



## Study of Material Flow Analysis of Paper Waste in Municipal Solid Waste of Lahore Cantonment

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### ABSTRACT

This research study explains the material flow of paper from households to containers and ultimately to landfills. Moreover, it shows different behavior of various households towards the consumption of different paper products and the way they reuse them. Sampling was carried out from households, kerbside containers and landfills where material flow of paper was studied. Percentage composition was calculated on different waste items including paper. Six major paper items were segregated namely glossy paper, cardboard, tissue paper, boxboard, office paper and newspaper. Moreover, proximate analysis was carried out to find out the values for fixed carbon, ash content, moisture content and volatile organic compounds (VOC's) for different paper items mentioned above. Material flow of paper from households to kerbside containers and then to landfills was observed. The results showed that waste paper from the households is of very fine quality and before reaching to the landfill site it is either sold, reused or recovered. Today in Pakistan, the act of recovering paper from the waste stream is carried out by the informal sector which if followed by the formal sector too can raise profits and economic development.

### INTRODUCTION

With the changing lifestyle of people and more and more urbanization, there is an increased flow of materials and production of solid waste (Ackerman 2005). Pakistan, in the last few decades has become one of the leading examples of those countries where urbanization has advanced at an exceptional level (Jeong et al. 2007). Developing countries are presently facing a lot of environmental problems, especially related to solid waste management and Pakistan is one of them. It is essential to note that in Pakistan there is a prominent difference between waste generation and the amounts of waste that reach the disposal sites. All of the municipal waste is unable to reach final disposal sites because much of the waste, like paper, is recovered. To know the ultimate fate of a specific waste item, its material flow analysis is studied which includes the analysis of the entire life cycle of a waste item (EPA 2007).

As the population of the unit settlement increases, so does the quantity and the variety of solid waste also increase. Solid waste qualities and quantity differ depending on the country and even within the same country according to the region, and within the same city according to the district. The variety and quantity of solid waste depend more on the income level, consumption and usage habits (ISTAC 2011).

Material recovery can be divided into two broad types i.e., informal and formal material recovery systems. Source separation or segregation is mainly the domain of informal sector. At household level, most reused, recycled or recovered materials for domestic purposes are paper, cardboard, plastic bottles, plastic bags and cans. After segregation the remaining municipal solid waste is composed of such materials that are unfit and not suitable for domestic use and that is the point where the waste enters in formal collection systems. Some households sell the recoverable and reusable materials and earn profit. At high income levels the recovered items from the waste stream are sold by the domestic servants. These transactions depend on the end use of the recovered items. Paper is one of the recovered items from the municipal waste stream and holds a paramount importance among reusable waste products. In providing waste, informal waste collection service scavengers play an important role. They collect the reusable waste items from the households and sell it further in order to earn profit. At household level, paper in various forms like newspaper and cardboard is sold to the scavengers. While studying material flow analysis of various waste items in municipal waste streams, the entire life cycle of a product is studied. Material flow analysis of solid waste allows studying the composition of solid waste which has revealed the importance of waste. Solid waste has a great potential to make a profitable enterprise (UNEP 2005).

Landfills are one of the most common ways of disposing off the solid waste, but they serve as a means of leachate production and soil contamination. The land available for filling with solid waste is running out and this is a problem worldwide that seriously needs to be addressed and focused. However, this burden on landfills can be reduced by the combination of recycling and composting organic waste strategies (Ali 2009).

Municipal waste is one of the biggest contributors towards the composition of solid waste. Some alternatives can be considered such as recycling and reusing minimum sixty percent, composting of organic waste, incineration of residual waste (waste to energy) maximum twenty percent (Moten 2009).

