Research Article

Solid waste management practice in Karachi through GIS techniques

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Abstract

The extreme development of cities and subsequent enlarge in an urban population in recent years has led to a considerable enhance in consumptions and generations of solid waste material in the developing countries. The gradually rising population has led to several solid and hazardous waste issues in the megacity Karachi, due to unsatisfactory policies, laws, political instability, and poor municipal administration. The main purpose of this research work was to assess the issue of population density, waste generation, collection, transportation, and management of municipal solid waste through GIS techniques. The obtained results revealed that rising population density and improper collection of municipal solid waste from collections points had a negative impact on the total volume of waste generation. The open burning and disposal methods were very common to treat the municipal solid waste agenda. The collection of MSW from bins and transportation to a landfill site by vehicles was not accordingly in the city. No transfer station was buildup for the temporary deposition of MSW for further processing for recycling purpose. The private sector was involved in the recycling of MSW on a small scale and paying to afghan waste pickers to collect waste from located bins to dumping site. The workers were proliferating the waste around the bins and on the roads, due to lack of proper training. Overall, the present study indicated that the new advanced eco-friendly technologies viz., modified-composting, smart biochar, plastic tile, plastic roads, energy recovery etc., are urgent needed to manage MSW problems and minimize health issues and environmental degradation.

Keywords: Collection; GIS techniques; Municipal; Population density; Solid waste; Transportation; Waste generation

Introduction

The multicultural megacity Karachi has been considered 2nd largest Muslim city around the globe and facing various environmental issues including municipal solid waste management is an important issue, due to an increase in population density [1, 2]. According to statistical data revealed that the total population of Karachi city has reached about 14,910,352 during 2017. The population has been rapidly increasing day by day and possessing several solid and hazardous waste issues in the megacity, due to lack of awareness, training, budget, corruption, and poor municipal administration [3, 4]. It is the largest big city of Pakistan with 10% of the total residents of a country and producing over 10,000 tons of

MSW per day [5]. Furthermore, it has been observed in towns of Karachi which is also responsible for the increase of municipal waste (MSW) generation, while on the other active system of management [6]. MSW is a residential and commercial waste formed in public or notified sites, as well as treated bio-medical wastes, however without industrial hazardous waste material [7]. The quantity of MSW generated in any given community is straight associated with in habitant growth, urbanization, industry, financial activities, and family unit consumption levels [8].

The modes of disposal of these wastes depend on the cultural practices of the people who live within the society, due to the ecological and human health issues collection, processing, transportation, recycling, and disposal of MSW are very important to waste management [9]. The quantity of MSW within the livelihood surroundings exerts pessimistic impacts on living beings. Also, concerning well-being, indiscriminate discarding of MSW enhances the risk of the spread of an extensive range of infectious disease [1]. Different strategies have been proposed for reducing, reusing, recycling, recovering energy, and disposing of solid waste Guerrero et al. [10], but these strategies are controversial according to the environmental impacts [11-13]. Furthermore, MSW is a universal issue and a big challenge for healthy life and sustainable environment [14]. It is a big challenge for the living-beings of the entire globe. Impact assessment is a precautionary and safety tool for the environment, which makes it probable to fulfill with ecological effective policies, and even incorporate early such policies into the expansion and decision-making processes [15].

In the former study, Yesilnacar and Cetin [16] conducted research work on the location of suitable sites for the discarding of toxic waste using geological, topography, and land-use system. Furthermore, Chang et al. [17] assessed a multi-criteria decision-making technique in a geographic information system (GIS) atmosphere for waste site issues in the South of Texas. Ghiani et al. [18] proposed an appropriate integer programming model for the site of collection points with limited capacity in a waste collection management scheme. Also, Ghiani et al. [19] revealed that the efficiency of locating the collection points by zoning the service sites. Eiselt and Marianov [20] applied dissimilar location models for gathering facilities of MSW. Sabir et al. [1] examined the solid waste management (SWM) process and implementation in the megacity Karachi and also investigated challenges faced by the liable establishment. Rathore and Sarmah [21] used a MILP-model for the lack of waste transfer station and their proper location for the segregation of waste material. Some scientists have worked on preventing solid waste material and suggested recycling waste to make new products and waste management [22, 23].

The appraisal of MSW is very significant for policymakers and scientists, because it deteriorate human health and the environment [4]. Furthermore, to understand that political instability, disappointing policies, and negligence of this department at the government level are responsible for the haphazard situation for this department. Now the administration of the city has made an agreement with a Chinese company for the betterment of the remaining pileup of waste in the city. This company has used its machinery (loader and dumper), but the circumstances are not so good. Globally waste production has been increased this is a time of the revival of nature to reuse things that possible. An increase in population growth is the main factor of waste generation in rural areas, solid waste management has not a big issue because they have been reused all things and usage of packaging goods are so minimized in these areas. In Karachi,

various initiatives have been taken to control the havoc condition of solid waste in which contract with the Chinese company has been also very important. Up to date, very limited information is available on the municipal solid waste collection, transfer, recycling, and proper disposal in this area. However, to fill this research gap the present study evaluates the current scenario of municipal solid waste through GIS techniques. In light of the existing work, this research work aimed to assess the population density, municipal solid waste generation rate, collection, transportation, and disposal of MSW through GIS techniques in the megacity Karachi.

Materials and Methods

Study design

In this study, quantitative and qualitative types of data have been used for the assessment of solid waste management systems. The data was gathered from different sources including web pages, newspapers, published material, books as well as government organizations. MSW (CDGK) was used for recognizing ground reality photography which may play a very important role in this investigation. The MSW collection and vehicles are imperative essentials to handle the circumstance of MSW management. In addition, to investigate the real facts, interviews of the vehicle drivers have also been conducted to recognize the type and waste carrying capacities of vehicles because it was a quite difficult task. Population and waste generation are closely associated with each other for their analysis spearman´s rank correlation coefficient method has been used. The population-density was calculated in this present work by using ArcGIS 10.3.1. In order to calculate the population density some very important steps has been used, firstly area was calculated by geometry calculation tool than calculate population density by using following formula.

