ASSESSMENT OF MUNICIPAL SOLID WASTE MANAGEMENT PRACTICES AND ENERGY RECOVERY POTENTIAL IN PAKISTAN

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ABSTRACT

This study was conducted to assess existing practices of municipal solid waste management and to estimate energy recovery potential from it. Because of growing amount of municipal solid waste (MSW) has raised many socio-environmental problems on one hand in the Pakistan and country is facing the shortage of energy due to rapidly population growth on the other hand. In this regard, main cities were selected for assessment of existing practices of MSW management. Same time, various samples of solid waste were collected from dumping sites of MSW and analyzed for energy recovery potential. This study shows that there is a large gap in managing MSW properly. Moreover, no any engineered landfill or any other environment friendly treatment facility has been observed for energy recovery purpose throughout the country as compared to the developed nations. On the other hand, the potential of bio-chemical and thermo-chemical conversion for producing energy in terms of power generation has been observed significantly that is about 216kWh/t and 552kWh/t respectively. The MSW have a great tendency to produce energy, which is highly neglected in the Pakistan. Behind this, lack of planning and lesser political concentration have become most responsible factors among all others for improper management of MSW in the country.

Keywords: Solid Waste, Population, Energy Recovery Potential, Environment

1. Introduction

The socio-environmental problems associated with the improper management of MSW on one hand and energy crises on the other hand have acquired alarming dimensions in the Pakistan like in other developing countries. Solid waste should be management in such a way that not only environment but also public health should be protected [1-2]. There are various causes of generating solid waste at the alarming rate and shortage of energy, from which one root cause is the growing population. The efforts to improve solid waste management system have become more complicated because of the high population growth rate and increasing of the economical activities in the urban areas of developing countries along with the lack of training in modern solid waste management services [3]. Urban waste generation and its disposal have become major global issues as the world's population grows and more peoples are migrating towards urban areas. Thus, the urbanization is globally increasing and according to the estimation, the urban areas would be occupied by six billion people in 2050 as compared to the 3.5 billion now [4]. Like in the other developing countries, population growth of Pakistan is fairly high. It has become at the 6th number with respect to population in the world with population of 188 million at present as reported in the world population data sheet 2014. Growing population needs energy source for their survival. In Pakistan, indigenous energy availability was 65,639 thousand tonnes of oil equivalent (TOE) in 2013 whereas; total primary energy supply remained as 64,588 TOE. Mostly the trend of energy

supply of Pakistan has remained to extract from the nonrenewable sources of energy like in other countries [5].

Moreover, rapidly growth in population and industrialization has caused the shortage of fossil fuels and thus they would not be available for long time due to their overconsumption which leads loss of economy. Not only loss of economical growth and employment but also social cohesion in the society has been affected because of energy shortage. Additionally, environmental problems including green house effect leading to climate change is mainly caused by emissions from energy generating system based upon fossil fuels and from open dumping of solid wastes. Here is the pressure point known as hotspot of conflict which is globally headache of all stakeholders. In this regard, there has been a growing world opinion in favor of looking alternatives to a non-renewable source. Pakistan is rich in renewable sources of energy (i.e. solar energy, wind energy, energy from solid waste etc) but unfortunately, lack of exploitation of these sources results the primary energy supplies today are not enough to meet even the present demand. On the other side, huge quantity of MSW is generating daily with 2.4% annually growth rate but its proper disposal is a seriously challenging issue for Pakistan now a day [1, 5 & 6]. And also there is major gap in between how to get energy from solid waste by properly managing it and to protect environment as well. In the light of these facts and figures, this study has been conducted which is at least an attempt to assess municipal solid waste management (MSWM) practices of country thoroughly and to estimate energy potential from MSW in terms of biogas & heat value leading to power generation potential.

2. Methodology

2.1. Area for study

Pakistan is administratively divided into the four provinces like Sindh, Punjab, Baluchistan and Khyber Pakhtunkhwa as well as the Islamabad Capital Territory and Federal Administrative Tribal Areas in the northwest. The twelve major cities (i.e. Islamabad, Peshawar, Quetta, Rawalpindi, Lahore, Faisalabad, Gujranwala, Sialkot, Multan, Sukkur, and Hyderabad) as shown in Figure 1 were considered for present study.

