investigate under the feasibility of power generation from waste and the prospects of how much energy can be derived (potential) from MSW waste. Also other option of converting waste into other forms of fuel (RDF – Refuse Derived Fuel) should also be investigated (Pyrolytic Conversion, etc.).