Population Density= Population/Area (sqkm)

Setting

Karachi is a megacity and contributing significant role in Pakistan economy. It is situated in the province of Sindh having latitude and longitude of Karachi are: 24˚54'20.16''N, 67˚4'55.92''E. Furthermore, it has been divided into five district viz., Karachi East, Karachi West, Karachi Central, Karachi South and Malir districts, while in November 2013 a new District (6th), Korangi was created by splitting district Karachi East the districts of Karachi further divided into 18 towns namely Orangi, Lyari, Saddar, Site, Kemari, Jamshed, Baldia, Landhi, Shah-Faisal, New Karachi, Korangi, Gulberg, Gulshan, Malir, Bin Qasim, Liaquatabad, Gadap and N. Nazimabad (Fig. 1).

Variables

Dependent variable

The dependent variable in this study is the waste generated per day (ton). Waste generation per day (ton), data of 2019 of different towns of Karachi has been used for analysis.

Independent variables

In this study for assessment, the Spearman correlation method has been used population is an independent variable so we plot it on the x-axis. While, increasing population with limited sources is an alarming indicator for a city.

Data sources/measurement

In this study, secondary data were collected from the official source of national census 2017 and semi-official sources of district councils.

Population density calculation through ArcGIS

The multicultural city affords the problem of a remaining pileup of waste with significantly rising of human population. In contrast, the city has not been facilitated with the raise of population which formed disorganized conditions for citizens. To address this circumstance for analysis of

population density was calculated in this study by using ArcGIS 10.3.1, a method for

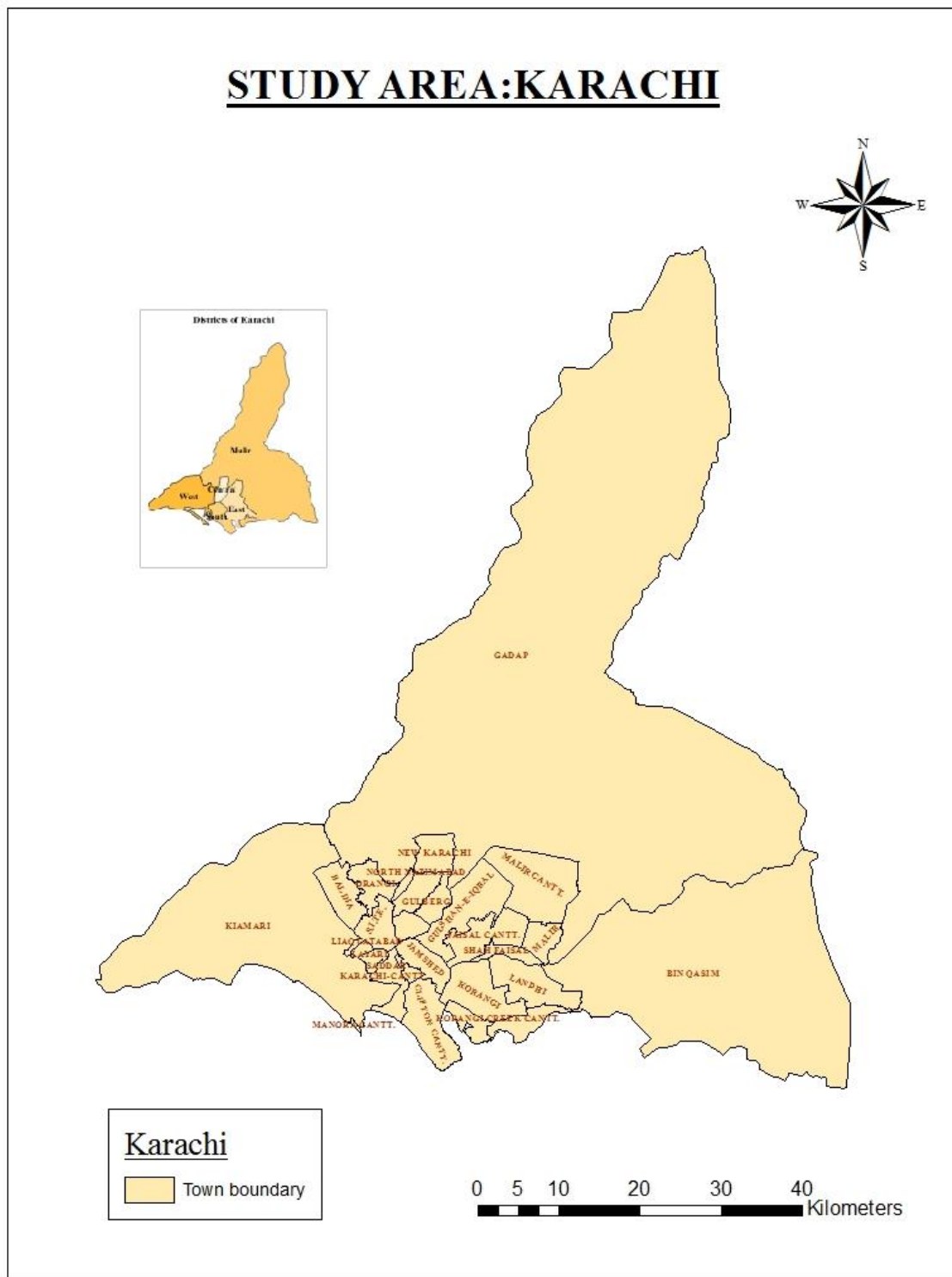population density calculation as given in (Fig. 2).

