An Integrated Solid Waste Management Strategy for Semi-Urban and Rural Areas of Pakistan

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***Abstract*—**In Pakistan, environmental degradation and consequent human health deterioration has rapidly accelerated in the past decade due to solid waste mismanagement. As the situation worsens with time, establishment of proper waste management practices is urgently needed especially in semi urban and rural areas of Pakistan. This study uses a concept of Waste Bank, which involves a transfer station for collection of sorted waste fractions and its delivery to the targeted market such as recycling industries, biogas plants, composting facilities etc. The management efficiency and effectiveness of Waste Bank depend strongly on the proficient sorting and collection of solid waste fractions at household level. However, the social attitude towards such a solution in semi urban/rural areas of Pakistan demands certain prerequisites to make it workable. Considering these factors the objectives of this study are to: [A] Obtain reliable data about quantity and characteristics of generated waste to define feasibility of business and design factors, such as required storage area, retention time, transportation frequency of the system etc. [B] Analyze the effects of various social factors on waste generation to foresee future projections. [C] Quantify the improvement in waste sorting efficiency after awareness campaign. We selected Gujrat city of Central Punjab province of Pakistan as it is semi urban adjoined by rural areas. A total of 60 houses (20 from each of the three selected colonies), belonging to different social status were selected. Awareness sessions about waste segregation were given through brochures and individual lectures in each selected household. Sampling of waste, that households had attempted to sort, was then carried out in the three colored bags that were provided as part of the awareness campaign. Finally, refined waste sorting, weighing of various fractions and measurement of dry mass was performed in environmental laboratory using standard methods. It was calculated that sorting efficiency of waste improved from 0 to 52% as a result of the awareness campaign. The generation of waste (dry mass basis) on average from one household was 460 kg/year whereas per capita generation was 68 kg/year. Extrapolating these values for Gujrat Tehsil, the total waste generation per year is calculated to be 101921 tons dry mass (DM). Characteristics found in waste were (i) organic decomposable (29.2%, 29710 tons/year DM), (ii) recyclables (37.0%, 37726 tons/year DM) that included plastic, paper, metal and glass, and (iii) trash (33.8%, 34485 tons/year DM) that mainly comprised of polythene bags, medicine packaging, pampers and wrappers. Waste generation was more in colonies with comparatively higher income and better living standards. In future, data collection for all four seasons and improvements due to expansion of awareness campaign to educational institutes will be quantified. This waste management system can potentially fulfill vital sustainable development goals (e.g. clean water and sanitation), reduce the need to harvest fresh resources from the ecosystem, create business and job opportunities and consequently solve one of the most pressing environmental issues of the country.

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I. Introduction

PROPER waste management plays a key role in the context of global cleanliness and sustainability drive and municipal solid waste is one classification of waste that is not being managed efficiently. In developing countries, approximately 60% of the generated waste is being effectively collected but eventually disposed of in open dumps, not eliminating the associated risks but only displacing them [1]. Scavengers' activity in relatively developed cities recycles about 15 to 25% of the waste but that unfortunately is not well-organized and causes health deterioration of the people involved. Most alarmingly, a major proportion of waste resides either unattended or dumped within or around the community causing deterioration of human health and degradation of water, air and soil. Although solutions exist, a major portion of waste is seen still lying around inside the community pointing towards ineffective implementation. In future, factors like rapid population growth [2], increase in urban density [3], poor planning and development [4], [5], changes in consumption patterns and lifestyle will result in increased waste generation and variations in composition within countries and cities [6], [7]. Due to this, pollution is likely to increase, accelerating the gap with economic stability [8].

Solid waste and its management is a global issue, however the gravity of this problem is more associated with developing countries. The municipalities in developing countries are deficient in financial resources and skills required to effectively manage this problem [6]. According to general observation, in Pakistani communities, the major barriers to waste segregation approach are inconvenience, lack of awareness and lax legislation. Open dumping in poorly designed dumpsites and informal recycling are the common waste management techniques in developing countries that come with their own associated issues [9], [10]. Dumpsites usually do not meet the environmental standards and are a source of air pollutants and leachate that can potentially contaminate air, surface and ground water and soil, consequently damaging human health [11]. On the other hand roughly 20% of the waste is being recycled by the informal sector but the lack of concern towards precautionary measures exposes waste collectors to high health risks [12].

Many cities especially those in low and middle income countries are unable to handle the increasing volume and diverse composition of solid waste [12]. Such problems are reported significantly in the major regions of South Asia including India, Pakistan, Bangladesh and Nepal. This problem needs to be addressed urgently as 5.2 million people, out of which 4 million are children, die each year when mismanaged solid waste serves as breeding ground for disease causing vectors and also results in bio accumulation of contaminants [6]. The impacts are high on the local community specifically children and scavengers who are more exposed to the hazards [11]. A practical and sustainable solution [13]-[15] with the use of technology [16] focused on bringing awareness and convenience to communities is needed to reduce health hazards and enable resource conservation for a sustainable future. Waste Bank is an effort directed towards similar objectives for the proper waste management in semi-urban and rural areas.

