Scientific Journal of Impact Factor (SJIF): 5.71

e-ISSN (O): 2348-4470
p-ISSN (P): 2348-6406

International Journal of Advance Engineering and Research Development

Volume 7, Issue 01, January -2020

Municipal Solid Waste Characteristics; A Case Study of Nowshera City, Khyber Pakhtunkhwa

Zeeshan Baseer[1], Shahryar Khan Baseer[2]

[1]M.Sc Environment Engineering, University of Engineering & Technology, Peshawar, Pakistan
[2]Director Environmental Engineering, Planners Consultant Engineers, Peshawar, Pakistan

Abstract —*Assessment of Municipal Solid Waste, its generation, characteristics, management and issues for Nowshera City was carried out according to ASTM-D5231-92-2008 testing method, while a general study on laws governing SWM was also discussed. The data generated was compared to the MSW assessment of other cities of Pakistan to find similarities. Estimated amount of recyclable material in MSW was found out while estimated amount of energy produced in Waste-to-Energy plants on Nowshera city waste was calculated. Environmental tests on river water and hospital waste was carried out. In the end the best Solid waste management solution for Nowshera city based on the project was discussed.*

Keywords-*MSW generation; waste characterization; water contamination; city waste generation; oxygen demand; Kabul River; scavenger; biohazard; hospital waste; most probable; water quality; leeching; waste to energy.*

I. INTRODUCTION

1.1. Background

Before the industrial revolution, population of countries were not concentrated in the cities, therefore there was no waste disposal problems. Similarly there weren't many products (and packaging) available and people used to reuse their tools, equipment, clothes etc. The main waste produced during this time was ash and human waste, that too in smaller concentrations (1). Archaeological excavations of ancient civilizations have found that early human waste was mainly composed of ash from fires, wood, bones and vegetable waste. The waste was simply packed into the floor over time or brushed aside (1).

During the industrial revolution in the 18th century, large populations moved to the cities to work in factories, due to which solid waste management became a big problem. In large cities of England, the build-up of waste caused a rapid deterioration in levels of sanitation and general quality of urban life. The streets became choked with filth, and with it diseases and infestation of rodents also increased, bringing with it even more diseases (1). With increasing devastation of Cholera and other infectious disease outbreaks, public debate on waste management gained popularity, which resulted in the formation of the World's first Laws and Guidelines for management of waste in 1848, in London, UK (1).

After discovering the dangers of MSW in the 1800's, the MSW is now managed by the municipal authorities of each city. This management is done through daily or weekly collection, storage, transport and final disposal. The SWM Hierarchy is an important component for managing the solid waste efficiently. The Hierarchy has five options that are arranged according to their energy or environmental benefits (2).
The five options of SWM Hierarchy are shown in the figure below

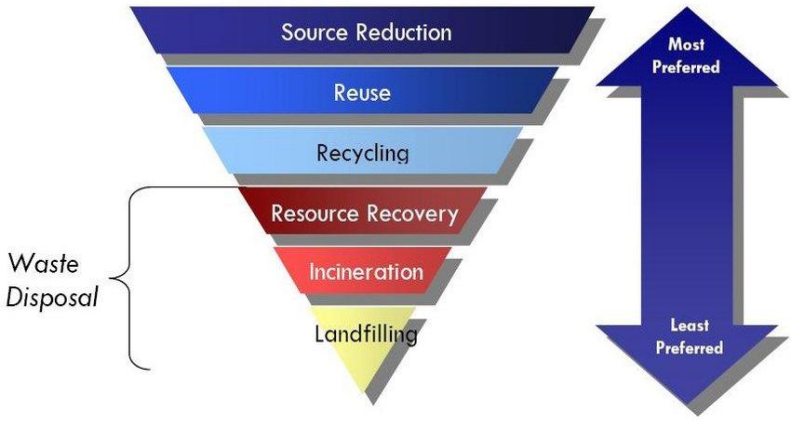


Figure of Solid Waste Management Hierarchy, showing preferred and least preferred options among the five.

The most preferred option is to reduce waste at source. Minimizing the use of dangerous or polluting materials and also reducing packaging material from products to reduce the quantity of waste. While the least preferred method is to dispose it in engineered sanitary landfills.

Nowadays the typical municipal solid waste (MSW) consists of Organic Waste (Leaves, food remnants etc), Paper/paperboard, Glass, Metal, Plastic, Textile, Solid/Rock/Construction material etc (3). Municipal Solid Waste (MSW) is generated at various stages of daily human life activities. And if it is not properly and safely managed, the accumulation of this waste leads to adverse impacts on human health and environment (4)

1.2. Solid Waste Management in Pakistan:

Due to continuing economic growth, urbanization and industrialization the volume and variety of solid and hazardous waste increases around the World. Under a UNEP study, it is estimated that total amount of MSW generated globally increases by 8% per year. (5)

According to a SWM study called "Guidelines for Solid Waste Management" (June 2005) conducted by EPA, JICA and UNDP in Pakistan (6), the following points are made about SWM in Pakistan;

- There is inadequate waste management. Only 51-69% of areas covered for SWM services
- Municipal SWM services are irregular, inefficient and manual
- Although scavengers play an important role in recycling, there is no support for them or any support structure
- There is very poor management of hazardous waste (hospital, factories etc)
- Municipals spend considerable budget on SWM, but they don't get any funds or taxes for SWM improvements and maintenance.
- Open burning of waste is common, adding to air pollution

Similarly, "National Study on privatization of solid waste management in 8 cities of Pakistan - EPMC (1996)" calculates that Pakistani cities are growing at the rate of 3.67-7.42% annually (7). Major cities in Pakistan are estimated to double their population in the next 10 years. These cities, with such high influx of population and inadequate or non-existent system of SWM in place, create situations to generate high concentration of waste.
It is estimated that in 1996, 54,888 tons per day of solid waste was generated in Pakistan (7). The study revealed that rate of generation of waste on average varies from 0.283- 0.613 kg/capita/day. Or 1.896 - 4.29 kg/house/day in all selected 8 cities (7). For 2018, the estimated Solid waste generation with 7% compound increase will be around 243,175 metric ton per year.

