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Effective Utilization of Municipal Solid Waste as Substitute for Natural Resources in Cement Industry

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Abstract

The aim of this study was to evaluate the municipal solid waste (MSW) composition of Peshawar city and its affective utilization for energy purpose in the cement industry. A total 14 days consecutive testing of MSW samples was conducted for winter and summer periods for the purpose of evaluation of the waste composition followed by calculating its heating values. Compliance level of MSW at source was determined which was based upon the questionnaire distribution followed by the financial analysis and feasibility evaluation of the project. The results revealed that the average waste composition of the samples consists of organic waste contents (20.72%), combustible items (37.86%), readily saleable items (20.95%) and other miscellaneous waste items (20.46%). Moreover, the samples were then tested for the evaluation of calorific value and it was found that the heating value of MSW is recorded up to 35513 KJ/Kg whereas; the value for coal is around 38000 KJ/Kg. These findings revealed that the replacement of coal by MSW may be more efficient and might be effectively utilized in the production of cement as the energy production of MSW and coal is nearly same. In addition, the utilization of MSW as a replacement of coal has a great potential of enhancing the service life of the landfills. Besides, NPV analysis of this study revealed that the project is worthwhile to be implemented as it shows high returns regarding financial aspects.

Keywords: Municipal Solid Waste; Management Practices; Environmental Concerns; Dumping Areas; Calorific Value; Natural Resources.

1. Introduction

Currently, Pakistan is facing environmental problems and is under energy crisis. The country is also facing social concerns which are due to the mismanagement of MSW. These issues have achieved a greater level of alarming dimensions. Improper MSW management not only leads to environmental degradation but also attributes to the public health risks [1]. The enormous amount of waste being generated is due to the rapid industrialization, urbanization, over population, non-utilization of waste as a resource and improper MSW management from source to destination. The MSW generation rate is directly related to the socio-economic activities of the people. Higher social and economic activities lead to greater generation of MSW [2]. In urban areas, the expected population would be six billion people till 2050 [3, 4]. Prediction shows that the global population may reach up to nine billion by 2050 [3, 5]. Moreover, according to the assessment, the developing states may face 99% and 55% of population growth and urbanization rate respectively [3, 5, 6]. With the rapid pace of urbanization, the expected growth in rural and urban population may reach up to 34%

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and 66% respectively [7, 8]. Till 2050, the decreasing trend of the rural population while enhancing the urban sprawl is shown in Figure 1.

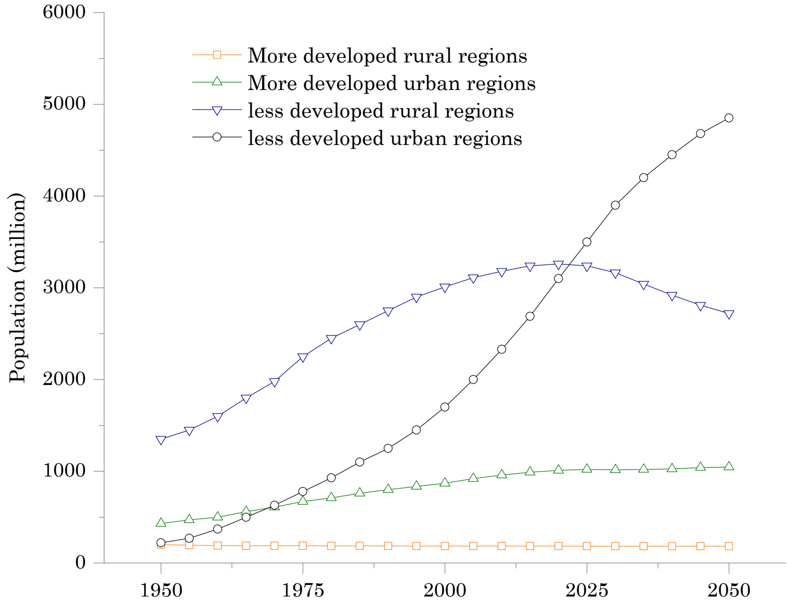

Figure 1. Percentage showing rural and urban population globally [7, 8]

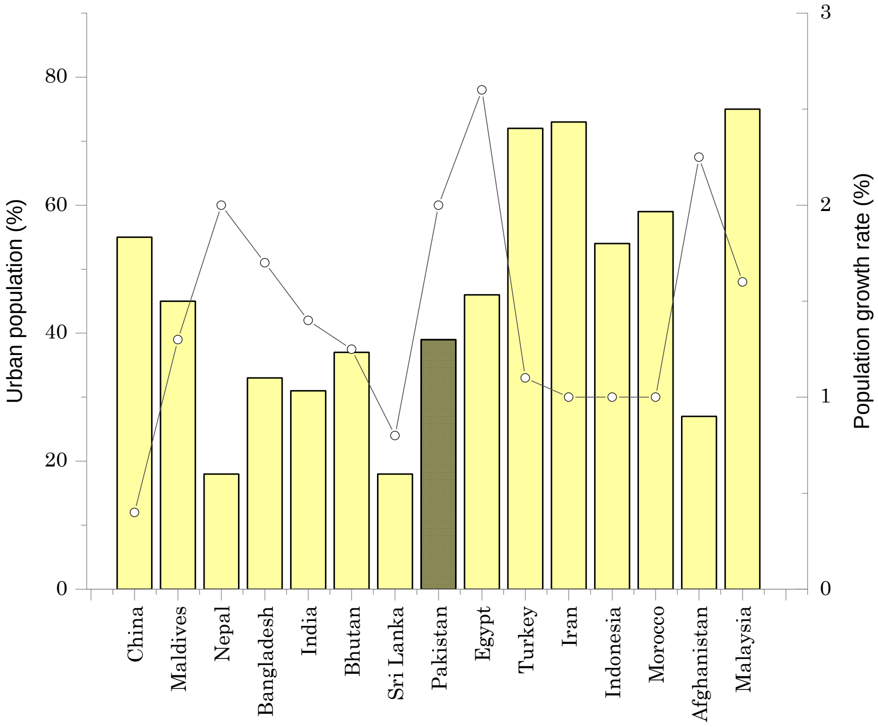

Figure 2. Different countries showing the urban population and rate of growth [8, 9, 10]

In comparison with the developed areas, the rural areas of the under developing regions are facing a decreasing trend in population whereas the urban areas are facing an increasing trend alarmingly. Pakistan like other developing states is also facing higher population growth rate. The current population of Pakistan is 189.12 million, out of which 115.2 million comprises of rural and 72.50 million of urban population respectively [9]. Currently, Pakistan is the sixth populated country in the world but its population is expected to reach to 363 million if it retains the same rate till 2050 [9]. Population growth rate (PGR) is a major indicator for the change in population that plays a vital role for a country to be economically developed. The PGR of Pakistan is more prominent in comparison with the Muslim and other neighboring states excluding Egypt and Afghanistan [9, 10]. People are drifting from rural to downtown areas in order to get better facilitation of education, jobs, life style and living and other such factors. This practice results in rapid urbanization growth in Pakistan. The population of metropolitan areas has increased from 38.6% to 39.2% during 2014 to 2015 [10], giving it a rating of three among the regional states as shown in Figure 2. Besides, the MSW generation rates in major cities of Pakistan in respective year is depicted in Figure 3 and tabulated in Tables 3 and 4.

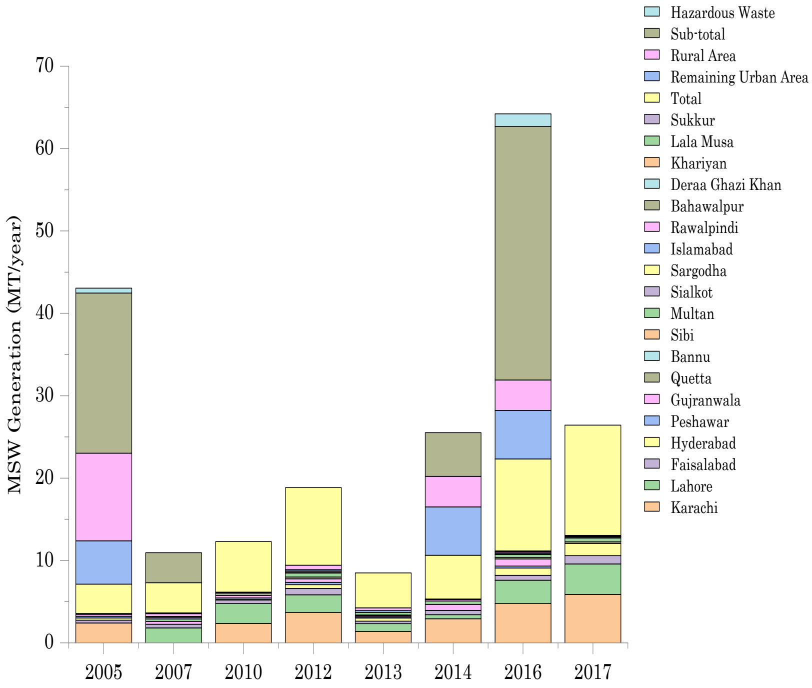

Figure 3. MSW generation rates in major cities of Pakistan in respective year

Urban population will cross 122 million by 2030 if the current trend in urbanization is increasing continuously [8, 9, 11], that will ultimately enhance the energy consumption [12]. Energy source is directly related to the survival of growing population. Energy is taken as a lifeline of the economy and is the main indicator in the sustainability of commercial, domestic and industrial revolution activities. The primary energy consumption (PEC) in Pakistan in year 2014 increased at an annual rate of 3.6% that lead to 66.8 million tons oil equivalent (MTOE) with non-energy purpose of 3.4 MTOE and transformation of 23.6 MTOE [10, 13]. The entire primary energy consumption is estimated to be 69.21 MTOE in the year 2015 whereas 71.7 MTOE in the year 2016 as shown in Figure 4.