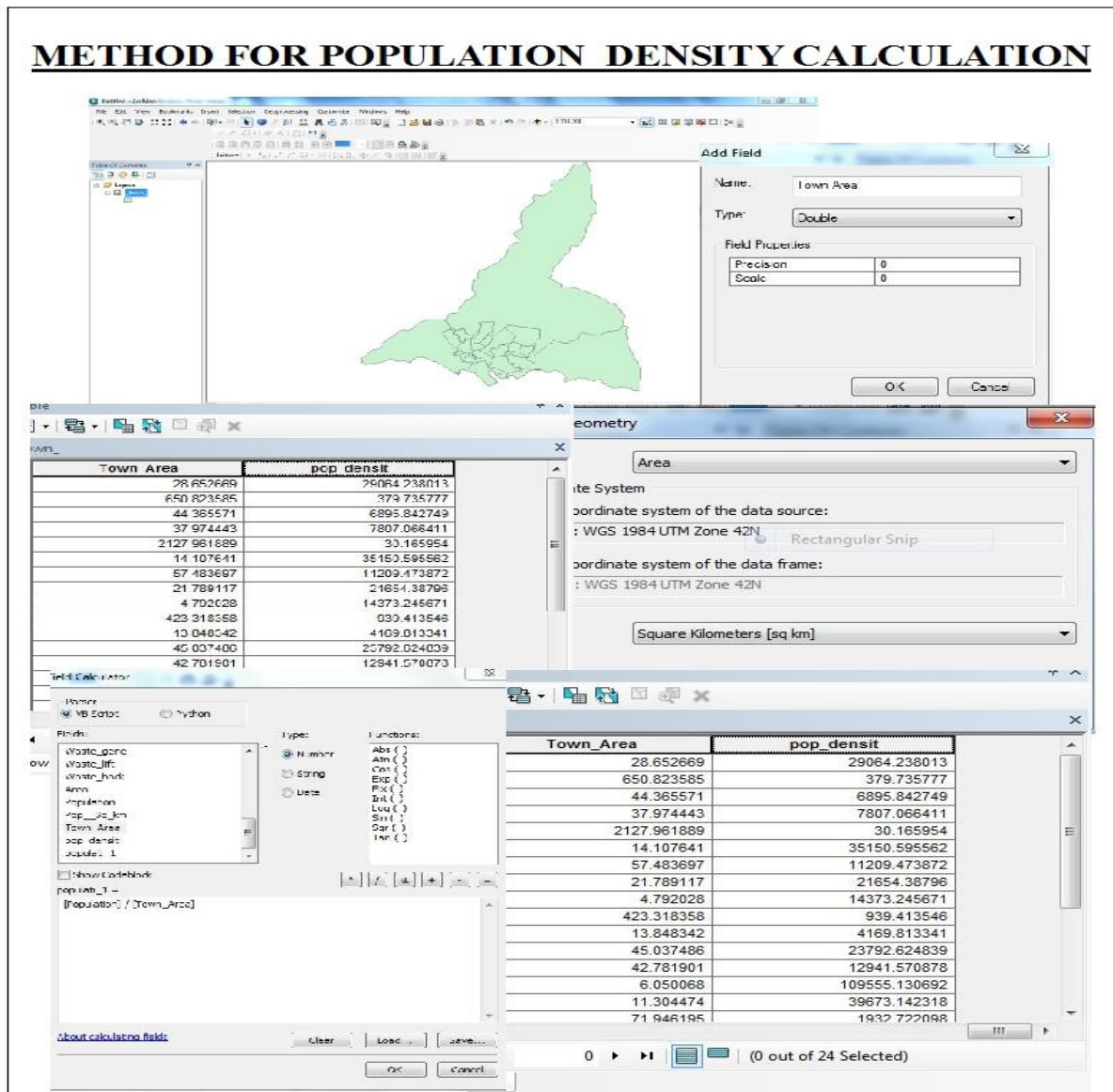**Figure 1. Study Area of Karachi, Source: Author**

Figure 2. Method for population density calculation, Source: Author

The (Fig. 3) shows the population density of Karachi towns. Lyari, Liaquatabad, Gulberg, North Nazimabad, New Karachi, Shah Faisal towns are representing huge population, whilst (Table 1), revealed apparent facts regaring population, area, and population density in dissimilar towns of Karachi.