1.3. Laws governing Solid Waste Management in Pakistan:

The following laws deal with Solid waste management in Pakistan (8);

1. Section 11 of Pakistan Environment Protection Act, prohibits discharge of waste in high concentration
2. Draft Hazardous Substances rules of 1999
3. Islamabad capital territory bye laws, 1968 by CDA Islamabad
4. Section 132 of the Cantonment Act 1924, deals with deposits and disposal of rubbish etc.
5. Provision contained in the Local Government Ordinance 2014

The Government of Pakistan enacted the Pakistan Environmental Protection Act (PEPA) in 1997, which provides a framework for establishing of Federal and Provincial environmental protection agencies (EPA). Similarly one of the tasks of the EPA's is to assist the local council, local authorities, Government agencies and other persons, to implement proper solid waste management system that complies with International standards, established by the EPA (8).

1.4. Nowshera City and SWM assessment

Nowshera or *"Nowkhaar"* or *"Nowshaar"*, is main city of Nowshera district of Khyber Pakhtunkhwa. Located at 271m above sea level, on the bank of Kabul River and around 43 kilometer away from the Provincial capital, Peshawar, having coordinates at $34^{o}0'55N$ $71^{o}58'29E$. Nowshera is 1,748 KM^2 in size, where 52,540 Hectors is agriculture land (9). According to 2017 population survey, the population in Nowshera District was 1,518,540. Table No.2 highlights Nowshera District and Tehsil level Population and number of Houses Breakup in 2017 survey.

Table No.1: Population Summary of Nowshera region 2017

DISTRICT AND TEHSIL LEVEL POPULATION SUMMARY WITH REGION BREAKUP

KHYBER PAKHTUNKHWA

DISTRICT / TEHSIL	REGION	POPULATION	NO OF HH
NOWSHERA DISTRICT		1,518,540	198,808
	RURAL	1,179,890	152,066
	URBAN	338,650	46,742
JEHANGIRA TEHSIL		353,490	45,112
	RURAL	267,768	33,752
	URBAN	85,722	11,360
NOWSHERA TEHSIL		727,749	96,001
	RURAL	530,076	68,181
	URBAN	197,673	27,820
PABBI TEHSIL		437,301	57,695
	RURAL	382,046	50,133
	URBAN	55,255	7,562

Nowshera city houses many Pakistan armed forces colleges and therefore has a huge cantonment area that is well developed. According the 2017 Pakistan Census, the city houses close to 22.30% population (338,650) in urban areas, while almost 77.70% population (1,179,890) were rural dwellers (as given in Table No.1).

Nowshera consists of 47 union councils, and although there are 4 Municipal committees, 1 Town committee and 3 Cantonment areas with regular solid waste collection, it is still not enough to cover the entire region of Nowshera city.
Therefore for most locals, dumping MSW in open spaces and low lying areas, especially close to water ways is the routine. The waste is generally burned in open fires, or the heaps of waste are reduced by regular rains that *wash* away most of the rubbish in water ways.

II. RESEARCH PROBLEM & METHODOLOGY

2.1. Research Problem

Development of efficient and sustainable solid waste management system requires accurate information about various variables such as the population, waste generation rates, and composition of the waste. These are some of the primary parameters among several others, which are needed to develop a strategy for solid waste management of any town or city. More importantly, these parameters are usually unique and dependent upon the specific socio-economic conditions of a locality. Hence, the parameters estimated for other towns and cities are not readily applicable or quite useful everywhere.
Nowshera is a mid-sized city located in the central region of the Khyber-Pakhtunkhwa province. It can be characterized as an urban area based on its population density but still has many features of rural communities such as cattle and agricultural-farming. The municipal solid waste thus generated does not necessarily have the same characteristics as that of large urban centers in Pakistan.

Keeping in mind the above issues, the objective of this Study was;

- To determine the composition and characteristics of MSW in Nowshera city;
- To estimate the per capita MSW generation rate in Nowshera city;
- To determine the daily amounts (volumetric and weight) of MSW collected and disposed of from the Nowshera city;
- To analyze medical waste against some diseases (Aids, TB, Hepatitis & Typhoid);
- To analyze water from River Kabul near the Nowshera MSW Landfill;
- Analysis of Nowshera city MWS against other cities of Pakistan; and
- Estimate the power generation potential of Nowshera city MSW.

2.2. Methodology

In order to achieve the objectives of the research study, we had to follow a defined methodology and use standard test methods. The standard test method used for characterization of Municipal solid waste is called ASTM - American Society for Testing and materials - Standard testing method for determination of the composition of unprocessed municipal solid waste (D5231 - 92 - 2008), as this satisfied the need for methods to be structured, produce accurate and reliable results and that can be repeated. The method explains the procedure for measuring unprocessed MSW, by employing collection and manual sorting of unprocessed MSW, over a period of 7 days.