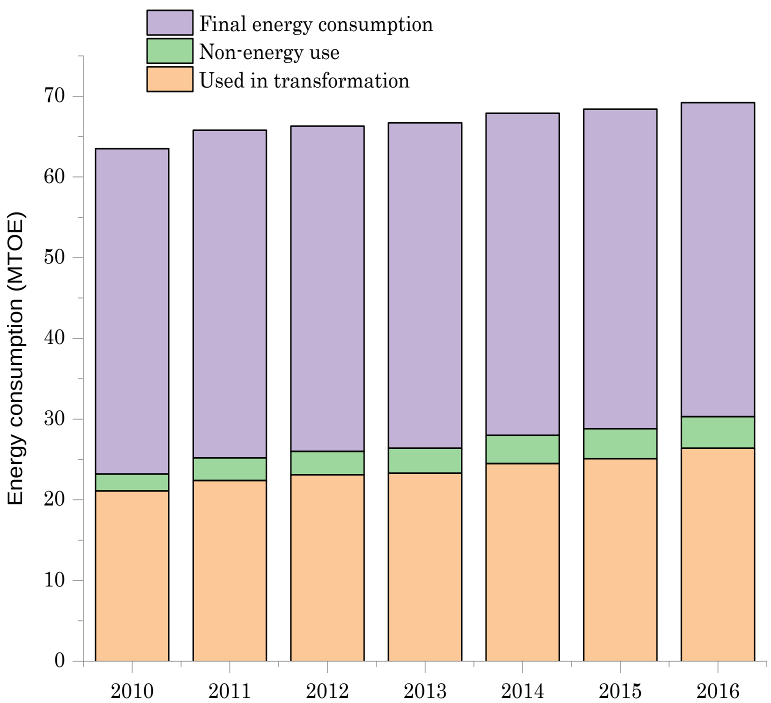

Figure 4. Utilization of elementary energy [10, 13]

Pakistan is relying on non-renewable energy sources for the energy extraction whereas other countries are extracting energy from biomass [9, 14], as depicted in the Figure 5. Energy needs for Pakistan is anticipated to increase at an ACGR of 4.37% to 6.09% which is dependent on the GDP growth that ranges from 116-148 MTOE till 2022 as shown in Figure 6 [13, 15, 16].

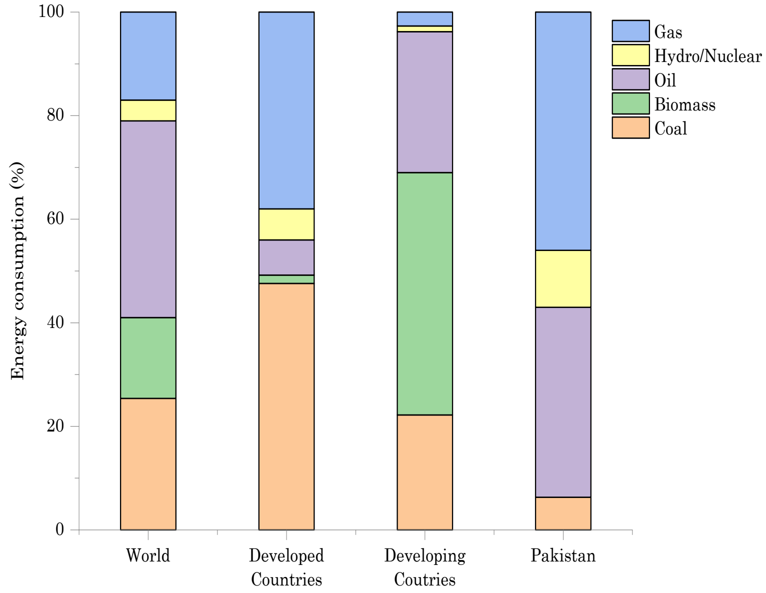

Figure 5. Furnishing of total elementary energy of Pakistan and globally [10, 13, 14]

The country is facing energy crises at an alarming accelerating rate and due to this fact; Pakistan is facing many challenges currently. Subsequently, this increasing breach amongst the energy supply and demand has given birth to economic crises in the country [17]. Due to the shortage of energy, the gas production is reduced that leads to dependency on fossil fuel and fewer usage of renewable resources like wind energy, solar energy or waste to energy programs [18, 19]. Moreover, the low budget situation of power supply firms, undeveloped power production capacity, limited hydel resources and cheap coal attributes to the energy shortage in the country [9, 12]. A financial development through an economic growth leads to positive and significant impact on energy consumption [12]. Besides, due to increasing population, the MSW generation is increasing each day that contaminates the environment and its surroundings by one way or another if the MSW is not managed in a right manner. Secondly, rapid urbanization is subjected to agricultural demand and industrial growth which ultimately requires energy sources. The world is using the non-renewable sources for energy production from centuries and the fossil fuel resources are depleting because of rapid growth in industrialization and population. Subsequently, the reduction of fossil fuel results in economic failure. Moreover, the energy utility pattern is overlapping specifically in Pakistan since the population and industrialization is growing at rapid rate [20]. As the income of Pakistan is categorized to be in the middle, the energy issues are getting worst since previous decades. Increase in economy and population leads to the continuous energy demands of the country [12]. Economic growth, development, energy security and sustainability are the key indicators of any energy system [10]. Due to shortage of power in the country, the economy's long run growth has decreased from 6.5% to 2% [11, 12]. This parameter has negatively affected the exports, international competitiveness, employment and poverty in Pakistan [21].

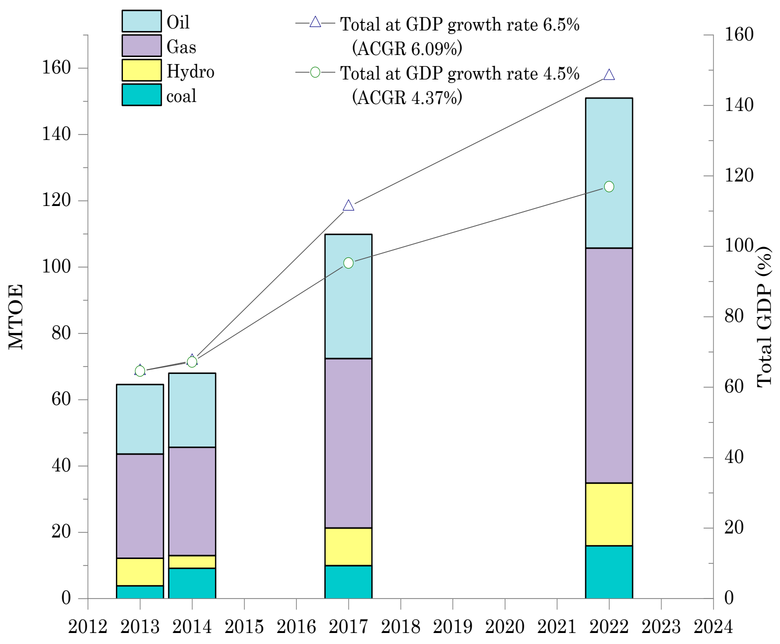

Figure 6. Projected energy demand [13, 15, 16]

It is the need of the current as well as future sustainability to save the world from environmental degradation and wastage of resources. The world is dependent upon fossil fuels since beginning. The reliance on such fossil fuel causes global warming that leads to the climate change issues due to human activities and utilization of these fossils [22]. These fossil fuels not only deplete the natural resources but also release various greenhouses gases i.e. CH_4, CO_2 and NO_x which causes adverse environmental impacts. The release of the mentioned gases from various sources has increased since 1970 that is mainly contributed by 40% from CH_4 and 60% from CO_2 [23]. The earlier studies [17, 24, 25], shows that MSW is releasing 550 Tg methane emissions per year globally which makes it the 4th largest contributor in the world. Some of the researches [26, 27], conclude that the mismanagement of MSW landfills contributed to third major source of methane emission which is predicted to increase to 816 MtCO2-eq till 2020 if they are not addressed in time. Currently, Pakistan is at place of 135th to contribute 0.8% of the global greenhouse gases and due to dependency on the non-renewable energy sources, this position is expected to increase by 2030 [17, 28, 29]. The large amounts of MSW generation due to technological development, economic expansion and changing lifestyle is attributing to serious environmental issues because of inappropriate management systems [30, 31, 32]. Like other developing states, Pakistan is also facing challenges in MSW Management because of the rapid urbanization and deficiency of formal recycling of waste into resources [28, 33, 34]. Despite of enormous amount of MSW generated, the economic growth of developing countries has severely affected due to the crises in energy [35]. Therefore, the discharge of emissions from plants that operates on non-renewable energy is one of the responsible parameters in environmental deterioration.