The Per capita MSW generation in the megacity was 0.5 kg per person per day and approximately 2929402.293 tons per year. It is anticipated that an increase the MSW generation has significant correlation with dense population. As shown in (Fig. 4) indicated that the clear facts about the waste generated rate of Karachi, the town of Korangi, Saddar, New Karachi, and Baldia which represent the highest value in the given map.
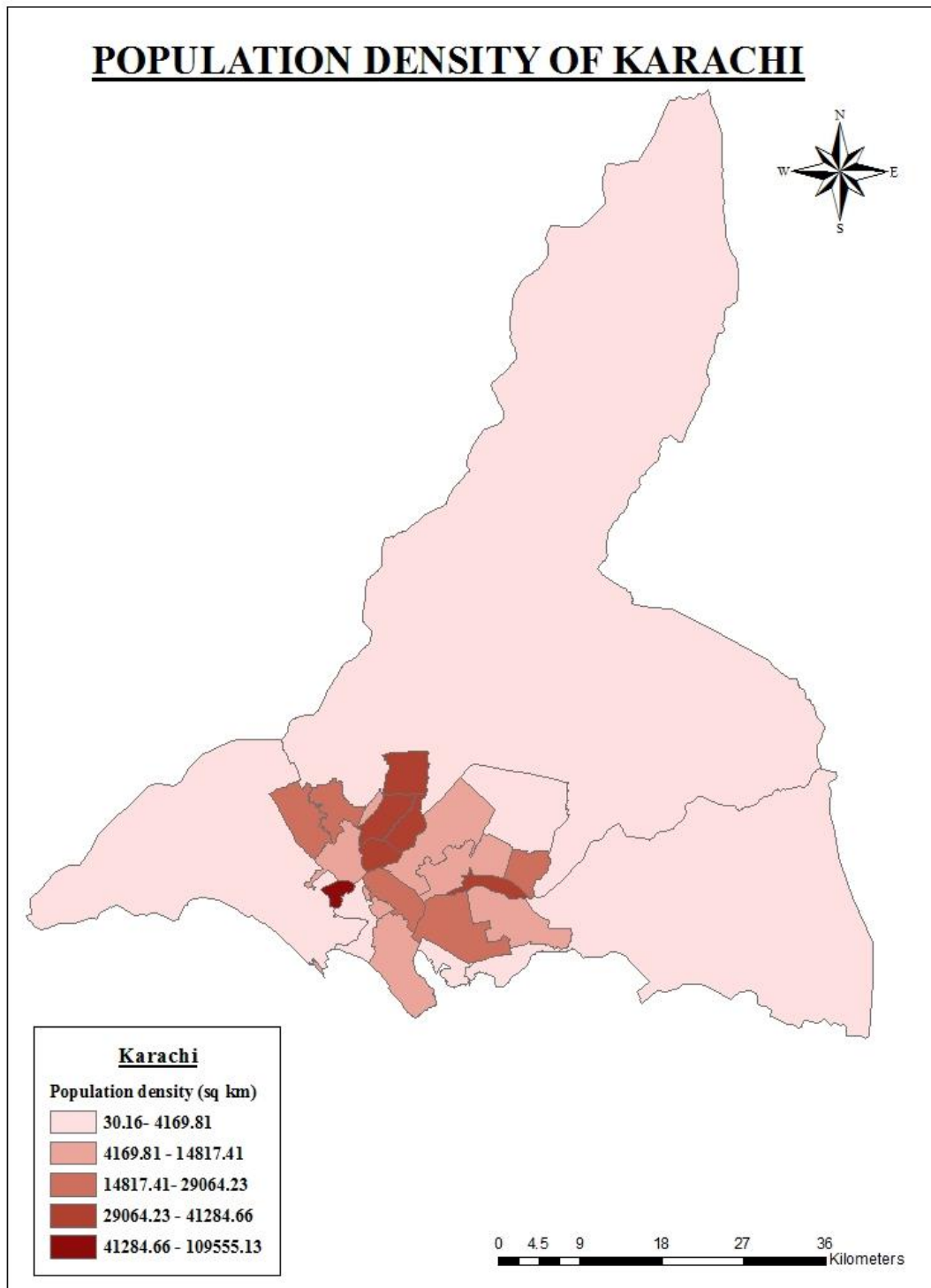
Figure 3. Population density of Karachi towns, 2017, Source: Author

Table 1. Area, population, and population density in different towns of Karachi

Fid	Shape	Town names	Count	Area (Km)	Population	Population density (Sq Km)
0	Polygon	Baldia	8	28.652669	832768	29064.23801
1	Polygon	Bin Qasim	7	650.823585	247141	379.735777
2	Polygon	Clifton Cantt.	1	44.365571	305938	6895.842749
3	Polygon	Faisal Cantt.	1	37.974443	296469	7807.066411
4	Polygon	Gadap	8	2127.961889	64192	30.165954
5	Polygon	Gulberg	8	14.107641	495892	35150.59556
6	Polygon	Gulshan-E-Iqbal	13	57.483697	644362	11209.47387
7	Polygon	Jamshed	13	21.789117	471830	21654.38796
8	Polygon	Karachi-Cantt.	1	4.792028	68877	14373.24567
9	Polygon	Kiamari	8	423.318358	397671	939.413546
10	Polygon	KorangiCreek Cantt.	1	13.848342	57745	4169.813341
11	Polygon	Korangi	9	45.037486	1071560	23792.62484
12	Polygon	Landhi	12	42.781901	553665	12941.57088
13	Polygon	Layari	11	6.050068	662816	109555.1307
14	Polygon	Liaquatabad	11	11.304474	448484	39673.14232
15	Polygon	Malir Cantt.	1	71.946195	139052	1932.722098
16	Polygon	Malir	7	16.84774	454956	27003.97731
17	Polygon	Manora Cantt.	1	0.755214	5874	7777.923986
18	Polygon	New Karachi	13	21.103041	871232	41284.66669
19	Polygon	North Nazimabad	10	17.26352	708583	41045.10629
20	Polygon	Orangi	13	19.953676	520609	26090.88182
21	Polygon	S.I.T.E.	9	27.316297	404757	14817.41848
22	Polygon	Saddar	11	20.005357	36366	1817.81313
23	Polygon	Shah Faisal	7	10.985282	447993	40781.20002
Source: Author Waste generation scenario of studied area						

Data analysis methods

For the analysis of data Spearman's rank correlation coefficient (rs) method was used in this study. This was the most reliable technique to find out the correlation between the two variables. T value and degree of freedom have also been calculated.

rs=1-6Σd²/n³–n ----------------------(2)

Where: d= the difference in rank of the values of each matched pair.