Figure 1: Location of Study Sites

Generally, the solid waste generated by human activities and problems due to its improper management resemble in the developing countries except some variances between regions and locations based upon geographic, industrial, infrastructural, legal, sociocultural and environmental factors [7]. Information regarding MSWM practices of selected cities has been taken from literature and by personal observation.

2.2. Characterization of MSW

For characterizing the MSW, its various samples were collected from residential areas including high rise dwellings (HRD), medium rise dwellings (MRD) & low rise dwelling (LRD) as well as from commercial areas weekly and monthly. The segregation and weighting of samples were carried out by manually and using physical balance respectively to determine physical composition and generation rate of MSW. Further, representative samples of each components of MSW were prepared for proximate and ultimate analysis according to quartering method [8-9]. Moisture content, total solids, volatile solids and fixed carbon of MSW sample were determined by adopting standard method [10 & 11]. During collection of solid waste, onsite handling, storage and processing of MSW were analyzed by personal observation. However, data regarding collection transfer, transport and disposal of MSW was obtained from environmental protective agency (EPA), municipality authority and by visiting sites.

2.3. Energy Recovery Potential of MSW

As all of environmentalists and other stakeholders concerned with energy system are well familiar that there is an energy recovery potential (ER_p) in abandon quantity which is hidden in the heterogeneous mixed MSW. Various techniques and methods are used to estimate energy from waste. Some of them are based upon empirical models and others are according to experimental approaches [12-13] like calorimetric measurement for heat recovery and biomethane potential test system (BMPTS) for biogas recovery. Here, theoretical biogas potential (BP_T) of MSW was estimated from molecular formula of MSW and heat energy is obtained from results of bomb calorimeter method. In this regard, calorific value (CV in kcal/kg) and elemental analysis of solid waste sample were performed in the laboratory by using Bomb calorimeter and standard procedure of BBOT 23122013 method respectively. Then ER_p in kWh/ton and BP_T in m^3/tonVS were estimated by using Eq.1 [8-9] and 2 respectively.

$$(ER_P)i = CVi \; X \; Wi \; X \; 1.6 \qquad (1)$$

$$BP_T = \left[\frac{\left\{\frac{(4a+b-2c-3d)}{8}\right\} CH4 \; X \; Sp.Wt. \; of \; CO_2 + \left\{\frac{(4a-b+2c+d)}{8}\right\} CO_2 \; X \; Sp.Wt. \; of \; CH_4}{C_aH_bO_cN_d \; X \; Sp.Wt. \; of \; Biogas} \right] X \; 1000 \qquad (2)$$

Where, Wi is the weight of each component of MSW in kg; Sp.Wt. indicates specific weight at standard temperature pressure (STP) and $C_aH_bO_cN_d$ is the molecular formula of MSW.

3. Results and discussion

3.1. Generation and Quantification of MSW in Pakistan

The solid waste generation rate of Pakistan like in the developing countries is much lesser as compared to the developed nation. However, the capability of Pakistan like other developing nations regarding to manage MSW is not economically as well as socio-environment friendly as compared to the developed countries [14]. Basic information of selected cities of Pakistan is given the Table.1. This shows about 25.420 million tons of MSW except hazardous wastes is generated per year in the Pakistan which is mostly disposed off in open environment without any engineering principle. No proper engineered landfill or any other disposal facility is available even in the major cities of country for disposal of MSW [5 & 6]. Similarly, $2.5x10^5$ tons of hospital waste containing 20% infectious waste is yearly generated which is not properly treated. Unfortunately, no well-

designed incineration or any other thermal treatment facility has been found in the majority of hospitals in the country [5].

Table 1: Basic information of selected cities of Pakistan [6, 8 & 15-19]

No.	City Corporation	City Area (Sq.Km)	Urban (%)	Population (Million)	GR (kg/c/d)	TQ (tons/day)	TQ (MT/Year)
1	Karachi	3,527	97.7	23.00	0.761	12,000	4.38
2	Lahore	1,772	82.4	9.719	0.75	5890	2.150
3	Faisalabad	5,856	62.7	6.047	0.48	2122	0.775
4	Hyderabad	5,519	50.8	3.429	0.7	1812	0.661
5	Peshawar	1,257	48.5	3.308	0.489	785	0.287
6	Rawalpindi	5,286	53.2	3.040	0.453	1489	0.543
7	Gujranwala	3,622	50.2	2.800	0.51	1196	0.437
8	Islamabad	906.00	65.7	1.740	0.45	423	0.154
9	Sialkot	3016	26.2	1.733	0.313	411	0.150
10	Multan	3,720	42.2	1.606	0.32	1265	0.462
11	Sukkur	5165	50.9	1.384	0.45	595	0.217
12	Quetta	2653	74.4	0.896	0.378	607	0.222
Remaining urban areas				13.798	0.612	8445	3.082
Total				72.50	6.666	37040	13.520
Rural Areas				115.20	0.283	32602	11.900
Sub - Total				**188.00**	**6.949**	**69,642**	**25.420**
Add 5% for Hazardous waste						3482	1.271
Gross Quantity of MSW						**73,124**	**26.691**