The main methodology for the calculation of waste generation rate included the following steps:
1. Coloured plastic bags were provided to the selected houses
2. Households were asked to store all waste for daily collection, including recyclables
3. After collection, the waste was weighed each day and results recorded

4. Additionally details on the number of inhabitants, local SWM process, recyclable percentage etc was collected through a questionnaire.
5. The final data was used to calculate the estimated MSW production, per capita MSW production rate and also to estimate the energy production from Nowshera MSW

The equipment and apparatus used in the project at different times are Weight Balances, Plastic Containers, Clean Sheets, Safety Equipment and Plastic Bags.

As it takes long time to measure the total population, therefore representative sampling of the total data was undertake, which was used to extrapolate the complete data, an established practice followed in research. And to achieve this representative samples were selected from Nowshera city population, ensuring that equal quantity of MSW sample are selected as following:

1) High Income Group (HIG): Houses with monthly income level above Rs. 15,000.
2) Moderate Income Group (MIG): Houses with monthly income level ranging from Rs. 7,500- 15,000.
3) Low Income Group (LIG): Houses with monthly income level below Rs. 7,500.
4) Commercial Group: Market having 30-40 businesses

For the purpose of this study, the following 13 categories were selected for SW characterization study:
i. Plastics & rubber, ii. Metals, iii. Paper, iv. Cardboard, v. Rags (textile), vi. Glass, vii. Bones, viii. Food waste, ix. Animal waste, x. Leaves / green plant etc, xi. Wood, xii. Residuals/ Fines and xiii. Stones/ Construction material .

The local office of engineering consultancy firm, which was located at a house in Saddar in Nowshera, was selected for the collection, storing, sorting and measuring the Municipal solid waste.

For the purpose of Hospital Waste testing only one sample was collected from the inside of a prominent medical hospital in Nowshera city. The sample was collected following all safety precautions. Collected samples was sealed in plastic bag and transported the same day to testing laboratories. The sample was tested at a reputable medical testing laboratory to determine the presence and types of four types of diseases, that is, AIDS, TB, Typhoid and Hepatitis.

The survey of open dumping sites of MSW in survey area was conducted during the first three days. GPS coordinates and pictures of the site were recorded.

It was also decided to analyze the quality of water in River Kabul near the landfill, to see the effects on water quality. For this purpose a representative samples of the Kabul River water was taken from different locations near the Nowshera waste dumping site using a boat and plastic containers. For water quality testing we tested for the following:

1) Total Dissolved Oxygen (DO): This test checks the oxygen content of water. Oxygen is important for aquatic life and the higher the oxygen contents the easier for aquatic life to thrive in the water. Oxygen content increases with diffusion of atmosphere with water, either through movement over rocks, waterfalls or due to wind or due to photosynthesis of aquatic animals. DO decreases due to decaying organic matter besides other natural reasons. The normal range is from 7-15 mg/l.
2) Chemical Oxygen Demand: This is the industrial standard test for indirectly measuring amount of pollutants that cannot be oxidized biologically. The higher the chemical oxygen demand, the higher the pollutants.
3) Chloride Content: This test measures the total chloride content. In drinking water the salt taste comes from chloride, since it forms sodium chloride in water. Salty water is also not good for aquatic life. Chloride content increases with water softening, chlorination, water moving over salt rocks or from industrial/rubbish effluents. The value should be lower than 250 mg/l.
4) Most Probable number (MPN): Also called method of Poisson zeroes, this method calculates micro organism and enzyme growth in water. Although this method does not give you the exact estimate of micro organism in the test sample, but it does give you some indication of the level of micro organism in water. It is important to check for sewage runoff in drinking water.

III. RESULT AND ANALYSIS

3.1. Initial Survey of Nowshera SWM

During the survey it was observed that the Municipal solid waste management of Nowshera city does not cover the entire city, therefore in many areas the locals have dumped solid waste in open spaces, where either the solid waste is burned or rain washes it away into water carrying canals.

Research in Lahore in 2008 found that more than 90% of collected waste is either openly dumped at low lying areas, along road sides or placed in open surfaces where they are carried through water carrying canals and sewers to rivers (10).

In Nowshera it was also observed that many waste heaps were created in open areas by locals, especially near water carrying canals and sewers. Similar the local municipality was also dumping the collected Nowshera city solid waste in an open area next to the Kabul River (as can be seen in the map Image No.2 below).

The open MSW dumping sites observed in the survey are shown on map No.1 given below;

Map No 1: Locations of open MSW dumpsites in survey area

Above satellite map images show the locations of unregulated MSW open dump sites
The Municipal authorities of Nowshera highlighted the location of the Nowshera Land-fill next to River Kabul. The satellite map location is shown below

Map No 2: GIS Location of Nowshera Municipal garbage dump by Kabul River

Since reliable data for total solid waste generation for Nowshera was not available, therefore it was assumed that for the estimated population of 1.518 million (2017) persons and having an average of ***7.7 person per household*** and there are estimated 184,675 households located in Nowshera city, according to population survey of Pakistan 2017.