n= the number of pairs

Σ= the sum of

Results

Spearman's rank correlation coefficient

In this present work, the association between population and waste producing was carried out by using Spearman's rank correlation technique, that can be used understand the correlation among two variables. The data in (Table 2) showed that two data sets of the population and waste producing per day (ton) form unlike towns of Karachi, the ranking has been specified to two data sets separately from maximum to minimum level.
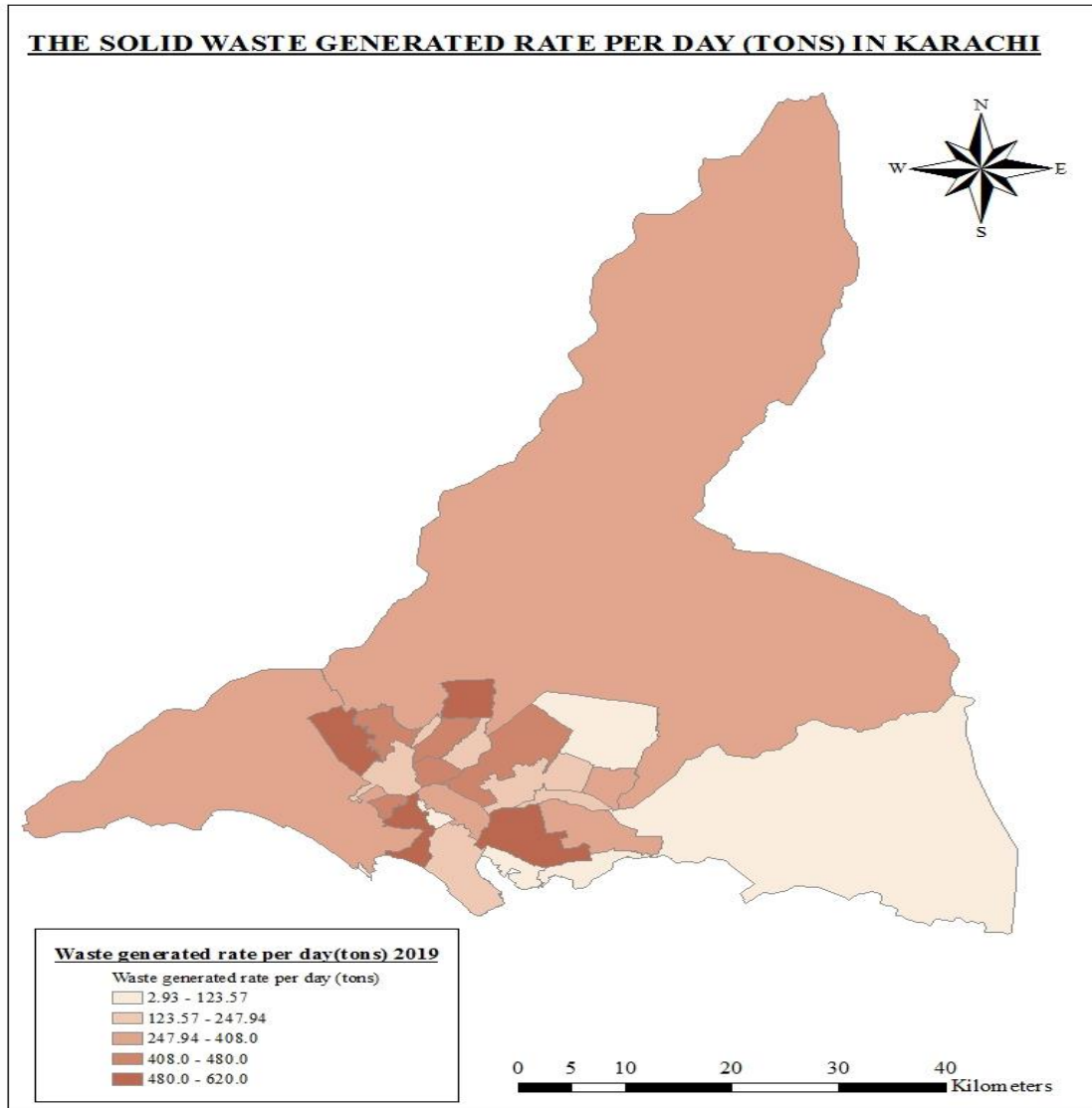
THE SOLID WASTE GENERATED RATE PER DAY (TONS) IN KARACHI

Waste generated rate per day(tons) 2019

Waste generated rate per day (tons)
- 2.93 - 123.57
- 123.57 - 247.94
- 247.94 - 408.0
- 408.0 - 480.0
- 480.0 - 620.0

Figure 4. Solid waste generated per day (Ton) of Karachi at the town level in 2019. Data Source: SWM, CDGK

$$rs = 1 - \frac{6\Sigma d^2}{n^3 - n}$$

$$rs = 1 - \frac{6\Sigma 713}{(24)^3 - 24}$$

$$=0.69$$

Rejection level (α)=95%

$$=0.05$$

$$t = rs\sqrt{\frac{n-2}{1-rs^2}}$$

$$=0.69\sqrt{\frac{24-2}{1-(0.69)^2}}$$

$$t=4.47$$
$$df= (n-2)$$
$$_{= (24-2)}$$
$$df=22$$

Rejection level=0.05
Critical value of t=2.07

The obtained data revealed that the significant value of t test is less than our t level (4.47), which represent the association among population and waste generation, while the level of rs was 0.69. It shows that there is a significant positive correlation was observed in among two variables. As data in (Fig. 5) revealed that the optimistic correlation between two variables.

Table. 2 Ranking of data sets

| Towns	Rank	Waste generation (ton) per day	Population	Rank	D	d²
Layari	8	420	662816	5	-3	9
New Karachi	3	530	871232	2	-1	1
North Nazimabad	5	480	708583	4	-1	1
Shah Faisal	16	223.9965	447993	13	-3	9
Liaquatabad	6	450	448484	12	6	36
Gulberg	15	247.946	495892	9	-6	36
Baldia	4	500	832768	3	-1	1
Malir	12	320	454956	11	-1	1
Orangi	9	410	520609	8	-1	1
Korangi	1	620	1071560	1	0	0
Jamshed	10	408	471830	10	0	0
S.I.T.E.	17	202.378	404757	14	-3	9
Karachi-Cantt.	23	34.4385	68877	20	-3	9
Landhi	13	305	553665	7	-6	36
Gulshan-E-Iqbal	7	430	644362	6	-1	1
Faisal Cantt	19	148.2345	296469	17	-2	4
Manora Cantt	24	2.937	5874	24	0	0
Clifton Cantt	18	152.969	305938	16	-2	4
Korangi Creek Cantt	22	48	57745	22	0	0
Malir Cantt	21	69.526	139052	19	-2	4
Saddar	2	600	36366	23	21	441
Kiamari	14	290	397671	15	1	1
Bin Qasim	20	123.57	247141	18	-3	9
Gadap	11	390	64192	21	10	100
						Σ= 713