There are different items present in the composition of solid waste such as organic, inorganic, recyclable biodegradable and non-biodegradable materials. Paper is one of the most important recyclable materials present in municipal solid waste. According to a publication "Business Plan: Paper Recycling Plant" Pakistani paper market is large and growing but the pace of growth is declining because of the increase in cost of production due to rapid increase in fuel and energy prices. Despite of the constraints, the market will grow because of the increase in demand for paper products forthcoming years. Over the years a remarkable increase in paper consumption has been seen in Pakistan. This increase is obvious as shown in the period of 2001-02 when the consumption of paper took a huge jump showing the growing need of paper in daily life which demands the concentration and focus on the study of material flow analysis of paper (Moten 2008).

There is a flow of paper from facilities (households, offices, firms, etc.) to kerbside containers and then to landfills and recycling facilities. The increasing flow of paper indicates the increasing consumption of paper products. This trend of increasing paper consumption is due to increasing population, increasing trend of getting an education, better living standards and urbanization. Unlike other reusable and recoverable waste items paper is consumed by people on almost daily basis specially the households.

## MATERIALS AND METHODS

**Study area:** The research area selected was Ali View Society, an area located in Lahore Cantt and comprises of three phases, 1, 2 and 3. The number of houses in phase 1 is 148, phase 2 is 125 houses, and phase 3 is 120 houses. Three households each from the respective phases will be selected for sampling. Waste Buster is responsible for the collection of waste in this area. Waste vehicle's capacity ranges between 5m<sup>3</sup> and 10m<sup>3</sup>. There is a waste trolley used for stor-

ing the collected waste by workers till it is disposed off. They collect the waste from the containers provided outside each household. The collected waste is segregated and materials like reusable paper are recovered and sold further to industrial units. The leftout waste, that is composed of organic fraction, is used in making compost. Some households with the help of private workers segregate their waste before throwing them away in the containers for the municipal workers to collect. Materials like newspaper and cardboard are segregated and used at source for various domestic purposes or are sold to the scavengers (Real Estate Office).

## Data Collection

Research involves collection of two types of data i.e. primary data and secondary data.

**Primary data:** Primary data collection was done through questionnaire, survey and sampling of waste.

**Questionnaire:** The purpose of questionnaire was to determine usage and consumption of paper in households, kinds of different paper products that are being used in different households and to calculate waste generation rate.

**Sampling:** This study involves solid waste sampling from three areas:

1. Households (located in Ali View Lahore Cantt)
2. Kerbside containers (of the previously selected households)
3. Landfill site

**Sampling from households:** Sampling from households was carried out in Ali View Society located in Lahore Cantt for seven days, one time during a day. Three random households were selected for the sampling purpose. 10 kg of the household solid waste was taken from each household and was further segregated and different items present in the solid waste were weighed with the help of a weighing machine.

**Sampling from kerbside containers:** Sampling from containers was done to calculate the percentage composition of waste items present in kerbside containers. These containers are used for the solid waste disposal by the households. The purpose of sampling from the containers along with the calculation of percentage composition of waste items was to find out the composition of solid waste specifically paper waste and to see which components of paper waste are missing that were previously present in when sampling from households was carried out.

**Sampling from landfills:** Sampling from landfills was carried out to determine the amount of paper waste that reaches

the landfill site and to calculate the percentage composition of the representative solid waste sample. Another purpose was to see that either the paper waste at the landfill site is segregated from the rest of the solid waste or not and if yes what are the further stages that waste paper has to pass through.

**Secondary data:** The collection of secondary data was done via literature review.

**Laboratory work:**

**Lab analysis:** The segregated paper waste from the households was taken further to the lab for analysis and three categories of lab analysis were mainly focused:

1. Percentage composition (physical analysis)
2. Proximate analysis (chemical analysis)

**Percentage composition (Physical analysis):** Percentage composition was carried out to determine the weights of different items present in solid waste. Sampling was carried out for seven days from representative ten houses and further the items segregated from sampling of seventh day was taken to the lab for analysis.