The world is looking up of substitutes for conventional non-renewable energy that would not only provide energy security but will also ensure an ecofriendly sustainable development. Likewise, the reliance on the conventional energy sources and improper MSW disposal leads to misbalance of demand and supply in the market that ultimately leads to the cost hypes of the non-renewable energy sources and over expenditures for handling the huge amount of MSW with no revenue generation. This practice is moving people to look up for more beneficial, viable and cheap energy sources across the globe [22, 35]. One the researchers [36] investigated the utilization of MSW as a replacement of alkali activated slag cement and concluded the improved characteristics of cement. Moreover, MSW is primarily used as a road subbase material, landfill structure material, embankment fill, as cement raw material and concrete products [37]. In one of the studies [38], MSW was successfully utilized in the production of eco-cement. This eco-cement was successfully produced from raw meals made up of 85% residues and 15% additives, and clinkered at 1000 °C, which was within the maximum operating temperature range of a typical incinerator. It showed no hydraulic reactivity but achieved an immediate compressive strength of over 50 MPa after carbonation activation.

In Pakistan, the exploitation of various renewable energy resources can never be denied, but unfortunately Pakistan is still under numerous energy crises and is facing a lot of challenges since last decades [12]. Hence, such energy crises may be counter balanced with the utilization of MSW. In this study, the MSW composition of Peshawar city along with its calorific value has been focused. In Pakistan, the annual progression rate of MSW generation is 2.4% that is replicating an alarming growth [28] and has raised a serious concern for its affective management [9, 28]. Concerning the mentioned issues, an effort has been made in this study to investigate the potential of MSW being generated in Peshawar city, Pakistan.

The rest of the paper is organized as follows. Section 2 briefly discusses the scope of the study, section 3 presents experimental program, section 4 provides results and discussion while the study is concluded in section 5.

2. Scope of the Study

In comparison with the developed states, the MSW generation rate in Pakistan is increasing day by day like other developing countries. The ability of implementing the 5R hierarchy of MSW management in its reduction, reusing, recycling, recovering and refusal is inadequate in the country. Consequently, the mismanagement of the MSW leads to economic, social and environmental issues. The MSW generation is directly proportional to the population growth. Since the population of Pakistan is increasing each day with the generation of huge amount of MSW that necessitates proper management but unfortunately, the MSW is thrown openly onto lands, water and alongside the streets and roads. Similar to other developing nations, Pakistan is not giving proper attention to the MSW management and the emerging concerns in this domain as a result of which the country is facing serious problems. The mismanagement of MSW is due to various reasons that include lack of human resources, improper infrastructure for MSW management facilities and weak financial conditions of the country. Therefore, this research work is carried out to find the MSW composition of Peshawar city, Pakistan followed by the assessment of calorific values of the combustible items for the purpose of energy generation along with monetary value of the saleable items in the MSW stream. In this way MSW would not only be utilized in an efficient way, rather to implement a sustainable MSW management program that might lead to the enhancement of economy, social acceptability and environmental feasibility of the country. For more details of the present study, the proposed plan for effective MSW management is depicted in Figure 8.

3. Experimental Program

3.1. Study Area

A pilot study was conducted in Peshawar city from December 2017 to June 2018. Peshawar is the capital of Khyber Pakhtunkhwa, Pakistan and is the ninth largest city of the country according to the census of 1998. It is situated in a valley near the Khyber Pass, eastern end. It is at a distance of around 170 Km from the capital of Pakistan. The climatic condition of the city is semi-arid, having slight winters and hot summers.

3.2. Waste Management Authority

Water and Sanitation Services Company Peshawar (WSSCP) is responsible for waste management of Peshawar city. WSSCP run under Peshawar Development Authority (PDA). The current waste management system focuses on collection, transportation and disposal only. PDA has divided the city into four major regions namely Town-I, Town-II, Town-III and Town-IV on the basis of collection regions whereas the disposal sites are located in three regions, i.e. Landi Akhun Ahmad dumping site, Hazar Khwani dumping site and Hayatabad Phase VII dumping site.

3.3. Dumping Sites

Hazar Khwani dumping site is owned by the government of KPK and is spread over an area of 1,089,000 sq-ft near Hazar Khwani chowk, Ring Road, Peshawar. The site is utilized for dumping the waste of town-I and II of Peshawar city that comprises of almost two-third region of the city. The site is situated at a distance of 6 km from ring road, adjacent to GT road bus terminal. The MSW is collected from the commercial hubs and urban areas including educational institutes, residential buildings and restaurants etc. There are 12 dumping pits and almost all of the pits have been occupied by the MSW till now. The area of each pit is around 54,500 sq-ft and the depth ranges from 100 to 300 ft. The area is surrounded by commercial and residential hubs.

Landi Akhoon Ahmad dumping site is utilized for dumping the MSW of town-III of Peshawar city that comprises of almost one-third region of the city. The site is situated at a distance of 1.5 km from ring road, adjacent to Pushtakhara chowk. This site comprises of seven pits, out of these pits, only one pit is available for dumping that is being used till now. The area of each pit is around 63340 sq-ft whereas its depth ranges from 250 to 400 ft.

The MSW of town-IV is dumped in a site located in phase 7 Hayatabad, Peshawar. In this facility the MSW is dumped in the dumping pits followed by a layer of soil on the day end in order to mitigate the foul smell. This site is operational since 1988 but as this site is reserved for the MSW of Hayatabad Township only therefore, it has not yet reached up to its saturation level. Around 100 tons of MSW is dumped in this facility on daily basis. The MSW management system at this site is relatively in a better condition but still it didn’t reach up to the benchmark of an ideal MSW management system.

3.4. Categories of Society w.r.t. Income Levels

The composition of MSW greatly depends on the income levels of an area. The MSW generation from high class income levels will be having much more valuable items as compared to the MSW stream of a low class income level area. The classes of areas are divided in the following categories.

3.4.1. High Income Class

These are the residential areas having relatively good infrastructure like buildings, roads, water, and security. The high class income area is properly planned with good MSW management systems. The people of such area normally work in corporate sectors having good income levels. These areas are generally occupied with small family households.

3.4.2. Middle Income Class

These residential areas are characterized by small apartments or flats. These areas are normally occupied by relatively more households as compared to high income class areas. The residents of such an area are normally job oriented people with average income level.

3.4.3. Low Income Class

These are the areas with poor amenities and social services with unplanned infrastructure. Such areas are located on the peripheries of Metropolitan cities normally known as slum areas. The residents of such an area normally do petty jobs like working as foremen.

3.5. Current and Proposed MSW Management Practices in Peshawar

The current MSW management practices in Peshawar focuses only on the collection, conveyance and disposing off of the wastes without utilization of the valuable items from the MSW stream which eventually leads to an economic failure and an unsustainable system. The current and proposed plan of MSW management is depicted in Figures 7 and 8 respectively.