In Pakistan, despite the rising demand of recycling industries, local solid waste rots in open dumps cause environmental hazards and resource wastage. The concept of Waste Bank revolves around substantially reducing the amount of waste on the roads and going into the open dumps by re-utilizing it as raw material consequently decreasing the demand to harvest fresh resources from the ecosystem. Waste Bank is an integrated modernized system that consists of a designed infrastructure as a physical warehouse for temporary waste storage. Organic waste will ideally be disposed directly to the composting plant constructed on the landfill. Recyclables will go through refined sorting, open air-drying and compaction for a cost effective transport to the recycling industry. This transfer will be mobilized through hired existing scavenger network currently providing door to door collection and segregation of waste but in an unsafe and disorganized manner. However with the facilities that Waste Bank will be providing to these scavengers and the community, the collection will be more refined and safer for health. Using this network, Waste Bank will be reducing its operational cost and creating employment and business opportunities. All operations will be controlled through a mobile application.

Conclusively, in Pakistan Waste Bank will provide a sustainable solution to manage approximately 20 million tons of waste [13]. To design such a system, there is a need to collect some basic data about the generated waste in the city. Since the system is to be established starting from a city, data regarding the waste generation and characterization is necessary for that city to define the feasibility of the revenue generation and business potential.

II. Material and Methods

A. Study Area

Our study area was Gujrat city which was to be divided using stratified sampling technique into the categories based on their income level. Three colonies belonging to different social status were selected. The colonies are namely:

1. Mohalla Nizamabad (Lower class)
2. Al Nabi Colony (Middle class)
3. Shadman Colony (Upper middle class)

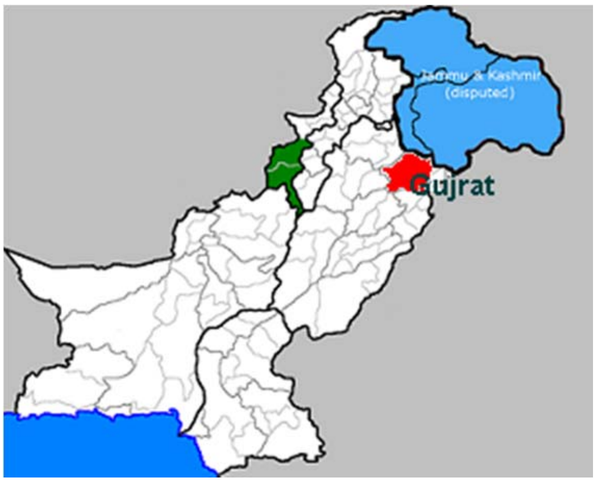

Fig. 1 Location of Gujrat City

The extrapolated results are on the basis of population for Gujrat Tehsil obtained from Pakistan Statistical Bureau 2018 [17]. This tehsil is located in Gujrat district and consists of 65 union councils (administrative units).

The following are the dimensions finalized to obtain authentic data that will help us in our business decisions.

- Waste characterization and quantification for Gujrat, Pakistan
- Quantification of compliance level of communities towards awareness campaign

B. Waste Characterization and Quantification for Gujrat, Pakistan

Three colonies, as mentioned above, were selected based on their difference in social status. Out of each colony, 20 houses were selected where the sampling was carried out. Selected households were convinced to cooperate with us for this research and offered their dedicated and unbiased services to achieve the objectives. The households were provided with three color coded bags in which they were to sort their waste which were collected for further processing and analysis.

Households were reminded one day prior to collection through a phone call not to throw out their waste and keep it at home for our collection. To further ensure this the collection process was started early in the morning before the scavengers began their collection. All three bags from one household were tied together to avoid mixing with bags of other households. The collected waste was then sorted into various fractions which were weighed using a weighing balance up to the accuracy of 0.5 kg. For calculating DM, subsamples of sorted waste fractions were taken after homogenization. These samples were weighed immediately to avoid moisture loss with time and were then put into the oven at 105 °C for 24 hours. Possible errors expected due to power failure were accommodated. The left over DM was weighed and recorded. DM was calculated using the following expression:

$$DM (\%) = 100 \times \text{Mass after drying} / \text{Mass before drying}.$$

C. Quantification of Compliance Level of Communities towards Awareness Campaign

Self-designed awareness brochures were distributed among the selected households. These brochures informed the subjects about proper ways of segregating waste. The households were also provided with three color coded bags in which they were required to segregate their waste into organic decomposable (white), recyclables (green) and trash (yellow). Participating households were given a day on which their waste would be collected and also reached through telephone call one day prior to the collection day to remind them of their task.