**Proximate analysis (Chemical analysis):** Proximate analysis was carried out in laboratory to determine the following:

1. Moisture content
2. Volatile organic compounds (VOC's)
3. Fixed carbon
4. Ash content

**Moisture content:** The representative 10 kg solid waste from the households was taken into lab for analysis. The waste items were weighed with the help of a weighing machine and that weight of the waste items was referred to as “wet weight”. After that, every paper component present in the representative 10 kg waste sample was heated in the oven at 105°C for 1 hour.

$$\text{Moisture content (\%)} = \frac{\text{Wet weight} - \text{Dry weight}}{\text{Wet weight}} \times 100$$

**Volatile organic compounds:** Dried samples of paper were taken and crushed. Five g from each crushed samples was taken for analysis. Furnace was set at 950°C and samples were kept in it for 30 minutes with lids.

Following formula was used to calculate the value for volatile organic compounds in different paper samples.

$$\text{Volatile organic compounds (\%)} = \frac{\text{Weight of sample before heating} - \text{weight of sample after heating}}{\text{Weight of sample before heating}} \times 100$$

**Fixed Carbon:** With the help of the values of the weights

obtained after heating the paper samples in the furnace for the second time without lids and the initial weights of the sample and crucible before heating, the values for fixed carbon for each paper sample were calculated. Formula used for the calculation of fixed carbon is:

$$\text{Fixed Carbon (\%)} = \frac{\text{Weight of sample before heating (without lid)} - \text{weight of sample after heating (without lid)}}{\text{Weight of sample before heating (without lid)}} \times 100$$

**Ash Content:** Ash content is the residue left after the samples are heated in the furnace without lid. The formula to calculate ash content is given as follows:

$$\text{Ash Content (\%)} = \frac{\text{Weight of crucible + sample remaining after heating} - \text{weight of crucible}}{\text{Weight of sample before heating}} \times 100$$

**Data analysis:** The amount and types of paper waste generated, reused and going to the landfill site were determined through the questionnaire survey and calculation of percentage of paper items in households, containers and landfill site.

**RESULTS AND DISCUSSION**

Material flow analysis was conducted for paper waste along with other type of solid waste items. Solid waste sampling

Table 1: Percentage composition of waste in household solid waste.

Sr. no	Type of solid waste item	Weight of the item (g)	Percentage composition (%)
1	Cardboard	382.45	22.2%
2	Office paper	91.35	5.3%
3	Glossy paper	33.42	1.94%
4	Newspaper	659.14	38.27%
5	Boxboard	191.33	11.11%
6	Fruit & vegetable waste	231.26	13.4%
7	Wood	0	0.0%
8	Textile	2.79	0.16%
9	Metal	34.06	1.98%
10	Plastic	22.8	5.52%
11	Soft plastic	13.42	0.78%
12	Disposable glass	36.27	2.11%
13	Aluminum foil	6.53	0.20%
14	Polystyrene packs	0	0.00%
15	Batteries	21.18	12.19%
16	Oil bottles	122.12	15.90%
17	Sharps	0	0.01%
18	Expired medicines	0	0.02%

Total weight of the solid waste: 1,722.1 g (1.7221 kg)  
 =101.3g (0.1013 kg/capita/ day)

Table 2: Percentage composition of waste from kerbside container.

Sr.No	Type of solid waste item	Weight of the item(g)	Percentage composition (%)
1	Cardboard	575.09	51.51%
2	Office paper	13.84	1.24%
3	Glossy paper	0.00	0.00%
4	Newspaper	7.85	0.70%
5	Box board	164.46	14.73%
6	Fruit & vegetable peelings	130.72	11.71%
7	Wood	29.73	2.06%
8	Textile	0.00	0.12%
9	Metal	0.00	1.28%
10	Plastic	19.2	3.13%
11	Soft plastic	20.19	1.80%
12	Disposable glass	22.78	2.04%
13	Aluminum foil	0.00	0.03%
14	Polystyrene packs	8.91	0.10%
15	Oil bottles	136.10	1.12%
16	Sharps	0.00	0.00%
17	Batteries	0.00	10.00%
18	Pesticides bottles	0.00	0.00%
19	Expired medicines	1.55	0.01%
20	Syringes	0.00	0.00%