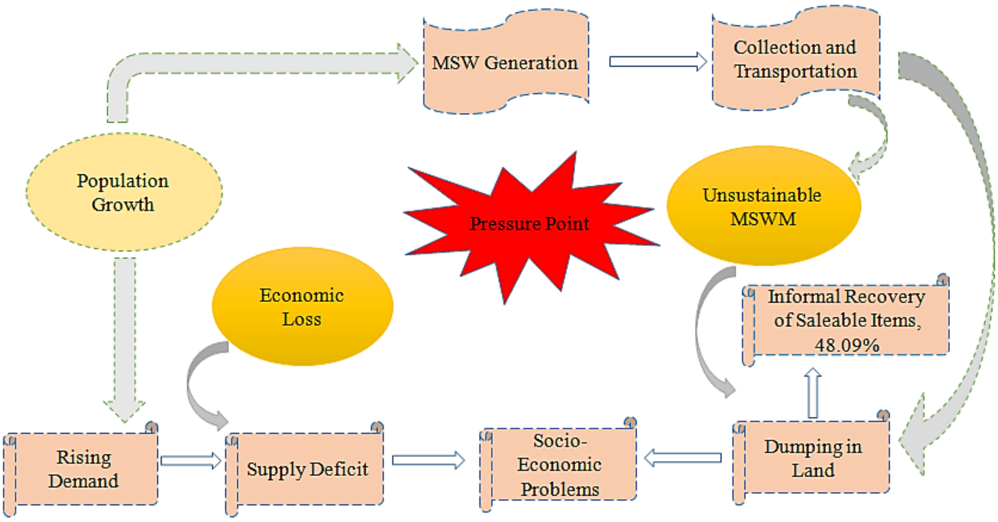

Figure 7. Current MSW management practices

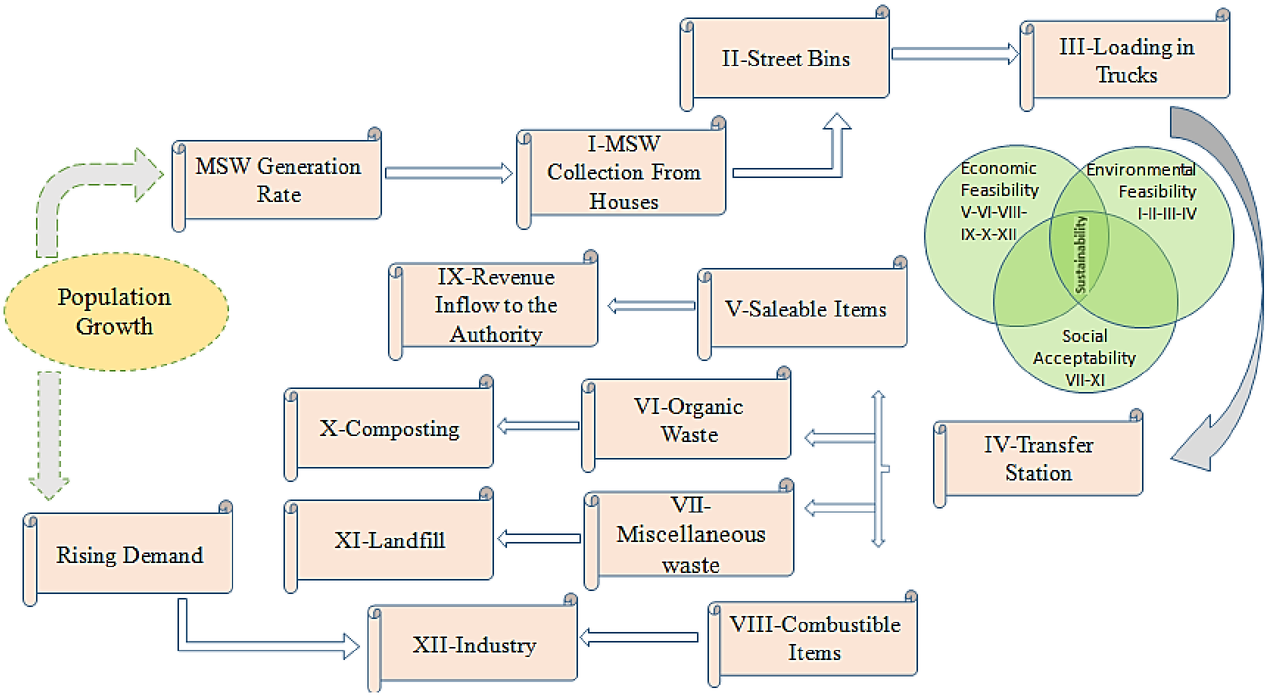

Figure 8. Proposed MSW management practices

3.6. Sorting Procedure

For the testing process of municipal solid waste, the whole Peshawar city is divided into five zones i.e. Zone –I, Zone –II, Zone –III, Zone –IV, Zone –V. The testing method mainly comprised of door to door waste collection system, which was further followed by manual sorting technique. The testing method used for this purpose was ASTM D 5231-92. Bags were distributed in the targeted areas for the collection of the waste. The waste collecting bags were gathered from the selected household in the evening and brought to the site, where all the waste was mixed for homogeneity and then the total weight of the waste was recorded. Consequently, the samples were gathered in an 800 kg weight followed by conning and quartering of the bulked sample till a standard sample of 94 Kg to 136 Kg is achieved as shown in Figure 9. The sample was further segregated into various MSW items. After segregation process, each sample was weighed and its percentile was recorded as depicted in Figure 10. The testing method was employed for a consecutive period of fourteen days in summer and winter seasons for the purpose of recording the variation and trends in the MSW stream. The sample of waste is categorized into various items as shown in the Table 1.

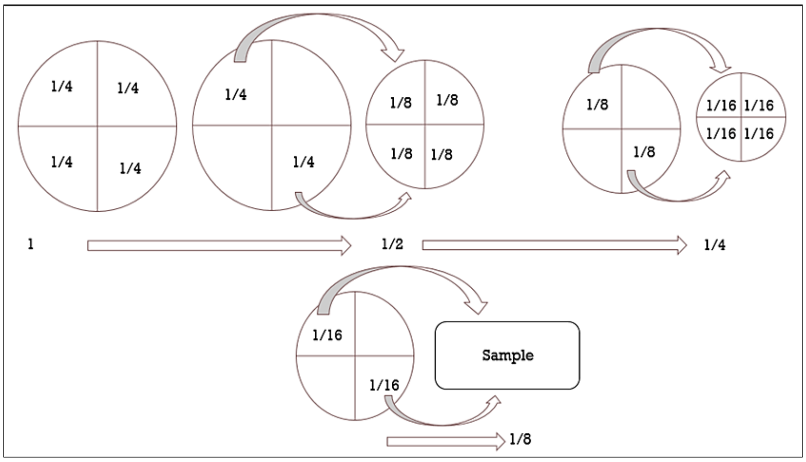

Figure 9. Coning and quartering procedure of 800 kg sample

Figure 10. Sorting procedure of MSW

Table 1. Typical residential MSW particulars

S. No	1	2	3	4	5	6	7	8	9	10	11	12	13
Particulars	Bread	Paper	Plastic	Rubber	Glass	Metal	Food Waste	Yard Waste	Diapers	Leather	Textile	Ceramics	Debris

The percentile of each item was calculated by the following formula:

$$\text{Percentage of each waste item} = \left(\frac{\text{Weight of segregated sample}}{\text{Weight of total sample}}\right) \times 100$$

3.7. Heating Value of MSW

For calculating the calorific value of MSW items, standard methods of ASTM D 5468-02 was followed. Combustion is considered as one of the most significant parameters in the energy production domain. The combustion process implicates the oxidation of component in the fuel. The heat exploited through this reaction is known as heat of combustion. Such test is conducted in Anmol Laboratory, Lahore, Pakistan through bomb calorimeter apparatus. The sampling procedure for calculating calorific value of MSW is given as under.

The sample of MSW is dried in an oven followed by grinding it into a homogeneous powder using grinding machine. For the purpose of finding the calorific value of the sample, the powder is converted into lumps. Prior to taking the lump for testing, calibration was performed using benzoic acid. After completing the calibration, MSW sample was suspended and the fuse wire was fastened across the electrodes followed by closing the oxygen bomb. The container of the calorimeter was filled with 2000 g of water whose temperature has been adjusted between 19-21^{o}C. To reach the equilibrium, stirring was performed for around five minutes before starting a measured run. During the combustion process, the cell got heated, subsequently, the heat was transmitted to water placed in the cell and the temperature of the cell was recorded. After that, the bomb was fired by holding the ignition button till the light turned off. The reference lines for both initial and final temperatures were calculated as follows.

ΔT is calculated as:

$$\Delta T = (Tc - rc(c-b)) - (Ta - r1(b-a)) = Tc - Ta - r1(a-b) - r2(c-b)$$

Gross calorific value is calculated by the following formula:

$$GCV = (\Delta tW - e1 - e2 - e3 - e4)/ms$$

W: Energy equivalent of the calorimeter in ^{o}C identified by standard tests

GCV: Heat of combustion of mass sample in cal/g, gross calorific value

ms: Mass (g);

Δt: Net temperature rise correction (^{o}C);

$e1$: Rectification of calorific values for heating of nitric acid when 0.0710N alkali utilized as a titrant;

$e2$: Rectification of calorific values for heating of sulphuric acid;

$e3$: Rectification of calorific values for combustion of fuse wire;

$e4$: Rectification of calorific values for combustion of benzoic acid sample (6318 cal/gm) (mBA) cal;

$c1$: Millimeters of standardized alkali solution;

$c2$: Sulphur content in the sample (%);

$c3$: Fuse wire consumed during firing (cm);

W: Energy correspondent of the calorimeter, determined in stabilization;

m: Mass (g).

Table 2. Population and MSW generation rates of the targeted areas of Peshawar city, 2018

S. No.	Zones	Reach	Areas Covered	Income Level	Population (in capita)	No. of Average Households	Total Waste (Kg)	Total Houses covered	Total People generating waste	Sampling Duration (days)
1	I	Charsadda Road link	Shahi Bagh Faqeer Abad Mahal TeraiI MahalTerai-II	Middle Income	93107	8	11480	190	1520	14
2	II	Ring Road Link	Sikandar Town Hazar Khwani Pishtakhara Achini Qamardin Garhi	Low Income	120917	8	10920	195	1560	14
3	III	University Road Link	Tehkal Arbab Road University Town Palosai Shaheen Town	High Income	129134	7	10360	210	1470	14
4	IV	Old City Peshawar	Yakathooth Jahangir Pura Karim Pura Lahori Gate Gulbahar	Middle Income	137169	8	11060	200	1600	14
5	V	Hayatabad	Phase-I Phase-II Phase-III Phase-IV Phase-V Phase-VI Phase-VII	High Income	34587	6	11340	250	1500	14

Table 3. MSW generation rates in major cities of Pakistan during 2005, 2007 and 2010