3.2. Initial Survey of Nowshera SWM

It was decided to get 100KG representative samples from the 3 residential groups and one sample from commercial group. Three areas for residential on the basis of their income level, and one area of Non-Residential commercial from different Union Councils (UCs) of Nowshera Kalan, Nowshera were selected as below:

a. U/C Shamair Ghari (Street Rajja) Disst Nowshera KPK (30 homes) - LIG
b. U/C Nawa Kalan (Street Katho Khel) Disst Nowshera KPK (22 homes) - MIG
c. U/C Chowki Town (Street Shahussaini)) Disst Nowshera KPK (17 homes) - HIG
d. Commercial Areas (Shops, restaurants, markets, fruit and vegetable shops)

Based on the number of houses from where MSW was collected from, the Average MSW Generation of each house per day was calculated, which is given in below table

Table No.2: Waste generation rate for each type of housing

Category	Total Wt of MSW generated in 7 days	No of Houses	Avg KG/House Generation per day
LIG	713.0	30	3.39
MIG	711.0	22	4.61
HIG	713.0	17	5.99
Commercial	240.0	10	3.42
AVERAGE MSW GENERATION RATE			***4.29***

From the above table the average waste generation rate for Residential and commercial areas in Nowshera comes to ***4.29 KG/House/Day***.

3.3. Per Capita MSW Generation for Nowshera

From the research we also find the per capita solid waste generation for Nowshera city, as shown in the table below. With an average of 7.7 Residents per house, the waste Generation per person per day in Nowshera city was calculated, which is given in below table No.3

Table No.3: Per Capita Average MSW generation for Nowshera city

Category	Total Wt of MSW generated in 7 days (KG)	No of person = No of houses x Avg person per home	Per Capita MSW generation (KG/Capita/Day)	
LIG	713.0	30 x 7.7 = 231	0.44	Kg/capita/day
MIG	711.0	22 x 7.7 = 169	0.6	Kg/capita/day
HIG	713.0	17 x 7.7 = 130	0.78	Kg/capita/day
Average Per Capita			**0.606**	Kg/capita/day

From the above table it can be seen that highest per capita MSW generation rate belongs to the MIG group. This is according to the common correlation of MSW generation with levels of economic development of the region, which states that high income generating areas would consume more and therefore produce more MSW compared to Low income areas (11).

3.4. Total calculated MSW Generation for Nowshera

Using the estimation of the Average MSW production for Nowshera, we can also estimate the Total Municipal Solid Waste generation in Nowshera per day and per year as below.

Table No.4 Waste generation rate for each type of housing

Item	Formula	Value
Nowshera population	Using 2017 data	1,518,540
Nowshera No of Houses	Using 2017 data	198,808
Avg MSW Production per House per day		4.29 KG/house/day
Avg Per capital MSW generation		0.606 KG/capita/day
Estimated Total MSW Production per Day	Using; Per Capita x Total Population	920,235 KG/day

Similarly the total Municipal Solid Waste generation for Nowhera based on the above estimates comes to the following:

Table No.5: Estimated total MSW generation per year in Nowshera

Total MSW Generation in Nowshera per YEAR based on per Capita	920,235 KG/day X 365	335,885 Tonnes/Year

Similarly for Nowshera city, research has shown the following:

Table No.6: Waste Generation estimates for Nowshera in 2016 and with recyclables

S. No	Cities	Generation Kg/c/day	Avg Rate Kg/h/day	Waste Tons/day	Generated Tons/Year
1	Nowshera*	0.606	4.29	920	335,885

3.5. Results/Discussion of MSW Characterization

Using the ASTM standard method to manually sort the MSW of Nowshera into its constituencies was conducted according to the methodology.
It was shown the average solid waste characterizing before scavengers remove recyclable material, for Low, Medium, High income groups and for commercial regions of Nowshera city as given in the following table

Table No.7: Average solid waste characterization for different groups in Nowshera city (%age weight)

	LIG	MIG	HIG	Commercial
Plastics & Rubber	9.07	8.71	9.14	13.29
Metals	5.43	5.07	4.07	6.86
Paper	7.43	6.79	7.00	8.79
Card board	8.00	7.21	8.79	9.86
Rags (textile)	5.07	6.14	4.07	6.21
Glass	5.43	5.29	5.21	6.43
Bones	4.79	4.93	4.79	4.93
Food Waste	12.57	13.57	15.57	11.36
Animal Waste	5.29	4.57	3.79	3.64
Leaves/Grass etc	5.57	6.43	5.14	5.57
Wood	4.21	5.43	5.00	5.57
Fines	11.57	10.86	12.57	7.50
Stones/Construction material etc	17.43	16.57	16.71	12.86
Total Wet in KG's	101.86	101.57	101.86	102.86

3.6. Nowshera MSW Average Composition by Weight

The Average composition by weight (%age weight) of Municipal solid waste of Nowshera city is as following:

Table No 8: Average composition (%age weight) of Solid waste in Nowshera

S.No	Composition	%age (Average) Nowshera city*
1	Plastics & rubber	**10.05**
2	Metals	**5.36**
3	Paper	**7.50**
4	Card Board	**8.46**
5	Rags (Textile)	**5.38**
6	Glass	**5.59**
7	Bones	**4.89**
8	Food Waste	**13.27**
9	Animal Waste	**4.32**
10	Leaves, Grass etc	**5.68**
11	Wood	**5.05**
12	Fines	**10.63**
13	Stones, Construction material	**15.89**

* This average is before scavengers removed recyclable material from the waste

3.7. Nowshera MSW Composition by %age Weight

The chart on right shows the average percentage weight composition of solid waste in this research.