On collection day, waste was analyzed in terms of sorting efficiency to calculate in percentage the compliance of households to the awareness they were given on the day survey was conducted. The first step of this process was to divide the sample population into two broad categories:

- People who tried to segregate
- People who did not try to segregate

The percentage sorting efficiency of the households, who did not attempt at all to segregate their waste, was considered as 0%. For the second category, the misplaced waste fractions (if any) were extracted from each bag and weighed to calculate the error in sorting. Errors from all the bags were then added to calculate the total error. All the rest of the waste was considered to be correctly sorted. The weight of correctly sorted waste was then divided by the total collected waste to calculate the combined percentage sorting efficiency of the participating households.

III. Results and Discussion

The main aim of the research was to find out the quantity of waste being produced per capita in Gujrat. The average per capita waste generation (wet mass basis) of all three colonies is 0.39 kg/capita/day. Extrapolating this value with the current population of Gujrat Tehsil we found out that about 595 tons of waste is produced per day in Gujrat whereas in a year about 209434 tons is expected to be produced. These values have been obtained from research in the urban areas assuming that rural area waste generation would be about the same.

The results in Table I show that, on average, out of the total waste being produced in Gujrat, 64% is organic decomposable, 18% is recyclables and 18% is trash. This composition has been measured considering the conventional definitions of these fractions whereas in reality some trash items are also being recycled e.g. wrappers.

The average moisture content in organic matter was 78.6% and DM was only 21.4%. As can be seen in Table II, upon recalculating our values we saw that in Gujrat Tehsil DM of waste is 68 tons/day. With this value, 30289 tons is expected to be produced in a year. Therefore, we come to an interesting conclusion that in total wet waste, a major portion is organic degradable (64%) which has high density and low compressibility [19]. However, upon drying organic dry matter makes only 13.7% of the total waste. Dry recyclables are 17.3% whereas dry trash is 15.9%.

Organic decomposable matter is the heaviest compared to other fractions but the least in volume whereas recyclables and trash are lighter but occupy more space. This is a supportive fact for our business which emphasizes that since the areas for landfills are exhausting with time there is a need to recycle waste fractions that occupy more space and do not decompose easily.

TABLE I
Waste Characterization for Gujrat, Pakistan

Waste Fraction	Collected and Sorted: Low Income	Middle Income	High Income	Average waste generation	
	kg/capita/day				kg/capita/year
Organics	24.36	26.23	40.50	0.24	89.32
Recyclables	9.14	4.98	11.68	0.07	25.29
Plastic	3.59	1.05	2.46	0.02	6.96
Paper	3.92	2.10	4.92	0.03	10.71
Metal	0.98	0.79	1.84	0.01	3.54
Glass	0.65	1.05	2.46	0.01	4.08
Trash	7.75	6.03	11.94	0.07	25.22
Medicine	0.83		1.19	0.01	1.98
Diapers	4.15		3.58	0.02	7.57
Polythene	1.94		4.78	0.02	6.57
Wrappers	0.83		2.39	0.01	3.15
Average total	0.26	0.39	0.55	0.397	139.82

TABLE II
Waste Production on DM Basis in Gujrat Tehsil

Strata	Wet Mass	DM		
	kg/house/day		kg/capita/day	kg/capita/year
Low Income	2.06	0.97	0.12	43.87
Middle Income	2.33	1.09	0.18	66.43
High Income	3.77	1.77	0.26	93.84
Average generation rate	2.69	1.26	0.19	68.04

The main sub characteristics of the fraction ‘recyclables’ included plastic with the generation of 0.02 kg per capita per day, paper 0.03 kg per capita per day and metal and glass both being produced at 0.01 kg per capita per day. Fig. 2 shows the likely generation rate of these sub fractions for the whole city based on these figures.

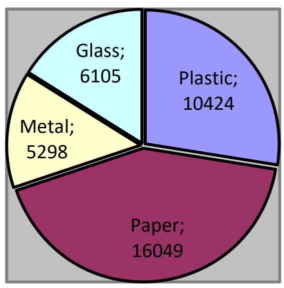

Fig. 2 Sub characterization of recyclables

Trash contains four major sub fractions namely medicine 0.01, diaper 0.02, polythene bags 0.02 and wrappers 0.01. All are measured in kg per capita per year however, per house and per year calculations can be seen in Fig. 3.