3.2. Composition of MSW in Pakistan

MSW generated in Pakistan is averagely composed of 64% of organic and 36% of inorganic waste. Moreover, the contribution of putricible, non-putricible (combustible), degradable and non-degradable wastes in the major cities of Pakistan were estimated and their average result was found to be 42%,22%, 3% and 33% respectively as shown in the Figure 2.

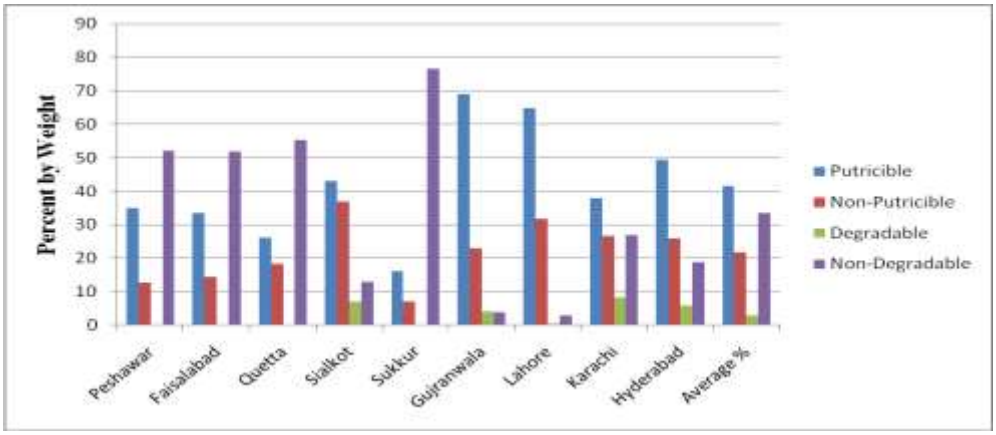

Figure 2: Average Physical Composition of MSW of Major Cities of Pakistan

From the composition of MSW, it can be realized that there is considerable potential of producing energy in terms of biogas from putricible wastes and heat energy from non-putricible wastes leading to power generation potential in the pakistan.

3.3. Evidence of MSWM in Pakistan

There is lake of well-developed environmental legislation and no national quality standard for solid waste management. No any proper planning mechanism and mostly MSWM issue is highly neglected by political parties throughout the country. No any proper handling, storage and processing practices of solid waste have been observed. Due to lack of awareness, segregation of valuable material is not properly performed. Only 70% in larger cities and 30% in small towns as a collection rate typically found with improper way [20]. There is no any proper designed route for

collection of MSW from different points of generation even in the major cities of country. Mostly burning and dumping of waste on road sides is frequently sighted [21]. Only lower than 50% of MSW is disposed off by non-engineering landfill and composting as compared to the other countries (ie. Denmark, Germany, France, Itly, UK, USA etc) [22-23]. About 20-30% of solid waste is recycled due to lack of basic recycling rules. Only scavengers are mostly engaged in this activity throughout the country to earn some money from recyclable items [24]. There are various financial and socio-economic factors which have constrained the management of solid wastes [25-26]. There is an urgent requirement to mechanize latest rules and regulations for management of MSW in order to meet the increasing demand of urbanization in terms of providing renewable energy source and the clean environment.

3.4. Characteristics and Energy Recovery Potential (ER_p) of MSW

Characteristic of MSW generated in Pakistan are almost similar because of equally four seasons of a year but only difference in weather pattern of various cities of the country. So only the characteristics of MSW generated in Hyderabad city were determined as in Table.2. By considering characteristics of MSW, it's ER_p in terms of BP_T and CV leading to power generation potential (PG_p) in kWh/t) have been estimated as given in Table.2 along with co-efficient of chemical formula (CCF). On the basis of that decision may be taken for MSWM in order to get energy.