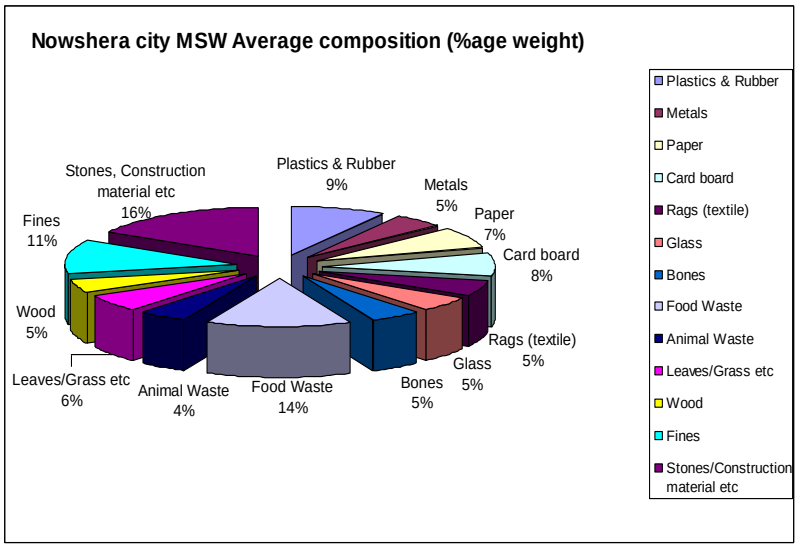
The biggest fraction of the solid waste consists of Organic material. Organic material composes of 33.88% and includes Food waste, Leaves/grass, Bones, Animal waste and wood.

Similarly the second highest fraction amounting to 28.57% is Stones/construction materials and Fines.

While the third biggest fraction consists of Paper and Cardboard, whose combined fraction is 15.07% of total MSW.

Plastic and Rubber formed the fourth largest fraction, followed by Glass, Rags (textile) and Metals, having average weight composition of 8.98, 5.31, 5.10 and 4.86% respectively

Chart No 1: Average composition (%age weight) of Solid waste in Nowshera



3.8. Analysis of MSW of Commercial Areas and Institutions

More than 40 commercial entities were observed in each Union council for MSW. Some of the MSW generated by commercial areas were too large in volume for each analysis. Therefore a representative samples from each Union council commercial area was taken for calculations.

Commercial areas generated mostly wooden crates, cardboard, paper and organic waste. And it was observed that in almost all commercial regions, either the commercial business owner themselves, or local scavengers, would recycle most of the MSW for hard cash.
The Commercial analysis report of Nowshera city is given below:

Table No.9: MSW Composition of Commercial regions of Nowshera city

	Commercial
Plastics & Rubber	13.29
Metals	6.86
Paper	8.79
Card board	9.86
Rags (textile)	6.21
Glass	6.43
Bones	4.93
Food Waste	11.36
Animal Waste	3.64
Leaves/Grass etc	5.57
Wood	5.57
Fines	7.50
Stones/Construction material etc	12.86

It was observed that commercial MSW consists of 31% organic waste. Commercial MSW also has higher percentage of Plastics & Rubber, metals, paper, cardboard, glass and rags. While food waste, animal waste, fines, stones/construction material was found to be at lower percentage compared to residential data.

3.7. Analysis of MSW in Hospitals and Medical Units for Biohazards

One KG sample consisting of syringes, bandages and gauze was taken from a prominent hospital in Nowshera city. The sample was sealed in plastic bag and sent to reputed Bio-medical lab for testing for diseases.
The sample results are given below:

Table No.10: Biomedical test results of hospital waste

S. No	Bio Medical Test	Test Results
1	AIDS test	Negative
2	T.B test	Negative
3	Typhoid test	Negative
4	Hepatitis test	Negative

All the test results came out negative and there was no trace of the four diseases, that is, AIDs, T.B, Typhoid and Hepatitis in the waste sample.

After discussing the hospital waste carrying diseases with a few of the hospital workers, they informed me that the hospital waste that can be harmful is burned in the back of the hospital. The workers also told me that recent government checking has forced most of the hospitals to burn the dangerous and hazardous waste, which confirms my results.

3.8. Analysis of Water in Kabul River near Solid waste Dump site

Three representative samples were taken from the center of the Kabul River, using a local hired boat, near the Nowshera municipal waste landfill site. The first sample was taken upstream from the landfill near Mardan bridge. The second sample was taken near the landfill near Iron Bridge, while the last one was taken downstream from the landfill, near "Kishti Pull" or bridge.
The three samples were sent for testing at UET Peshawar laboratory. The results of the water analysis are given below:

Table No.11: Water quality test analysis of Kabul River, near MSW landfill

S. No	Water Quality Test	Sample 1	Sample 2	Sample 3	Guideline WHO value
1	Total Dissolved Oxygen (mg/l)	7.1	5.8	5.5	7-15
2	Chemical Oxygen Deman COD mg/l	8	15	13	150 (NEQS)
3	Chloride content mg/l	40	39	45	250
4	Most probable number ml	92/100	160/100	51/100	0/100

From the analysis report it is obvious that the water quality is deteriorating due to the leeching of chemicals into the Kabul River. As we move from upstream to downstream of the Landfill, we see that the Total Dissolved Oxygen reduces from 7.1 to 5.8 and than 5.5 mg/l. The normal level is from 7 to 15 mg/l. The Low dissolved oxygen level will effect aquatic life of River Kabul.