Total weight of the solid waste= 1,116.4 g

Table 3: Percentage composition of waste from landfill site

Sr.No	Type of solid waste item	Weight of the item (g)	Percentage composition (%)
1	Cardboard	2.2	0.29%
2	Office paper	0.1	0.00%
3	Glossy paper	0.00	0.00%
4	Newspaper	0.00	0.00%
5	Boxboard	22.2	2.88%
6	Fruit & vegetable waste	245.26	31.90%
7	Wood	75.1	0.03%
8	Textile	2.79	0.00%
9	Metal	34.06	0.00%
10	Plastic	22.8	0.01%
11	Soft plastic	145.0	18.88%
12	Disposable glass	36.27	0.00%
13	Aluminum foil	6.53	0.02%
14	Polystyrene packs	0.00	0.00%
15	Batteries	35.88	0.02%
16	Oil bottles	122.12	0.04%
17	Sharps	13.0	0.00%
18	Pesticides bottles	0.00	0.00%
19	Expired medicines	0.00	0.00%
20	Syringes	4.5	0.58%

Total waste: 767.99g

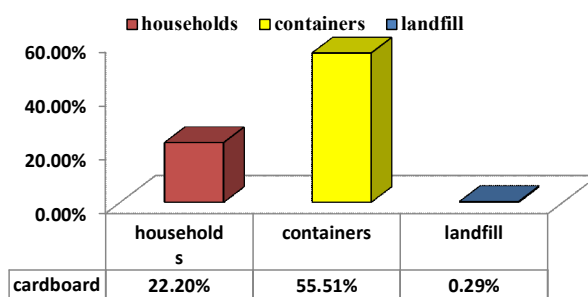


Fig. 1: Percentage of cardboard in households, kerbsides &amp; landfill.

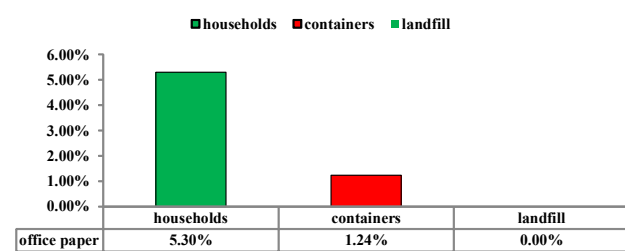


Fig. 2: Percentage of office paper in households, kerbsides &amp; landfill.

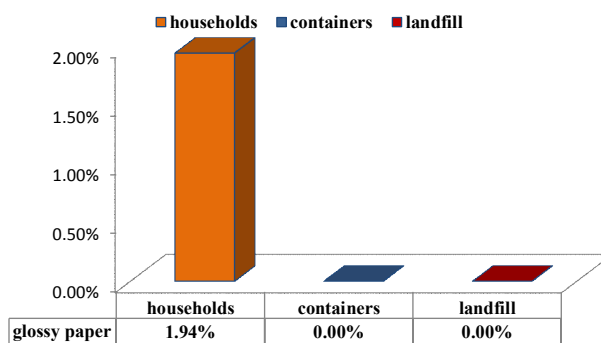


Fig. 3: Percentage of glossy paper in households, kerbsides &amp; landfill.

carried out from households, kerbsides and landfill revealed the results showing percentage composition of municipal solid waste.

Table 1 shows percentage composition of various municipal solid waste items present in households that were selected randomly. The results mentioned in this table show that household solid waste is composed largely of paper waste. Six types of paper waste were obtained from house-

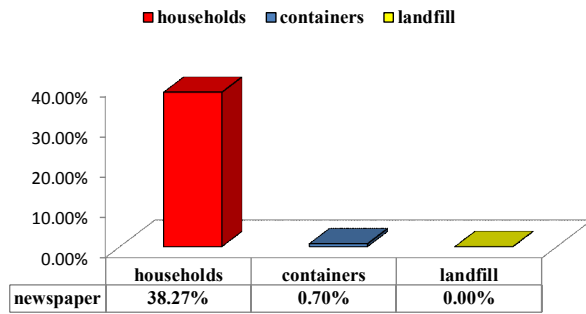


Fig. 4: Percentage of newspaper in households, kerbsides & landfill.