Source: Author
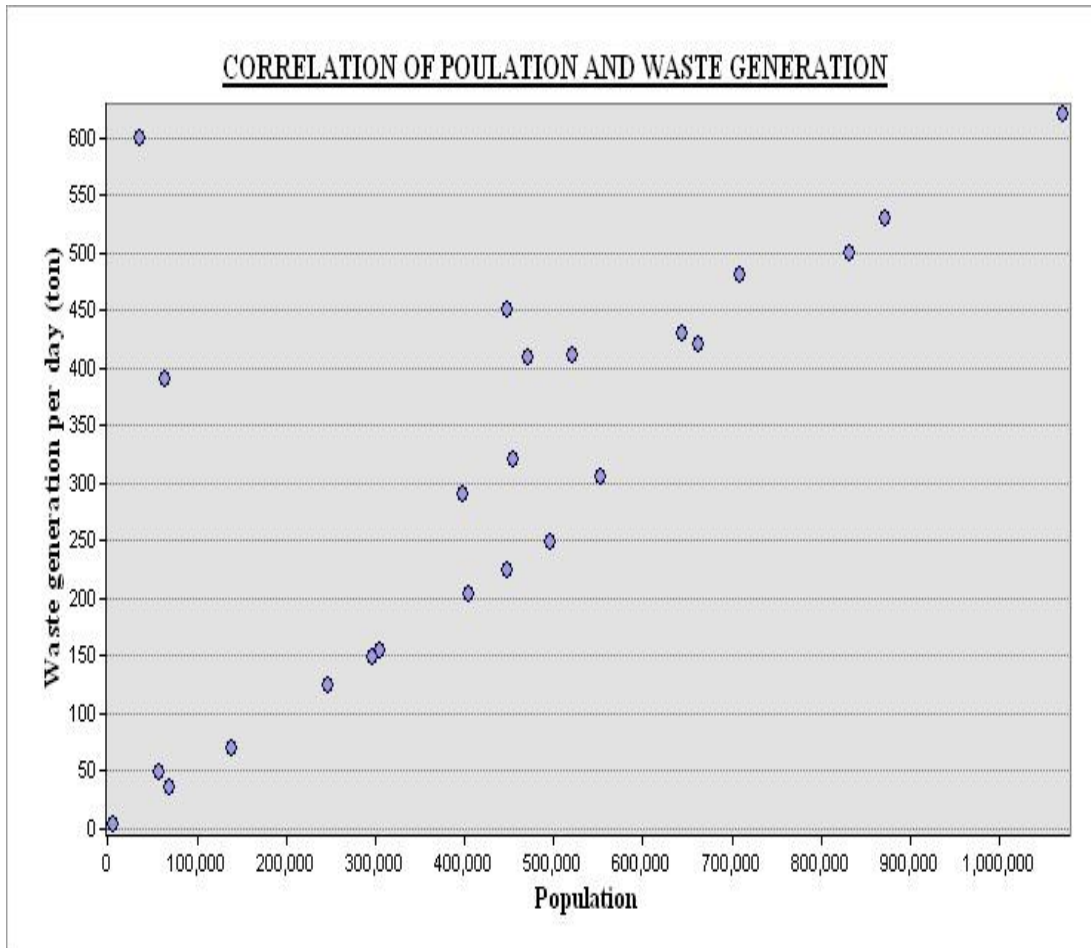
Figure 5. Correlation between population and waste management. Source, Author

Problems linked with solid waste management system in Karachi

The per capita MSW generation had been a significant challenge for a megacity Karachi, Pakistan. It is assumed that the rising MSW generation rate with directly correlated with the dense population because of the merge population. Unfortunately, other key factors are also responsible including, political instability is responsible for a disappointing performance in the field of solid waste management at the government level turned backlog issue disastrous in the time of monsoon because sewage nalas (streams) has been full of waste and drainage system of is collapsed in the time of the rainy season which exposed unsatisfactory performance of the municipal administration. Waste has been collected from houses in mixed form, because of lack of facilities it was very difficult for sanitary workers to separate recycling material at the primary stage. The non-government sector was engaged to manage MSW from city, they are paying Afghan waste pickers to collect the MSW from the community bins to open dumping site. In addition, Afghan waste collectors found to be very beneficial for clean-up waste material, but they also proliferate waste around the bins and congested roads. The data in (Fig. 6a) shows the pile-up of waste in the front of the flats. As exposed in (Fig. 6b) highlighted that the waste pickers are collecting the reusable item from a heap of waste. The data in (Fig. 6c) shows burning

waste along the road. (Fig. 6d) represents a heap of waste in an open plot.

(a) Pile-up of waste.	**(b) Collecting reusable item**
(c) Burning waste along the road	**(d) A heap of waste in an open plot**

Figure 6. Shows ground truthing, (a) Pile-up of waste, (b) Collecting reusable item, (c) Burning waste along the road, (d) A heap of waste in an open plot, Source: Author

Means of transportation in solid waste management

The collection of MSW from waste collection points by using different vehicles has found to be very importance to handle the situation of MSW in any area; however present study found that insufficient number of vehicles in the mega city Karachi (Fig. 7), which represents the different kinds of the vehicle of the government, the majority of