While the chloride content of the water rises from 40 to 45 mg/l. Chloride content creates saltiness in water, making water unusable for drinking, washing and even irrigating. Chloride and nitrates are added from garbage and industrial effluents.

The Chemical oxygen demand checks for pollutants in the water. Our test shows that the pollutants level increased from 8 to 15 mg/l. It is also observed that Oxygen demand is highest at the dumpsite, as pollutants are the highest at this point.

Lastly the Most probable number (MPN) test indicated level of micro-organism in the water. It is not a very exact test, but a very good indication of presence of micro organism in water. Since micro-organism are mostly added in water through human and animal waste runoffs, therefore our test results of 92, 160 and 51 mg/l indicates that landfill pollution is having an effect on the micro-organism growth in water. The test indicates that the normal value upstream from the dumpsite is 92 mg/l, but it increases to 160 mg/l at dumpsite due to increase of MSW. While the value reduces to 51 mg/l downstream, due to reduced dissolved oxygen, which is due to increase in leaching pollutants into the river from the dumpsite.

All the tests show that having a municipal landfill next to Kabul River is adding garbage and pollutants in the river,

which will affect aquatic life, environment and health. The higher levels of pollutants can be leached into food plants that are farmed downstream, using the polluted Kabul river water for crop irrigation.

3.9. Estimate of Recyclable Proportions in Municipal Solid Waste

The proportion of recyclable in MSW is directly influenced by the amount of paper, cardboard, metal, glass and plastic in the MSW (12). This is because metal (ferrous and non-ferrous), paper, cardboard, glass, plastic and even clothing, leather, books and house hold goods have re-sale value (13).
The recyclables are collected by scavengers and street children, who sell them to local Recycle station or "Kabar Khana", who sell it in bulk to the recycle factories in Pakistan.
Although this research did not record the amounts and types of recyclable taken away by the scavengers, but it can easily be assumed that 80% of all metal, paper, cardboard, glass, wood and plastic/rubber will be informally be recycled by local scavengers.

Comparing the results of Nowshera city, that contains all recyclables and re-saleable with the results of MSW composition of 8 cities of Pakistan in below table:

Table No 12: Comparison of Average composition (%age weight) of Solid waste

S.No	Composition	%age (Average) 8 cities of Pakistan	%age (Average) Nowshera city*	Estimated %age Recyclables in MSW stream
1	Plastics & rubber	**5.59**	**10.05**	**4.46**
2	Metals	**0.35**	**5.36**	**5.01**
3	Paper	**2.34**	**7.50**	**5.16**
4	Card Board	**1.69**	**8.46**	**6.77**
5	Rags (Textile)	**4.81**	**5.38**	**0.57**
6	Glass	**1.46**	**5.59**	**4.13**
7	Bones	**1.98**	**4.89**	**2.91**
8	Food Waste	**15.71**	**13.27**	**X**
9	Animal Waste	**3.28**	**4.32**	**1.04**
10	Leaves, Grass etc	**13.61**	**5.68**	**X**
11	Wood	**1.20**	**5.05**	**3.85**
12	Fines	**41.91**	**10.63**	**X**
13	Stones, Construction material	**5.76**	**15.89**	**10.13**

* This average is before scavengers removed recyclable material from the waste

3.10. Estimation of Capacity of Power Generation from MSW of Nowshera City

The management of MSW is one of the important parts of the inclusive environmental management in most of the developing countries (14).
As there are a number of environmental issues related to disposal of MSW, for example, the accumulation of MSW causes direct and indirect degradation of the environment and human health.

Therefore to overcome the increasing MSW, a viable solution is to burn it in incinerator. During which a large amount of the heat energy is converted into electricity energy. Such plants are called Waste-to-Energy incinerators. About 130 million tons of MSW is burned worldwide in around 600 WTE plants (15).

Waste to Energy (WTE) power plants use different technologies for converting the MSW into electricity energy. The four common processes followed in WTE plants around the World are Pyrolysis, Conventional Gasification, Plasma Arc Gasification and Incineration.

The first two, Pyrolysis and Conventional gasification require specialized conditions and are slow conversion processes. Therefore they are not used for handling high quantities of MSW of cities.
The third method called Plasma Arm Gasification has very good efficiency but it is a complex and expensive process. The cost of per unit generated energy by plasma arc method is double than the cost of energy produced through incineration. Therefore we will also not consider this method for this project.
The fourth method for WTE power plants might be less efficient but it is the simplest and easiest way of power generation from waste. And we will also use this method for calculating the potential energy that can be produced from Nowshera city Municipal solid waste.

To calculate the amount of energy that can be produced from Nowshera MSW, we require its Total energy content and Net calorific value of the MSW.

But it must be noted that Municipal solid waste have different moisture contents which are dependent on area demography and weather conditions of the area.
Therefore we will need to calculate the estimated weight of the MSW of Nowshera without the moisture content, to be able to get the accurate heat content (Calorific energy) of the entire MSW of Nowshera.