Major Cities	2005 [17]			2007 [39]			2010 [40]		
	Population	Generation Rate	Total Quantity	Population	Generation Rate	Total Quantity	Population	Generation Rate	Total Quantity
	(million)	(kg/cap/day)	(MT/year)	(million)	(kg/cap/day)	(MT/year)	(million)	(kg/cap/day)	(MT/year)
Karachi	10.82	0.61	2.42	0	0	0	13.38	0.61	2.35
Lahore	0	0	0	6.40	0.76	1.82	7.21	0.70	2.42
Faisalabad	2.31	0.39	0.33	2.50	0	0.43	2.91	0.48	0.43
Hyderabad	1.34	0.56	0.28	0	0	0	0	0	0.07
Peshawar	1.15	0.49	0.21	0	0	0	0	0.50	0.18
Gujranwala	1.31	0.47	0.22	1.40	0.43	0.34	1.67	0.47	0.30
Quetta	0.65	0.38	0.09	0	0	0	0	1	0.27
Bannu	0.05	0.44	0.01	0	0	0	0	0.44	0.01
Sibi	0.10	0.28	0.01	0	0	0	0	0.57	0.01
Multan	0	0	0	1.50	0	0.33	0	0	0
Sialkot	0	0	0	0.50	0.60	0.18	0	0	0
Sargodha	0	0	0	0.60	0	0.11	0	0	0
Islamabad	0	0	0	0	0	0	1.05	0	0
Rawalpindi	0	0	0	1.70	0.85	0.34	2.01	0	0
Bahawalpur	0	0	0	0.50	0	0.06	0	0	0.09
DG Khan	0	0	0	0.30	0	0.04	0	0	0
Khariyan	0	0	0	0	0	0	0	0	0
Lala Musa	0	0	0	0	0	0	0	0	0
Sukkur	0	0	0	0	0	0	0	0	0
Total	17.74	3.62	3.57	15.40	2.60	3.65	28.23	4.78	6.15
Remaining Urban Area	31.82	0.45	5.26	0	0	0	0	0	0
Rural Area	102.85	0.28	10.62	0	0	0	0	0	0
Sub-total	152.41	4.36	19.45	15.40	66.20	3.65	0	0	0
Hazardous Waste	0	0	0.58	0	0	0	0	0	0
Gross Total	0	0	20.03	0	0	3.65	0	0	0

Table 4. MSW generation rates in major cities of Pakistan during 2012, 2013, 2014, 2016 and 2017

Major Cities	2012 [41]	2013 [42]			2014 [43]			2016 [44]			2018 (Present) [45]		
	Total Quantity	Population	Generation Rate	Total Quantity	Population	Generation Rate	Total Quantity	Population	Generation Rate	Total Quantity	Population	Generation Rate	Total Quantity
	(MT/year)	(million)	(kg/cap/day)	(MT/year)	(million)	(kg/cap/day)	(MT/year)	(million)	(kg/cap/day)	(MT/year)	(million)	(kg/cap/day)	(MT/year)
Karachi	3.69	11.62	0.61	1.38	14.0	0.57	2.92	22.82	0.57	4.77	26.25	0.61	5.87
Lahore	2.15	6.29	0.61	0.95	0	0.15	0.51	10.35	0.75	2.83	12.38	0.82	3.71
Faisalabad	0.78	2.5	0.39	0.30	2.70	0.53	0.52	3.68	0.45	0.60	5.16	0.54	1.01
Hyderabad	0.45	1.39	0.56	0.38	9.20	0	0	2.99	0.8	0.87	4.57	0.89	1.48
Peshawar	0.29	1.24	0.49	0.15	0	0	0	1.79	0.38	0.25	0	0	0
Gujranwala	0.43	1.44	0.47	0.13	1.85	1.08	0.73	2.19	1.08	0.87	0	1.12	0
Quetta	0.22	0.73	0.38	0.10	0	0	0	1.14	0.38	0.16	1.35	0.41	0.20

Bannu	0	0	0	0	0	0	0	0	0	0	0	0	0
Sibi	0	0	0	0	0	0	0	0	0	0	0	0	0
Multan	0.46	1.45	0.45	0.32	2.06	0.53	0.40	1.95	0.53	0.38	2.13	0.58	0.45
Sialkot	0.12	0	0	0	0	0	0	0.58	0.31	0.07	0.52	0.33	0.06
Sargodha	0.13	0	0	0	0	0	0	0	0	0	0	0	0
Islamabad	0.16	0.74	0.53	0.22	0	0	0	0.74	0.53	0.14	0.62	0.56	0.12
Rawalpindi	0.54	1.77	0.58	0.32	2.50	0.21	0.19	1.77	0.21	0.14	0.34	0.34	0.04
Bahawalpur	0	0	0	0	0	0	0	0	0	0	0	0	0
DG Khan	0	0	0	0	0	0	0	0	0	0	0	0	0
Khariyan	0	0	0	0	0.04	2.57	0.03	0	0	0	0	0	0
Lala Musa	0	0	0	0	1.0	0.03	0.01	0	0	0	0	0	0
Sukkur	0	0	0	0	0	0	0	0.58	0.45	0.10	0.63	0.47	0.10
Total	9.42	29.17	5.07	4.25	33.34	5.67	5.32	50.59	6.44	11.17	55.87	7.18	13.40
Remaining Urban Area	0	0	0	0	5.87	5.87	5.87	5.87	5.87	5.88	0	0	0
Rural Area	0	0	0	0	3.71	3.71	3.71	3.71	3.71	3.71	0	0	0
Sub-total	0	0	0	0	33.34	5.67	5.32	188.02	7.58	30.76	0	0	0
Hazardous Waste	0	0	0	0	0	0	0	0	0	1.54	0	0	0
Gross Total	0	0	0	0	0	0	5.32	0	0	32.31	0	0	0

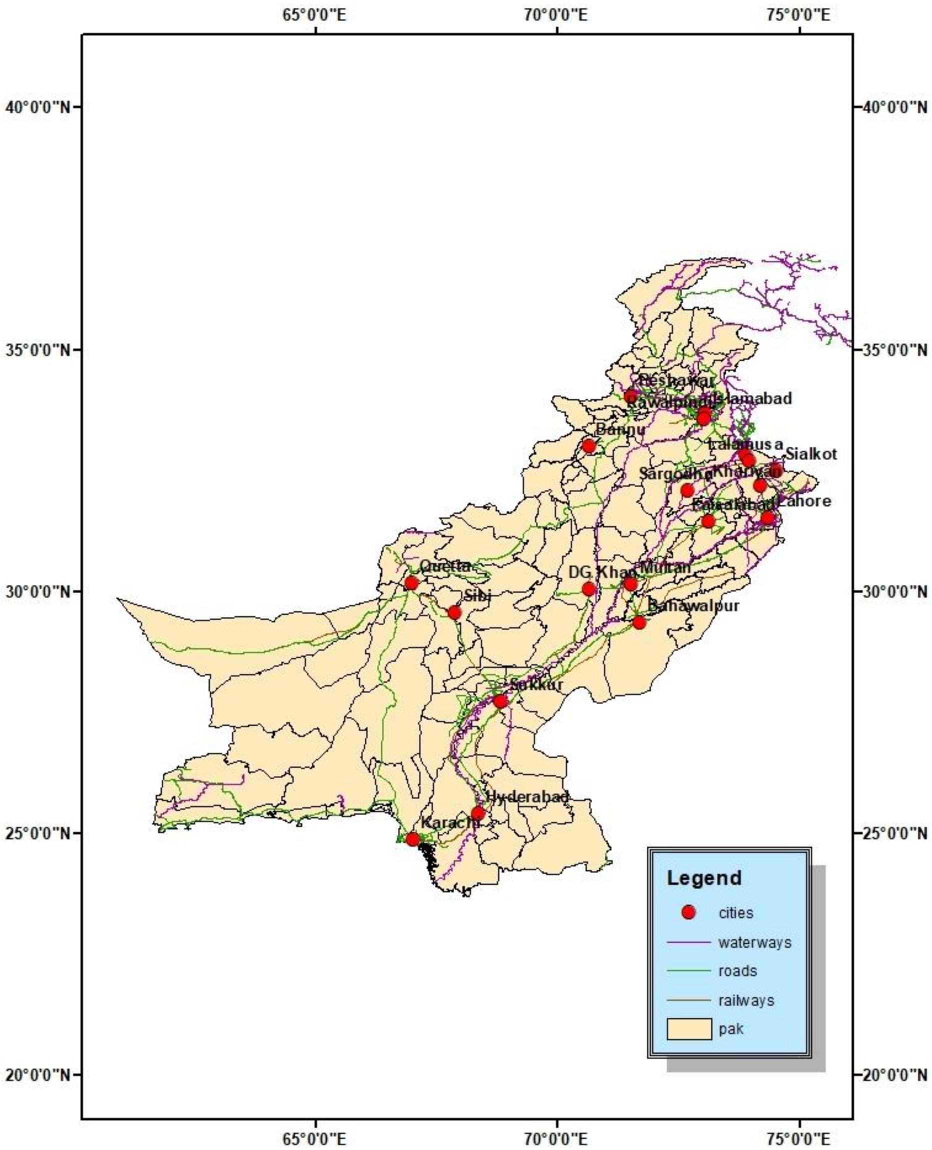

Figure 11. Map of major cities of Pakistan

4. Results and Discussion

4.1. Waste Composition Analysis

The total MSW generation in Peshawar is around 900 tons/day. However, the average waste generation rate of the households from the collected areas comprises of around 0.51 kg/cap/day. The zone wise waste generation rates are 0.54, 0.5, 0.503, 0.493 and 0.54 kg/cap/day for zone-I, zone-II, zone-III, zone-IV and zone-V respectively, as shown in Table 2. The higher values of waste generated is attributed to the higher socio-economic activities of the residents living in that particular area. As discussed earlier about the different income levels, zone-I is relatively a middle income area having more number of households as compared to zone-V.