which are not functional. Only North Nazimabad, Cantonment, Central district, and some areas of east districts served by government vehicles, and all Karachi is served by private contractor vehicles and Chinese companies. The data in (Fig. 8) indicated the types of vehicle have used in waste collection and transportation. Each vehicle is making 3 to 4 trips per day from the collection points to the dumping areas Ching-chi Rickshaw, motorcycle trolley, Mini tractor-trolley collects waste from the small, thin, and congested route and filled waste through labor old compacted dumper also gather waste from small routes filled through labor. Medium dumper, big dumper, mini dumper, medium tractor trolley was filled with the assist of a loader and follow the main route for transportation of waste to final dumping sites. The types of vehicles and their capacity are indicated in (Table 3).
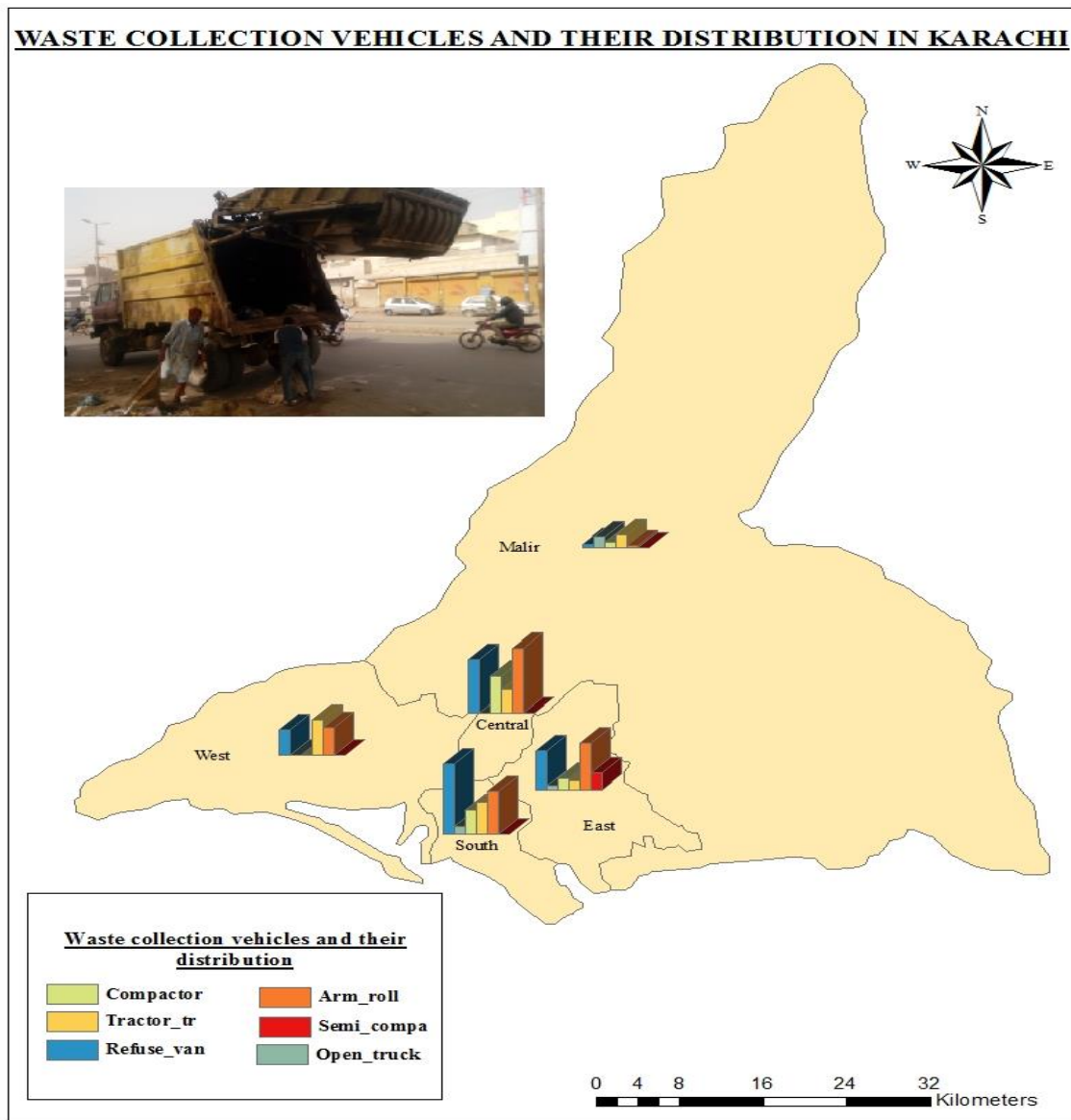

Figure 7. Government waste collection vehicles and their distribution in Karachi, Data Source: Ali and Hasan [24].

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a) Ching-chi Rikshaw

b) Motorcycle Trolley

c) Mini Tractor Trolley

d) Medium Dumper

e) Old Compress Dumper

f) Big Dumper

g) Mini Dumper

h) Big Compactor Dumper

i) Open Truck

j) Medium Tractor Trolley

k) Chinese Company Loader

L) Chinese Company Dumper

Figure 8. Types of vehicles used in waste collection and transportation (a) Ching-chi Rikshaw, (b) Motorcycle trolley, (c) Mini tractor trolley, (d) Medium dumper, (e) Old compress dumper, (f) Big dumper, (g) Mini dumper, (h) Big compactor Dumper, (i) Open truck, (j) Medium tractor trolley, (k) Chinese company loader, and (l) Chinese company dumper, Source: Author

**Table 3. Different types of vehicles and their load capacity**

S. No.	Type	Capacity
1	Ching-chi Rikshaw	600 to 700 kg
2	Motorcycle trolley	600 to 700 kg
3	Mini Tractor trolley	1.5 to 2 tons
4	Medium Dumper	12 to 14 tons
5	Mini Compress Dumper	3 to 4 tons
6	Big Dumper	18 to 2o tons
7	Mini Dumper	7 to 8 tons
8	Big Compactors Dumper	6 to 8 tons
9	Loader	Loading
10	Tractor trolley	3 to 4 tons
11	Tractor trolley	1.5 to 3tons
12	Vehicles of the Chinese company	4 to 10 toms
13	Arm Roll	5 to 6 tons