Using the data from World Bank's technical guide called "Municipal Solid Waste Incineration" we can calculate the actual weight of MSW of Nowshera that can be burned in Waste to Energy plants to produce electricity as given below:

Final Heating Value = (Average Calorific value x Dry Weight %age) / 100

Using this we will have the following final heating values of each constituent

Table No 13: Calculation of Final Heating Value of MSW of Nowshera in kJ/KG

S.No	Composition	Avg Calorific value (kcal/kg)	Final Dry MSW in %age	Final Heating value (kcal/KG)
1	Plastics & rubber	**7044**	**6.35**	**447.29**
2	Metals	**0**	**0**	**0**
3	Paper	**3914**	**3.55**	**138.94**
4	Card Board	**5395**	**5.07**	**273.52**
5	Rags (Textile)	**4818**	**3.39**	**136.33**
6	Glass	**0**	**0**	**0**
7	Bones	**0**	**0**	**0**
8	Food Waste	**3184**	**2.75**	**87.59**
9	Animal Waste	**3184**	**0.89**	**28.33**
10	Leaves, Grass etc	**5203**	**3.39**	**176.38**
11	Wood	**4384**	**3.01**	**131.95**
12	Fines	**743**	**0**	**0**
13	Stones, Construction material	**743**	**0**	**0**
	TOTAL		**28.40**	**1420.33 kcal/KG**
			Convert kcal into kJ	**X 4.184**
			=	**5942.66 kJ/KG**

Therefore for the city of Nowshera we have the following calculations

Table No 14: Final Results of Dry MSW weight %age and Total Energy content

S No	ITEM	VALUE
1	Total MSW without moisture content	28.40 % of Total MSW
2	Total Energy content of dry MSW	5942.66 kJ/KG

To calculate the Total Power Generation from MSW of Nowshera, we need to find the combustible total weight of the MSW produced every day.

- Estimated Total Production of MSW in Nowshera everyday **= 920,235 KG/Day**
- Estimated %age of MSW that is combustible **= 28.40%**
- Amount of Combustible MSW Weight per Day = 920,235 x (28.4/100) **= 261,346 KG/Day**

Thermal power systems typically have efficiencies of 10-20%. We will assume the efficiency of our WTE power plant to be 15%.

So to calculate the Estimated Total Power Generation from MSW produced daily in Nowshera city, we will use the following formula;

Estimated Power Generation = Amount of combustible wt X Avg Calorific Value X Efficiency of power plant

= 261,346 KG/day x 5942.66 kJ/KG x 15/100
= **232,963,563 kJ/day**
= **232,963 MJ/day**

To calculate the Total Capacity of the Power plant we will use the following conversion formula

	1 MJ/Sec	=	1 MW of power
Where	1000 kJ	=	1 MJ
	1 Day	=	86,400 sec

Using these we get

Estimated Power Generation = 232,963 MJ/day x 1/86,400 sec

= 2.69 MW

Therefore the minimum Capacity of the Waste to Energy Power Plant required for Nowshera city is calculated to be **2.69MW.** And the estimated electricity that can be produced every day from the MSW of Nowshera city is calculated to be **232,963 MJ/day**

IV. BEST MSW MANAGEMENT PLAN FOR NOWSHERA

4.1. Best Municipal Solid Waste Management Solution for Nowshera City

Although Waste to Energy Power plant would seem like a good idea for a city close to a river and water source, but as shown in my research, most of the MSW is recycled by poor "Scavengers" who collect and estimated 100% metals, 80% wood and cardboard, 70% Paper and Glass and 50% of Plastic and Rubber of the MSW generated every day. Until a new source of income is created for these people, they cannot be stopped from collecting recycling material to sell from MSW.

Therefore the best MSW management plan for Nowshera city should include the scavengers as well. And for Nowshera the plan should include Better Sorting of Trash, More recycling, Burning of Plastics and hazardous material, Composting and Sanitary Landfill.

Scavengers can be hired as trash sorters/collectors and the Government can provide their families with homes, free schooling and job security, so they do not have to force their kids to also work with them. The Scavengers will collect the trash from their allotted regions and sort them into 4 piles, Recyclable, Burning, Composting, Landfill. Recyclable will be sold by the scavenger for their own profit, while rest will be delivered to a central location.

The Burning items are burned in an incinerator. The composting items are delivered to a Government run composting facility that would convert kitchen waste, paper, cardboard, leaves and wood trash into compost within 2 months, which can be sold to Government and locals for use in gardens and organic farms.

All remaining trash items can be mechanically compressed and disposed in a Sanitary Landfill. Landfills can handle large amounts of waste and reduce open burning and emission of gases from trash breakdown, which are a big source of environmental and health pollution.

Without sorting and just dumping all trash in a large area designated as landfill has many bad side effects including impact on photochemical oxidation, global warming and acidification (16), while it is estimated that by increasing only one ton of MSW landfill without sorting, we increase CO2 production by 1.2 ton (17). While most dangerous is the threat to ground water quality and health of the community due to hazardous chemicals leaching from the landfill, into ground water (18). That is why it is important to create barriers between the MSW and ground, to avoid leaching of chemicals.

Since organic waste forms the major component of MSW, therefore through Biological conversion, that is composting or anaerobic digestion, the biodegradable fraction of MSW can also be converted into compost within a couple of weeks. The finished material can be sold to Government organizations on fixed rate. Such a plan would reduce waste, bring poor scavengers and their families out of poverty and manage landfills so they don't cause secondary pollutions.

V. FINAL DISCUSSION

The assessment of MSW of Nowshera city shows us that around 920 ton per day MSW is generated, which is around 335,885 tons per year. There are an estimated 198,808 houses and an estimated population of 1,518,540 persons in Nowshera.

The per capita MSW generation is 0.606, which is within the range of the national study that revealed the rate of generation of waste on average varies from 0.283- 0.613 kg/capita/day (7).

Similarly the average MSW generated per home for Nowshera city is 4.29 kg per house per day, which is on higher end of the national average of 1.896 - 4.29 kg/house/day in all selected 8 cities (7).