The testing was conducted in five mentioned zones of the city that was carried out for the winter and summer seasons (year 2017-18) for consecutive 14 days so as to observe the seasonal variation in the MSW composition. The timings for distribution of waste collection bags kept at 7:00 hours and its collection was done at 18:00 hours. The waste was then brought to the site for the purpose categorization as mentioned in sorting procedure. The waste composition of each day was recorded and analyzed in spread sheets. The MSW generation rates in major cities of Pakistan are shown in Tables 3 and 4 and graphically shown in Figure 11. While the MSW composition of winter and summer seasons are listed in Tables 5 and 6 respectively and graphically shown in Figure 12.

The results show that food waste has the highest values of 21.20% and 20.24% among all the waste items for winter and summer seasons respectively. This is due to the fact that food being the basic necessity of the human beings; therefore the food waste appeared in higher fractions. Moreover, the left overs of food items like tea bags, peels and other food related items which could not be further utilized are also included in the food waste. The second highest item in the MSW stream is diapers which accounts for 14.77% and 13.91% in winter and summer seasons respectively. Since, the trend of using disposable diapers and wipes is more common rather to use normal washable clothes because of the changing lifestyles and urbanization, therefore it is being utilized in a very huge quantity and such diapers and wipes eventually joins the MSW stream. Paper waste is the third highest waste generated item and its values ranges to 14.54% and 13.75% for winter and summer seasons respectively. As the corporate sectors in the metropolitan and downtown areas of the city demands for higher printing activities to fulfill their requirements therefore, the generation of paper waste is a major concern. Plastic items are being used very commonly for packing different edible items such as cold drinks, juices and meals while their contribution is up to 13.80% and 12.20% in the winter and summer seasons respectively. Whereas, the glass item was used to be in greater quantities for packing the edible items but since the last decade, it is replaced with plastic packages, its composition ranges to 5% and 5.44% in winter and summer seasons respectively which is more reasonable generation. Ceramics are normally produced from construction projects and houses as a waste, since such waste is produced only when it gets broken down during handling, therefore, its quantity hardly reaches to 2% of the MSW stream.

It is revealed that there is not much variation between the results of winter and summer MSW compositions except the yard waste which demonstrates that during winters, the yard clipping activities drastically decreases as the production of the grasses in yards during such seasons is negligible in comparison with summer season. Moreover, the mean MSW composition of the winter and summer seasons along with various purposes for which the waste might be utilized is shown in Figure 13. While the dumping and utilization assessment of the current and proposed plan is depicted in Figure 14.

4.2. Overall Variation of MSW Throughout the Period

In overall testing period, the bread component, plastic, rubber, food waste, yard waste, diapers, debris in the waste stream was in increasing trend while paper, glass, metal, leather, textile and ceramics were in decreasing trend.

Table 5. MSW composition of winter season

Date (2017-18)	Percentage of items												
	Bread	Paper	Plastic	Rubber	Glass	Metal	Food waste	Yard waste	Diapers	Leather	Textile	Ceramics	Debris
22/12	9.96	18.76	11.44	2.89	7.12	4.18	17.6	3.17	15.54	3.51	4.09	1.79	0.63
23/12	10.73	17.35	9.66	2.62	5.94	4.28	20.33	4.56	11.43	4.04	4.12	1.59	0.54
24/12	13.98	16.92	13.48	5.24	2.56	4.5	21.89	1.73	16.11	2.69	2.61	2.3	0.44
25/12	12	13.76	13.27	2.03	5.66	5.66	22.21	1.34	15.41	3.97	3.3	1.12	0.53
26/12	9.7	12.2	15.97	2.55	6.16	3.57	20.16	3.59	16.09	3.59	4.11	1.23	0.56
27/12	15.37	14	18.7	3.63	4.51	2.95	20.73	1.72	13.19	3.29	2.36	2.32	0.86

28/12	15.5	15.84	16.63	2.55	5.4	3.1	18.57	2.2	14.38	2.95	2.05	2.5	0.48
29/12	11.35	13.33	15.59	3.21	3.61	4.2	21.59	2.79	15.23	4.24	2.1	1.02	0.59
30/12	10.04	15.49	15.7	2.98	3.94	3.92	23.91	2.39	13.87	3.69	4.8	1.1	0.68
31/12	10.86	14.82	14.53	5.76	4.56	3.46	24.1	3.33	16.02	2.64	3.41	1.65	0.21
01/01	10.24	11.38	13.55	2.12	4.55	2.31	25.94	2.32	16.05	4.1	4.17	2.15	0.98
02/01	9.07	15.29	13.09	2.32	5.8	3.5	22.82	2.14	15.13	4.45	2.37	1.98	0.43
03/01	9.82	13.35	10.96	2.54	5.39	2.04	15.6	2.61	13.12	3.09	2.78	6.2	1.33
04/01	16.58	11.11	10.63	2.83	4.8	3.29	21.35	3.25	15.25	3.77	2.54	2.53	0.71
Ave:	11.80	14.54	13.80	3.09	5.00	3.64	21.20	2.65	14.77	3.57	3.20	2.11	0.64

Table 6. MSW composition of summer season

Date (2018)	**Percentage of items**												
	Bread	Paper	Plastic	Rubber	Glass	Metal	Food waste	Yard waste	Diapers	Leather	Textile	Ceramics	Debris
07/06	10.3	18.23	12.51	2.65	6.96	4.12	20.33	6.43	11.34	4.28	4.19	1.98	0.58
08/06	10.13	15.27	11.37	3.87	5.54	3.97	21.21	6.78	15.5	3.87	6.17	1.68	0.59
09/06	11.95	14.86	12.26	2.45	3.33	4.08	19.12	5.48	12.43	2.67	2.59	2.66	0.57
10/06	13.29	11.87	13.35	5.34	5.07	4.77	19.19	4.96	15.97	3.02	2.56	1.93	0.52
11/06	11.32	11.55	12.03	2.03	5.09	3.65	19.33	5.69	11.23	3.12	3.64	1.83	0.57
12/06	13.6	12.75	14.3	3.62	6.25	3.39	20.88	4.98	14.99	4.05	3.54	1.89	0.67
13/06	13.99	12.25	12.98	2.67	5.52	4.04	20.34	4.97	15.84	3.2	2.55	1.76	0.68
14/06	15.15	16.39	13.2	2.98	5.23	4.98	21.76	6.59	10.09	4.11	3.96	1.12	0.73
15/06	8.57	15.32	11.11	2.54	5.35	3.9	20.2	6.7	11.82	3.72	3.72	2.48	0.77
16/06	12.11	14.19	12.04	2.62	3.26	3.92	22.92	5.76	16.17	2.97	3.14	1.21	0.75
17/06	12.63	12.11	11.98	5.43	5.26	3.98	18.03	5.53	15.5	1.9	2.4	2.13	0.84
18/06	11.14	10.93	12.21	2.55	5.23	3.33	20.24	6.74	12.33	3.68	3.79	0.93	0.4
19/06	13.23	14.36	12.12	3.23	7.26	2.56	20.66	5.34	16.14	3.77	2.34	2.54	1.23
20/06	12.3	12.45	9.4	2.89	6.82	3.81	19.17	6.11	15.35	3.28	3.44	1.94	0.63
Ave:	12.12	13.75	12.20	3.21	5.44	3.89	20.24	5.86	13.91	3.40	3.43	1.86	0.68

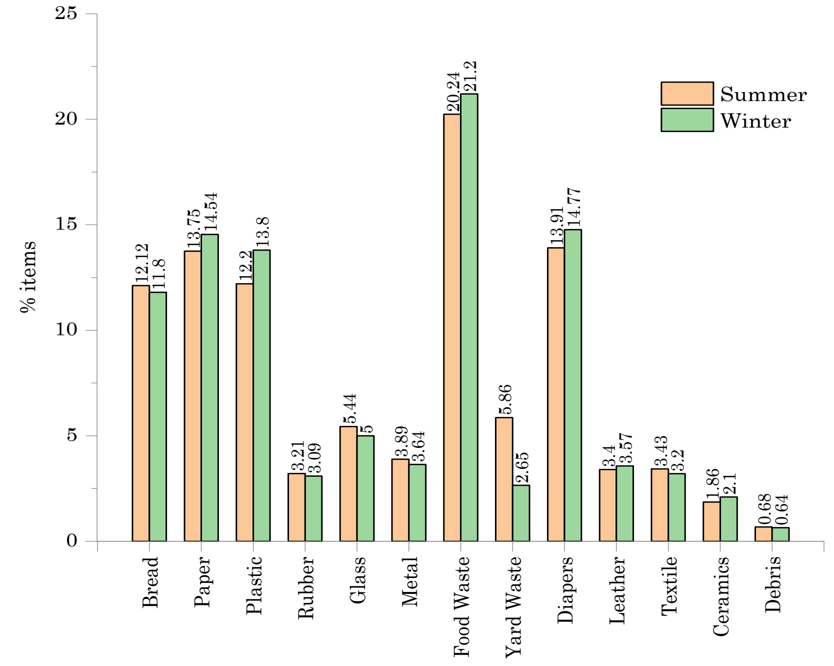

Figure 12. Average municipal solid waste composition (Dec 2017 to June 2018)