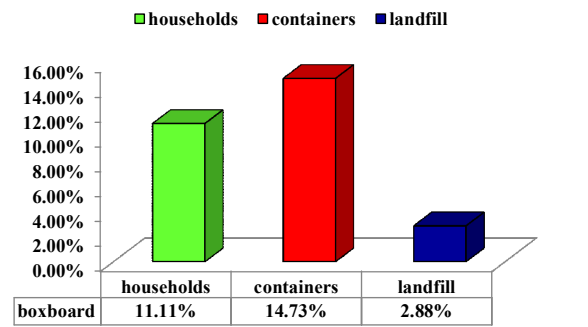


Fig. 5: Percentage of boxboard in households, kerbsides & landfill.

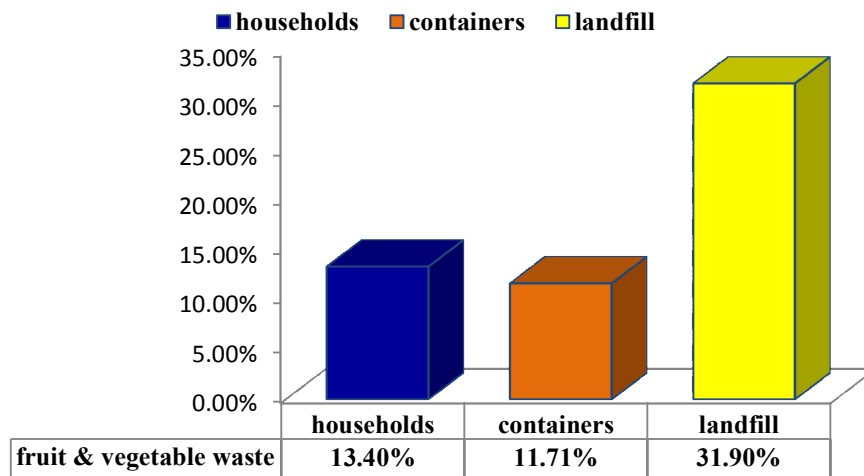


Fig. 6: Percentage of fruit & vegetable waste in households, kerbsides & landfill.

holds i.e cardboard, office paper glossy paper newspaper, boxboard and tissue paper. Newspaper was found to have the greatest percentage as compared to other waste items i.e. 38.27% followed by cardboard (22.20%), box board (11.11%), office paper (5.30%) and glossy paper (1.94%). Newspaper is mostly an important component of households. There is an apparent reason for the greatest percentage of newspaper present amongst municipal solid waste components. The first reason for the greatest percentage of newspaper is that the households almost have a daily supply of newspaper and secondly newspaper is not thrown along with other solid waste components such as kitchen waste which keeps it separate and in its original shape unlike other waste components.

After newspaper, cardboard was found to have greatest percentage (22.20%). Cardboard constitutes a larger range of household items such as different disposable food item packs, toothpaste packs, masala packs, stationary items and various kitchen products. Its percentage is less than news-

paper because usually the cardboard packs or products are thrown along with other waste which affects its percentage as well as weight. After cardboard, boxboard was found to be present in a greater proportion. Tetra packs are made up of material known as boxboard and tetra packs (milk packs and juice packs) are consumed by households on daily basis which is the reason why they form a broad category of paper waste in households.

Next important category that constitutes paper waste is office paper that was also found to be present in households (5.30 %). Office paper is the utmost need of school or college going children and office going people. Technology has advanced and now-a-days people try their best to have latest electronic appliances with them. Printer is one of the appliance that has gain importance with the passage of time. The households randomly selected for sampling were having printers. The relation of printers and office paper is interdependent. More and more printing requires greater amount of office papers that ultimately make paper waste

Table 4: Results of proximate analysis.