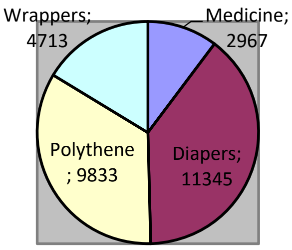

Fig. 3 Sub characterization of trash

Colonies of different living standards and income level were selected to analyze the effect of various social factors on waste generation. The results show that colonies of relatively high living standard and income (Shadman Colony) tend to generate more waste as compared to colonies of low and medium social status (Mohalla Nizamabad and Al Nabi Colony respectively). In Shadman colony, we collected 64 kg of waste from 17 houses where as 22 kg was produced by 20 house in Mohalla Nizamabad and 25 kg was collected in Al Nabi Colony from 16 houses. The difference between per house generation of three colonies can be clearly seen in Fig. 4 whereas difference in waste characteristics can be observed in Fig. 5.

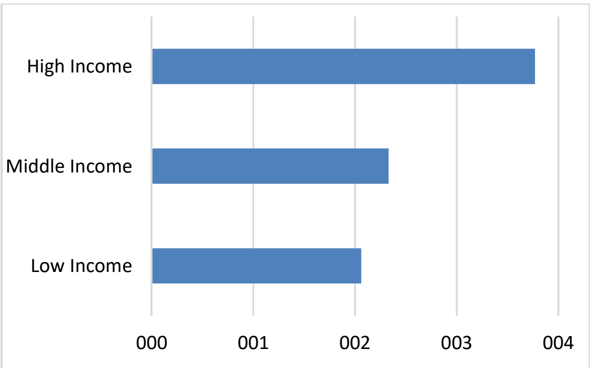

Fig. 4 Per house waste generation in kgs in different colonies depending on social status in Gujrat

The compliance or sorting efficiency was calculated in percentage and the results were unanticipated. We expected the sorting efficiency to be maximum in Shadman Colony since the people living here are more educated. However, the results have been opposite showing that the compliance level was maximum (64%) in Al Nabi Colony followed by 58% in Mohalla Nizamabad, where the education level was relatively low whereas in Shadman Colony the efficiency was at 35% only. The reason behind this result could be that the waste of these households is being managed by maids to whom the information regarding waste segregation never reached. Another valid reason for this could be the busy lifestyle of the people living in colonies with higher living standard. On the other hand, people of Al Nabi Colony and Mohalla Nizamabad manage and segregate their waste themselves. The reason behind the willingness of these two communities to solve the problem of waste management could be because these colonies suffer more being directly in contact with open dumps as compared to Shadman Colony where waste management is comparatively better. Nonetheless, the overall compliance percentage improved from 0 to 52% on one session of awareness only as can be seen in Fig. 6.

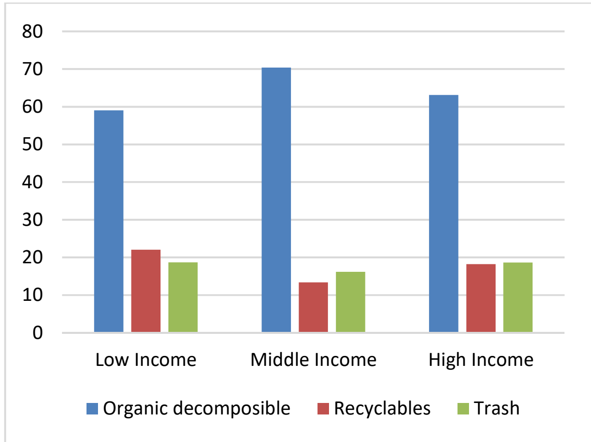

Fig. 5 Comparison of generation of waste characteristics depending on social status of colonies

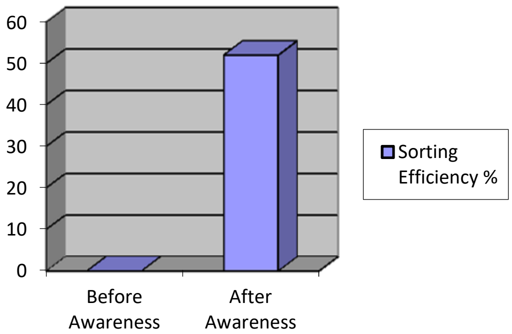

Fig. 6 Improvement in sorting efficiency due to awareness campaign

IV. Conclusion and Recommendations

The data collected for generated waste and its fractions are useful for designing an integrated waste management system. The percentage increase in sorting efficiency or compliance to the awareness brochure tells us that giving awareness to our targeted people will be a vital factor that will play a significant role in successful implementation of the proposed waste management system. It is also expected that with more awareness sessions, the sorting efficiency is likely to increase and can be compared to the systems of developed countries. Through our interaction with the communities, we have found that people are concerned about the situation of waste mismanagement in Gujrat and are interested to participate in initiatives that may resolve it. To make this research better it is recommended that:

- Research on all four seasons in Pakistan should be conducted to analyze the variations of waste generation between seasons.
- Research over several years should be conducted so that

growth trends can be measured.

- Awareness campaign should be expanded and results should be quantified to record step by step improvements.

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