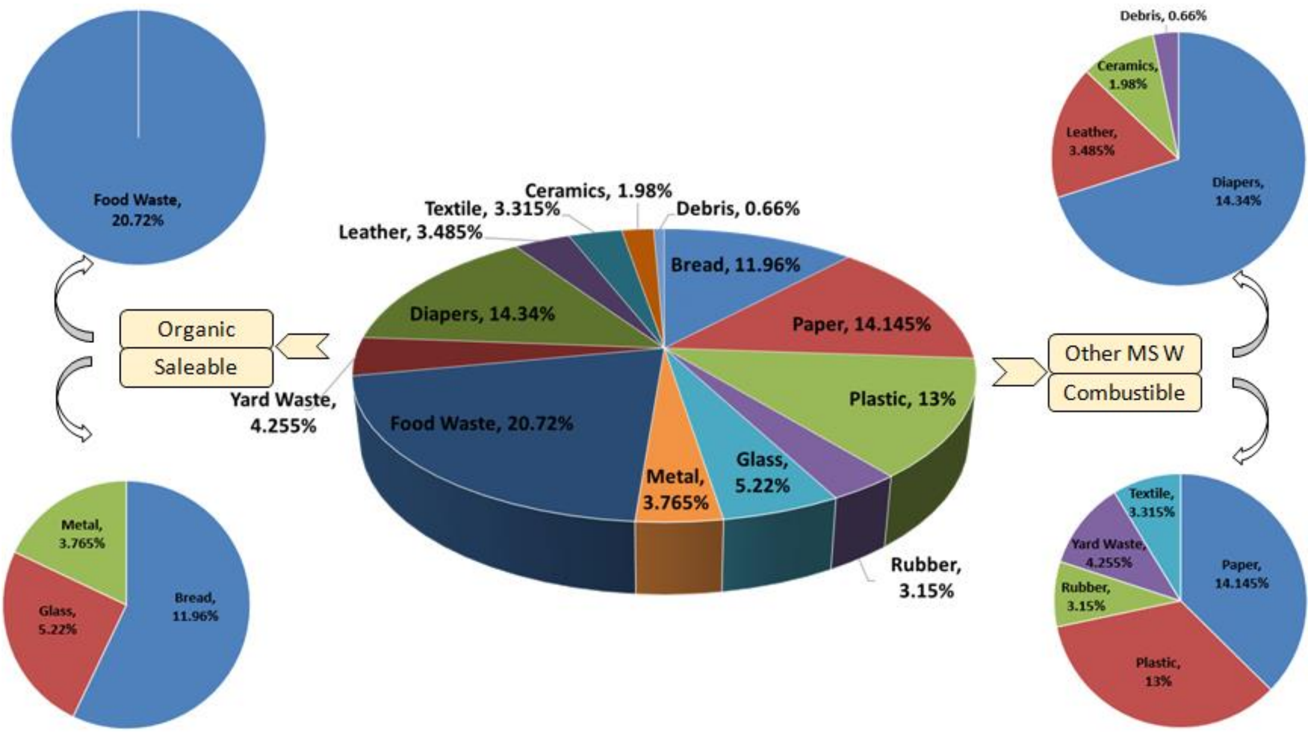

Figure 13. MSW utility for various productive purposes

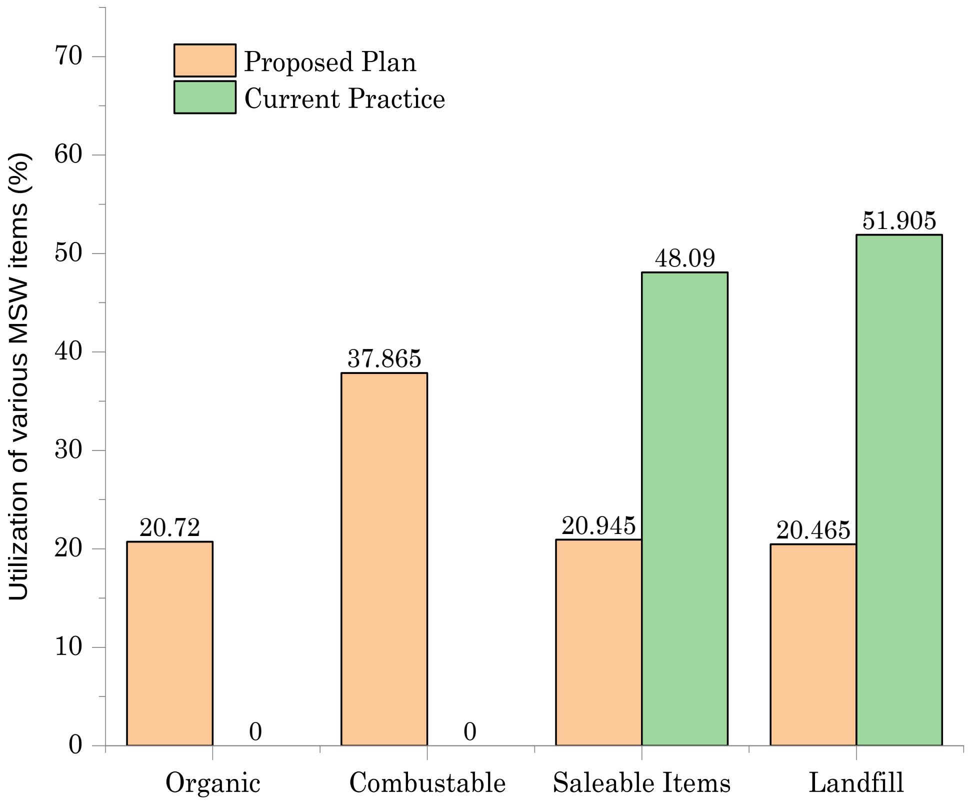

Figure 14. Utilization of MSW percentages in current and proposed plan

4.3. Compliance Level of MSW at Source Segregation

A survey of source separation of waste into organic, combustible, readily saleable and other waste items was conducted in the targeted area which was based upon the questionnaire distribution. Out of 2600 respondents, 2127 (81.8%) were willing to go for a source segregation system, 255 (9.8%) were unwilling for this practice whereas 218 (8.4%) did not responded to the questionnaire. The main reason for willingness attributes is due to the fact that the respondents well understand that there is lack of proper MSW management and consequently a little effort of the respondents can lead to a cleaner society and a better MSW management system. On the other hand, the unwillingness of some of the respondents attributes to the fact that they lack confidence in changing the system. Whereas, the respondents excuses to respond is because they were unaware of the worth of proper MSW management practices.

4.4. Financial Analysis

The total daily generation of MSW in Peshawar city is 900 tons. To assess the tonnage of each MSW item, the waste composition acquired from the testing is performed on 900 tons. Furthermore, a detailed survey regarding the monetary value of the saleable items was also conducted at the scrap purchasing vendors situated near Jamrod road, Peshawar (Industrial Estate, Hayatabad). The saleable items are sold out by the scavengers to the scrap dealers which are further purchased by the local material contractors for supplying it to the respective industries.

Table 7 shows the quantity in tons of the saleable items generated on a daily basis. The tonnage is based on the total waste estimates of the city. Subsequently, the total average revenue generation of the saleable items is acquired from the MSW stream. The total tonnage of the combustible items on a daily basis is shown in Table 8.

Table 7. Quantity of revenue generation of saleable items per day

Components	Average sample (Kg)	Expected daily generation (900 tons)	Price per ton (USD)	Revenue generation/day (USD)
Bread	11.96	108	120	12960
Glass	5.22	47	15	705
Metal	3.75	46.98	190	8926
Total daily revenue	-	-	-	22591
Total monthly revenue	-	-	-	677730

Table 8. Quantity of combustible items generated per day

Components	Average Sample (Kg)	Expected Daily Generation (900 Tons)
Paper	14.15	127.35
Plastic	13	117
Rubber	3.15	28.35
Yard	4.25	38.25
Textile	3.31	29.79

4.5. Feasibility Evaluation of project

4.5.1. Evaluation for the Combustible Items

Calorific values of MSW items

The MSW items specified for evaluating calorific values were tested in the Anmol Scientific Laboratory, Lahore, Pakistan. All of the tests were conducted at room temperature ranging from 19°C to 21°C. Both separate and mixed samples of waste were analyzed during the testing operations. The heating values and comparative cost analysis of MSW and coal are listed in Tables 9 and 10 respectively.

Table 9. Heating values of various MSW items

S. No.	MSW item	Calorific Value (KJ/Kg)
1	Mixed MSW	35513
2	Yard waste	18158
3	Plastic	28970
4	Textile	18079
5	Rubber	8171
6	Paper	13560

Table 10. Comparative Analysis of cost of MSW and coal

Costs	Coal	MSW
Transportation Cost (USD)	82	82
Material Cost (USD)	228	0
Calorific Value (KJ/Kg)	36500	35513

The heating value of coal is around 30000 KJ/ Kg to 38000 KJ/ Kg. The coal being utilized in Cherat cement factory, Khyber Pakhtunkhwa, Pakistan during the incineration activity of manufacturing process of cement that costs around 310 USD per ton. Meanwhile, the same quantity of MSW costs 110 USD per ton. However, the MSW if utilized for the same purpose might induce a huge price cut off in the final product. An analysis has been performed on the economics between the two items i.e. coal and MSW. Table 11 shows a comparison of the cost of the cement unit price when coal and MSW is utilized as a combustible material.