Sr. No.	Type of Paper	Moisture Content(%)	Volatile Organic Compounds (%)	Fixed Carbon (%)	Ash Content (%)
1	Office paper	10.02%	79.0%	12.57%	7.26%
2	Cardboard	5.38%	0.75%	0.76%	12.3%
3	Tissue paper	5.81%	91.2%	0.18%	3.38%
4	Glossy paper	3.98%	73.92%	18.46%	1.3%
5	Boxboard	8.27%	0.94%	0.91%	10.10%
6	Newspaper	6.55%	93.6%	34%	0.73%

composition of solid waste more and more. So, the presence of printers and sampling revealed results that showed the increasing use of office papers. There is another reason for the presence of office papers in households and that is their use by the school or college going children and working people. The houses randomly selected for sampling had working people which contributed towards the use of office paper. Pamphlets, invitation letters etc. are usually composed of glossy paper and was too found in households but less than other types of paper waste mentioned above which is only 1.94%. They are mostly kept by the households and are not thrown along other solid waste items.

After paper the other major category of municipal solid waste was found to have quite a prominent percentage and that is organic waste composed of fruit and vegetable waste. It constituted 13.40% of the total sampled municipal solid waste. Organic waste includes usually kitchen and garden waste if talking about households specifically. This organic waste is disposed off and people do not use it for reuse or recycling purposes. Though, with the help of an interview with the waste collection team of Waste Busters in the study area, the importance of this waste was known. Organic waste disposed off by the households and collected by the waste collection workers is further used in making compost and used as a natural fertilizer for crops or livestock feed.

Apart from paper and organic waste other waste components such as textile metal (1.98%), plastic (1.32%), soft plastic (0.78%), disposable glass (2.11%) aluminum foil (0.37%), batteries (1.23%), and oil bottles (7.09%) were also found in municipal waste stream though they constituted a smaller proportion of municipal solid waste. These items are consumed in a lesser quantity by the sampled households, therefore, were found in a lesser amount as compared to other waste items. There was no hazardous waste such as syringes, sharps and pesticides in the solid waste of households. Moreover, generation rate for municipal solid waste of the households was calculated which came out to be 101.3g (0.1013 kg/capita/ day).

The results show that solid waste from the households

can be divided into two broad categories i.e. inorganic waste (paper waste and other dry waste items) and organic waste (wet solid waste). Both types of waste have their own worth and contain certain items that can be reused or recycled and hold a prominent economic importance.

Table 2 shows percentage composition of various waste items present in kerbside containers of the representative blocks. It depicts the increased number of certain waste items as compared to the waste items present in household solid waste. There are certain products that are added, eliminated or have shown a decreased percentage composition if compared with the waste items of representative households. For instance a marked decrease has been shown in the percentage of newspaper as shown in Table 2 i.e. its level has dropped down from 38.27% in households to 0.70%. The percentage of newspaper is almost nil in kerbsides as compared to households. This shows that a larger percentage of newspaper do not reach kerbside containers.

Behind this there can be certain possible reasons, for instance either they are sold to the scavengers or junkshops or segregated and used for various household purposes which stop them from being a major portion of kerbside containers (Batool & Chaudhry 2007). In Pakistan most of these scavenging activities are carried out by the informal sector. Scavengers sell the reusable waste such as paper and earn profit. They not only benefit themselves but also to a healthy and economically sound status of the country (NAS & Jaffe 2003).