But it should be noted that this research includes the weight of the recyclable and re-saleable wastes as well. The recyclable and re-saleable MSW is normally removed by Scavengers who sell it to earn money.

Similarly this study also shows that like the national study on MSW in Pakistan, the highest percentage of MSW generated in Nowshera city is organic at 33.88%.

Tests conducted on hospital waste had shown negative results for presence of four diseases, that is, Aids, T.B, Typhoid and Hepatitis.

But the analysis of water from River Kabul, near the Landfill site showed that pollutant levels in the water were rising as we moved downstream from the river. This shows that the landfill was leaking pollutants in the water.

Overall this research has shown that although there is some level of MSW management practiced in Nowshera city, but it does not cover the entire region. And therefore there are many areas where the locals use open spaces for dumping of their MSW, which either is burned in open fires, or gets washed away in the water ways.

Similarly the Municipal landfill is not managed according to best MSW management standards. The landfill is made near Kabul River, which results in seepage of waste material, including hazardous material into water ways. The water of Kabul River is used for drinking and irrigation and the hazardous materials can end up in human food and water, creating many health issues.

Looking at the various MSW management techniques used around the World, which include Landfill, combustion, recycling and composting, I have also concluded that the best method for managing MSW in Nowshera will be a combination of Incineration, recycling, composting and Sanitary landfills.

Using the data of this research on MSW analysis, it was calculated that an estimated 2.69 MW waste to energy power plant can be installed in Nowshera that will have the potential to produce 232,963 MJ/day of energy.

Since most of the MSW is already burned in open fires and gets washed away, therefore a WTE plant will not only reduce MSW in Nowshera, but will also produce electricity. Similarly, if some parts of the MSW is recycled, while organic parts are composted, than that can also help reduce the MSW, which will eventually help reduce the use of landfill for managing MSW.

VI. ACKNOWLEDGEMENT

The author is grateful to University of Engineering and Technology (UET), Peshawar for all their help and guidance.

VII. REFERENCES

(1) William Rathje and Cullen Murphy (2010); Rubbish! The Archaeology of garbage. Retrieved from http://beginwiththebin.org/resources/for-education

(2) Williams, R. (2013); “Key Issues paper: Sustainable solid waste management & the green economy with contribution from”

(3) Sha' Ato, Aboho SY, Oketunde FO, Eneji IS, Unazi G, Agwa S. (2007) Survey of solid waste generation and composition in a rapidly growing urban area in Central Nigeria; UNEP report (2013): Municipal solid waste composition analysis study Juba South Sudan (pg 14)

(4) Pattnail, S. Reddy, M.V, (2009) Assessment of municipal solid waste management in Puducherry (Pondicherry), India. Resourc., Conservat. Recycl. 54, 512-520.

(5) UNEP United Nations Environmental Programme Division of Technology, (2009), Developing Integrated Solid Waste Management Plan Training Manual. Volume 1:Waste Characterization and Quantification with Projections for Future, Industry and Economics International Environmental Technology Centre Osaka/Shiga, Japan Pg 2.

(6) Pakistan Environment Protection Agency (EPA) (June 2005),"Guidelines for Solid Waste Management, UNDP/JICA/GoP pg 8,9,13,20

(7) Engineering Planning and management Consultants, Lahore (1996), "Data Collection for Preparation of National Study on Privatization of Solid Waste Management in Eight cities of Pakistan", Government of Pakistan / JICA

(8) Mr Akiolshii, (2002), "Final Report for Domestic Solid Waste Management in Pakistan; JICA short term expert

(9) Government of Khyber Pakhtunkhwa (2016); “Nowshera district Demographics” (Retrieved from http://kp.gov.pk/page/nowsheradistrictdemographics)

(10) K. Majeed, S. B. Adila and M. C. Nawaz (2008); “Economic potential of recycling business in Lahore,

Pakistan, Waste management 28"

(11) World Bank Publications (2012); "What a waste: A global review of solid waste management, Urban development series knowledge papers", World Bank.

(12) GHK Consulting Ltd and Urban Unit (Sep 2010), Sialkot Waste Assessment and Characterization Survey; Govt of Punjab

(13) UNEP United Nations Environmental Programme Division of Technology, (2009), Developing Integrated Solid Waste Management Plan Training Manual. Volume 4: ISWM Plan, Industry and Economics International Environmental Technology Centre Osaka/Shiga, Japan Pg 152-3.

(14) G. Murtaza and A. Rahman (2000); "Solid waste management in Khulana city and a case study of a CBO: Amadar Paribartan, Communication based Solid Waste Management", EOLSS

(15) M.S Korai, Rasool Bux Mahar, M. Aslam Uqaili, (2014); "Assessment of Power Generation Potential from Municipal Solid Wastes: A Case Study of Hyderabad City, Sindh, Pakistan; Mehran University of Engineering and Technology, Jamshoro, Sindh, Pakistan

(16) A. U Zaman (2010); "Int. J. Environmental Science Technology", 7/2

(17) N. J. Themelis (2003); "An overview of the Global Waste to Energy Industry", WTERT.

(18) K. Sudhir (2010); "Technology options for Municipal Solid Waste to Energy Project, WTERT.

(19) M.S Korai (2009), "Characterizing and composting the municipal solid waste of Hyderabad city, Institute of Environmental Engineering and Management, Mehran University of Engineering and Technology, Jamshoro, Sindh.