Table 11. Cost analysis of final product

Parameters	Cost of coal per bag (USD)	Cost of MSW per bag (USD)
Cost of combustible items	1.12	0.059
Material cost	1.49	1.49
Government tax	1.12	1.12
Total cost of final product	3.73	2.67

From the above parametric study, one can easily assess the financial feasibility of the conventional and proposed plan of BCR (benefit to cost ratio).

BCR = Value of benefits/ value of costs

BCR = Unit price of cement per bag by coal / unit price of cement per bag by MSW

BCR = 3.73/ 2.67

BCR = 1.39

Thence, the proposed plan is feasible. Feasibility of a project is ascertained with the help of BCR. BCR corresponds to a conventional way of analyzing cost versus benefits that is performed for the purpose of finalizing the entire feasibility of the project. For its value equal or greater than 1, the project is considered feasible. However, for a project the value of BCR if less than 1, it cannot be implemented [46].

4.5.2. Evaluation for the Readily Saleable Items

In order to initiate this work, labor is needed to segregate this waste so as to provide a quick segregation process. A detailed survey has been conducted near the Khyber Teaching Hospital Peshawar, wherein the labor were interviewed for the daily wage they are getting. 40 labors were interviewed for this purpose. Among these 40 labors, 30 were working for a daily wage of 4.75 USD whereas the remaining 10 labor were willing to do the work for 4.2 USD. According to the survey done in the field, it takes around one hour for a person to segregate 100 kg of waste. Table 12 shows the monthly labor expenditures required to segregate 900 ton of daily waste generated in Peshawar city.

Table 12. Expected monthly labor cost on the project

Waste Generated (Tons)	900
Shift (Hrs.)	8
Labour (Quantity)	1100
Wage (USD)	4.5 (Avg.)
Daily Expenditures (USD)	4950
20% Overhead (USD)	990
Daily Expenditures (USD)	5940
Monthly Expenditures (USD)	178200

Water and Sanitation Services Company, Peshawar (WSSCP) works under PDA and WSSCP provides services for the MSW management in Peshawar City. The detail of monthly expenditures of WSSCP for management of the MSW along with total expected labor cost is depicted in Table 13.

Table 13. Current expenditures by WSSCP for MSW management along with expected labor cost

Operations	Costs (USD)
O & M Costs	3800
Staff Salaries	31200
Labour Costs	263250
Grand Total (Monthly)	298250

Furthermore, a financial assessment of the expenditures and expected revenue generation from the saleable items of the MSW has been performed to find out the BCR and feasibility of the proposed plan. In this concern, the formula of BCR is stated as.

BCR = Generation of Revenue/ Total cost for MSW management

BCR = 677730 / 178200

BCR = 3.80

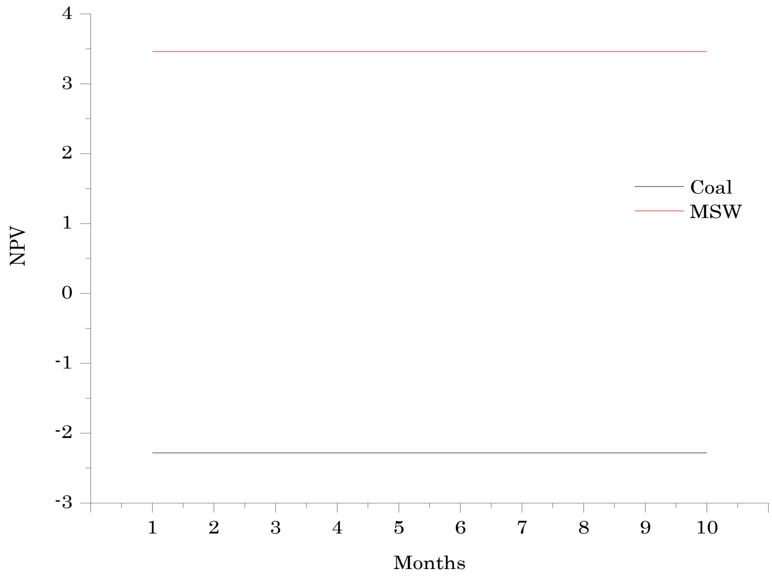

Figure 15. Net inflows and outflows (USD)

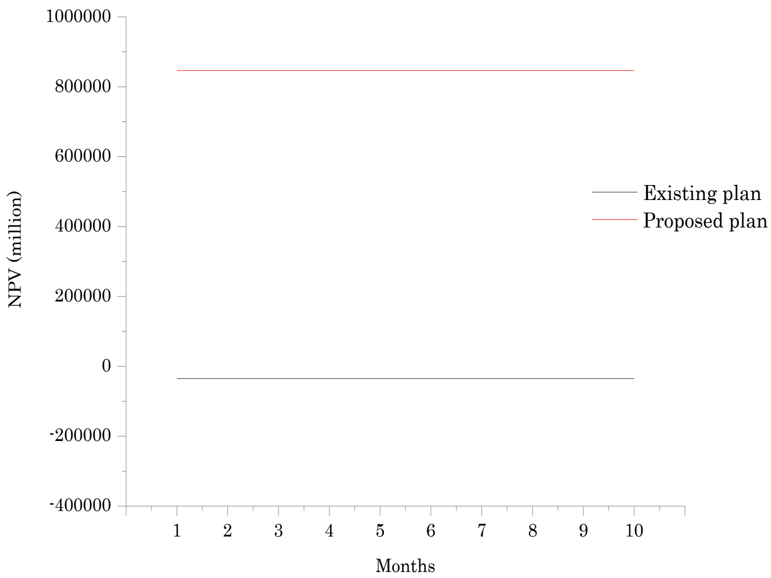

Figure 16. Net inflows and outflows (USD)

The BCR value clearly states that the project is feasible since the value of BCR is above one. A 3.80 BCR depicts that by investing 1 USD, the return is 3.80 USD. The result reveals a considerable revenue generation potential from the MSW of Peshawar city.

The Figures 15 and 16 show the net inflows and outflows of the project for a period of 10 months. According to the field of economics and finance, a project is feasible if the Net Present Value (NPV) is positive. It can be seen that the NPV of the project is 0.85 million USD. NPV is the net present value of a cash flow. As the money that is to be received after 2-3 years does not have the same value as it has today. So, from the NPV value it is evident that the money which will come after 1-10 months from now is worth waiting for whilst we spend our investment today. Since the NPV for the project is not only positive but it shows high returns. Hence from a finance perspective, this would be an ideal project.

As the average budget of PDA is 72 million USD per annum (PDA Budget, 2015-2016), this project is not only self-sustainable, but will also account for 11.29% of PDA's annual budget. This will be better than any other sources of budget for PDA itself as PDA would not be reliant on third-party customers or government for sanctioning this budget.

5. Conclusions

- From the findings it is revealed that the municipal solid waste (MSW) collected from Peshawar city holds huge impedance on energy production. For instance, the expected energy production of both the MSW and coal is nearly equal hence; the substitution of coal by MSW proved to be more efficient and might be effectively utilized for the production of cement. Consequently, the cement industry would not rely on the natural energy resources that lead to the utilization of MSW for its production.
- The data revealed that by the utilization of MSW as an energy resource induced a price cut off up to 28.4% per bag of cement production.
- The MSW being utilized for the energy production has a great potential of enhancing the service life of the landfills, subsequently the environment may be avoided by further deterioration. Since, the landfills located in Peshawar city are experiencing a huge amount of waste on daily basis; the utilization of MSW in the production of cement might enhance the capacity of dumping sites by 37.87% as it would not get dumped into the landfills. The residents living in the surrounding of these landfills can be secured from the unhygienic conditions and health issues associated with open dumping.
- Currently, PDA is spending 35000 USD on collection, transportation and dumping of the city waste and getting no return on the investment. However, the revenue generation from the saleable items if implemented at the authority level will not only generate monthly revenue of 6,77,730 USD but it will enhance the capacity of the dumping site by 20.95% as well.
- A benefit to cost ratio (BCR) of 1.39 demonstrates that the project might be feasible, economical and may be effectively implemented in cement industry. Consequently, the inflation in cement may be controlled and hence it may flourish the construction industry by encouraging the investors. On the other hand, the saleable items alone produce a BCR of 3.80 which will not only induce high returns into the system but will create employment opportunities for the individuals as well. Moreover, by utilizing the waste as a useful resource, a greater execution of waste management regulations with an improved relationship of public authorities with private sectors might be established.
- An NPV of 0.85 million USD shows that the project is worthwhile to be implemented as it shows high returns regarding financial aspects. Meanwhile, the local government of Pakistan is responsible for sanctioning developmental funds to Peshawar Development Authority (PDA). The annual budget of PDA for the year 2015-2016 is 72 million USD for such practices. By implementation of this proposed study, PDA might not only be able to manage the MSW effectively, rather it would induce a cash inflow of 11.29% to its annual budget, hence PDA might not be dependent on a local government for sanctioning of funds up to some extent (11.29%) that may lead to a self-sustainable system of the authority.
- The organic wastes if utilized for the production of animal feed or compost fertilizers may enhance the serviceability of the landfills by 20.72%. However, the other leftover MSW which comprises of only 20.47% of the total MSW stream that will eventually be dumped in the landfill which is quite lesser in comparison with the current MSW management practices. The significance of the data acquired by the authors suggest further study on sanitary land-filling technique rather than open dumping as abundant energy might be expected from biogas generation.

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7. Conflicts of Interest

The authors declare no conflict of interest.

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