The percentage of cardboard products such as tetra packs (milk and juice packs), fast food packs, disposable glasses and some other such materials has shown a remarkable increase. Paper items such as pamphlets, brown paper, office paper and tissue paper constitute a major portion of household solid waste composition. The results after sampling from the kerbside containers shows that various products are added in the solid waste composition list that are previously missing in the solid waste components lists for households. A major quantity of organic waste such as fruit and vegetable peelings are reduced in kerbside containers as

compared to their percentage composition in household containers that is from 13.40% in households to 11.71% in kerbsides. The organic waste is used to process compost which is used to make natural fertilizer for the crops and food for livestock as said by a member of the Waste Busters (responsible for the collection of waste in the study area) team in an interview. The use of organic waste and paper waste cut their percentage off from the kerbsides which indicates that they both are segregated before they reach landfills.

Wood is one of those waste items that are added in kerbsides waste and missing in household waste stream. Wood is not a common household item like others and therefore was not found when sampling from households was done, which means it is later added directly in kerbside containers by humans or animals as a result of different activities. Cardboard shows an increase in kerbsides as compared to their percentage in households (from 22.20% in households to 55.51% in kerbsides). The cardboard materials found in kerbsides are usually the cardboard used for packing purposes and that is mostly of food items. Nowadays people like to have more fast food items as compared to home cooked food. Fast food products have cardboard packing mostly. People consuming more and more fast food items leads to more and more disposal of cardboard packaging's in kerbsides. Boxboard has a similar characteristic as cardboard. Tetra packs are made up of such packaging that is composed of boxboard. They are disposed off into the kerbsides unlike newspapers due to which their quantity increases in kerbsides.

Table 3 shows the results of proximate analysis of the segregated paper products obtained from household solid waste that are office paper, cardboard, tissue paper, glossy paper, boxboard and newspaper. It shows the values for moisture content, volatile organic compounds (VOC's), fixed carbon (FC) and ash content (AC). The value of moisture content is the highest for office paper. Volatile organic compounds percentage was found highest for tissue paper though it is the lightest and present in minute quantity in kerbside solid waste and even in household solid waste.

Fixed carbon value is the greatest for newspaper, whereas ash content value is greatest for cardboard. So there are different values for fixed carbon, ash content, volatile organic compounds, moisture content and fixed carbon.

Comparison between different percentage compositions of waste items is shown by the graphs. The graphs depict the flow of paper and other components of solid waste between households, kerbsides and landfill. The graphs show the results depicted in the Tables 1, 2 and 3. The five major types of paper i.e. cardboard, office paper, glossy paper ,

newspaper and boxboard are present in negligible quantities at landfill site as compared to households and kerbsides. The graphical representation of their percentages in households, kerbsides and landfill are shown in the Figs. 1, 2, 3, 4 and 5.

Hence, the results show that paper before reaching the landfill sites is either sold, recovered or goes to the recycling facilities where fuel is made out of them. When Waste Busters team was interviewed they said that paper present in the waste stream that is collected from the households is of fine quality waste and before reaching to the landfill site it flows to the scavengers , junk shops, recycling facilities, fuel manufacturing companies or either used by the households themselves. Hospital waste such as syringes , expired medicines, sharps etc. are not found at landfill site because hospital waste is treated separately.

When material flow analysis was conducted for paper waste it showed that paper has huge potential for reuse and recycling. Today, in Pakistan the act of segregating, recovering and reusing paper is followed by the informal sector which if followed formally can generate quite a huge profit.

## CONCLUSION

Increasing population calls for a healthy and an effective solid waste management system and realizing the importance of material flow analysis. Material flow analysis of paper provides an opportunity to open new doors for economic and environmental prosperity. Paper flows from household to kerbsides and a little of it reaches the landfill facility because a greater chunk of the paper waste is segregated at source by the households and scavengers that form the informal sector. It means that reuse and recycling activities are being carried out by the informal sector in Pakistan. If material flow analysis for paper is given an emphasis and studied in detail by the formal sector, it can do wonders and increase profits tremendously. Paper keeps on flowing and a very little portion of it is completely disposed of in landfills. Household behavior also influences the flow of paper because their sense for reuse and recycling products from municipal waste stream matters a lot. Now our society is slowly and gradually heading towards awareness which promotes an environmentally and economically favorable society.

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