Table 2: Characteristic and Energy Recovery Potential of MSW

Proximate Analysis							
MC (%)		Total Solids (%)		Volatile Solids (%)		Fixed Carbon (%)	
29.19		70.81		53.56		10.72	
Elemental Analysis							
C (wt. %)		H (wt. %)	O (wt. %)	N (wt. %)		S (wt. %)	Ash (wt. %)
33.29		3.65	21.11	0.73		0.12	39.04
Energy Recovery Potential							
CCF				BP_T		CV	
a	b	c	d	(m^3/tonVS)	kWh/t	Kcal/kg	kWh/t
39	58	17	1	567	216	1904	552

According to the Table.2, the moisture content and total solids of MSW were obtained as 29.19% respectively. The lower moisture content represents that MSW is beneficial for combustion process as it minimizes the ignition temperature as well as rises the calorific value of fuel and vice versa in case of high moisture content. This means lower moisture content reduces the cost of drying process as drying is required for combustion of MSW containing high moisture content in order to increase calorific value [27-28]. The volatile solids and fixed carbon of MSW were determined as 53.56% and 10.75% respectively on the dry basis. Whereas the volatile solids of pure biomass like forest residue and oak wood and pine are 79.9, 78.1 and 83.3% respectively [29]. Generally, volatile solids are inversely proportion to the fixed carbon. This means fuel having high volatile must contains low fixed carbon, the case is same for MSW generated in the Hyderabad, Pakistan like for MSW generated in the Arusha, Tanzania [28].

The calorific value of present study (i.e. 1904 kcal/kg) approximately shows the similarity with the caloric value of MSW generated in China and Malaysia as 1992-2092 kcal/kg and1500-2600 kcal/kg respectively [30-31]. On the basis of calorific value, PG_P of MSW in Hyderabad-Pakistan has been estimated about 552 KWh/t which lies in the range of power generation potential of MSW generated in the Eluru, A.P, India that is 500-600 KWh/t [9]. Similarly according to the biogas potential, PG_p of MSW was estimated to be 216kWh/ton (Table.2) by considering 30% conversion efficiency. The lower value of PG_P of bio-chemical process than the PG_P of thermo-chemical process represents that only biodegradable fractions of MSW contribute to produce energy during the bio-chemical conversion process. However, in the thermo-chemical process all biodegradable as well as non-biodegradable fractions take part to yield high energy potential.

4. Conclusions

The developed countries have reached to get energy from solid waste at record level by managing it properly but unfortunately Pakistan is until stood far from this precious resource. Because of growing population and over urbanization, the major cities of Pakistan generate about 25.420 million tons per year of MSW. The composition of MSW has 64% and 36% as organic and inorganic components respectively. Moreover, the MSW generated in the major cities of the country is averagely contributed by 42%, 22%, 3% and 33% as putricible, non-putricible (combustible), degradable and non-degradable wastes respectively. About 70% and 30% as collection rates in urban and rural areas respectively have been observed. Most of collected waste is either openly dumped into low lying areas or burned. Neither any engineered landfill nor any treatment facilities has been observed even in the major cities of the country. Only 20-30% of solid waste is recycled informally. Moreover, the observations of this study show that there is the lack of source segregation, insufficient waste collection, improper design of collection routes, lack of equipments, the unavailability of funds etc. The biogas potential and calorific value of MSW have been found to be 567 m^3/tVS and 1904kcal/kg respectively. The potential of bio-chemical and thermo-chemical conversion for producing energy in terms of power generation has been observed about 216kWh/t and 552kWh/t respectively.

5. Recommendations

Following remedial measures are made on the basis of findings which should be taken by government of Pakistan for better MSWM system in each city to recover energy.

- Formulation of new policies & regulations and their implementation regarding SWM at provincial level and also development of commission at national level is the need of an hour.
- Strengthen capability of institutions by allocation of funds according to current needs to manage MSW. Enhancing segregation at the source of generation of MSW which would be better option for selection of scientific treatment and/or disposal technique of solid waste.
- Proper selection of disposal and/or treatment method by considering various parameters like efficiency in terms of waste volume, infrastructure requirement, investment & operating cost, public acceptability, operation & maintenance consideration etc.

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