Source: Author

Influence of seasons on volume and quantity of the municipal solid waste

The improper treatment and disposal methods of MSW management in the study area, which contributing Backlog quantity has been growing in Karachi, because of inappropriate situation and lack of bins from fundamental waste collection units. General, the people throw their garbage to streets, unconstructed plots, footpaths and nalas (streams) dumping of waste in drainage system resulting blocking the drainage system and causing several human health serious for example, electric specially heavily rainfall in monsoon season. As shown in (Fig. 9) highlighted the influence of seasons on volume and quantity of MSW.
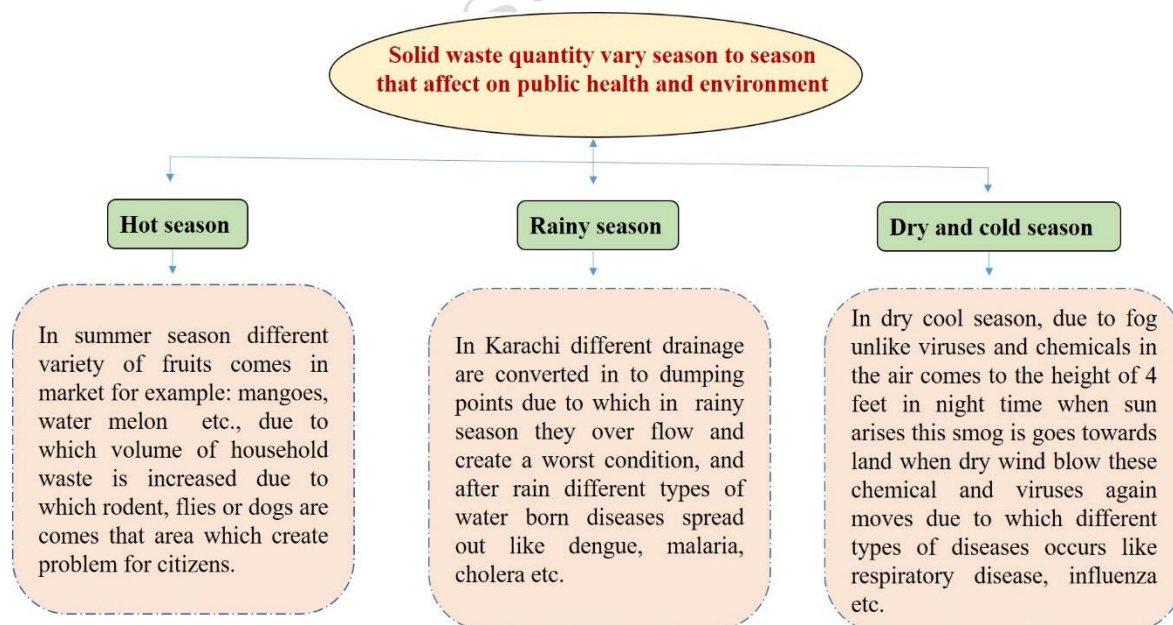
Figure 9. Impact of seasons on volume and quantity of solid waste, Source: Author

Discussion

This study has highlighted the issues faces municipal solid waste system in a multicultural city, assessment has been done through GIS Techniques statistical analysis of two variables have done, a positive correlation has found between population and waste generated rate per day (tons), qualitative assessment of means of transportation of solid waste also included and identified the types of vehicles with the help of pictures and explains their capacity which is very beneficial for policymakers and researchers to reduce the waste pileup by making proper strategy. The impact of the seasons shows their importance regarding municipal solid waste management. Mostly developing cities are facing a big challenge of solid waste management. Abbasi *et al*. [5] stated that the climate of megacity Karachi can be characterized by humid and moderate to hot circumstances. The mean lower0ºCand highest47ºC may vary in the summer season; furthermore, the average rainfall at Karachi is about 203 mm. It is assumed that the variation in temperature and rainfall may directly impact municipal solid waste generated, onsite handling, and management. Research work was carried about the possibility of energy generation from municipal solid waste (MSW) in Pakistan Korai *et al*. [25], predictable that the hypothetical biogas potential for MSW generated in the megacity Karachi by using elemental analysis. Furthermore, Khan *et al.* [26] revealed that Karachi city has a population of about20 million and generating 14,000 tons of MSW per day. Meanwhile, findings showed that no proper MSW management in this megacity and posing a risk to soil pollution, ground water marine life, and greenhouse gas emission in the air. Khan *et al.* [27] suggested that the application of decision support software for Karachi revealed that the current development needs to be reconsidered and

land-filling of RDF/ SRF to be converted by waste-to-energy options. Hoque and Islam [28] stated that composting is a very important method and completed in 40-45 days in this time 50-55% of the volume of waste is reduced from its original volume. Ali *et al.* [29] used the broad indicators to rank MSW in a major city and suggested that the integrated waste disposal systems to mitigate the GMGs emission to atmosphere. Siddiqi *et al.* [30] indicated that recyclable paper and plastics removed from MSW can produce nearly 290 gigawatt hours (GWh) in Karachi and 60 GWh in Delhi. Safar *et al.* [31] reported some recycling components for converting MSW into energy recovery and minimizing environmental pollution.

Conclusion and Recommendations

We concluded that there have lots of issues presents in existing solid waste management system, due to which it never shows better progress, waste collection, and vehicles are very significant components for management of MSW form waste collection generated points, but unluckily vehicles are inadequate to lift total MSW material from bins to disposal sites of Karachi. The population was another important indicator for the generation of waste in a city for analysis population density which was calculated in this study by using ArcGIS 10.3.1. The variation of seasons, i.e. rainy, hot, cold also affects the quantity and volume of solid waste community bins are a fundamental element of the solid waste management system so their proper placement and maintenance are very important. The followings are the significant contributions of the present study:

• The municipal solid waste generation is approximately 2929402.293 tons per year, and its volume and quantity varies from season to season, waste generation rate per day tons 2019 map of Karachi is very helpful for risk evaluation of the city.

• Spatial distribution of waste collection vehicles in Karachi through ArcGIS

techniques evaluated the basis for future waste collection vehicles planning and waste management projects.

• The study has calculated the correlation between population and waste generated rate per day (tons) indicated beneficial for future planning in the city, guide them as to where the future waste management service's related activities should establish.

• Burning and open dumping are common methods are practicing for waste treatment, it extremely recommended that compost technology should be practiced in this region to manage organic waste material, because it a robust low cost and an eco-friendly technology. The government should take interest to manage solid waste management and provide awareness programs and as well as training to waste collection workers. Finally, it is suggested that the eco-friendly integrated waste management practices should be introduced to manage MSW material, for example biodegradable waste material should be converted into make compost, bio fertilizers, biochar etc., and non-biodegradable waste material can be converted to make smart biochar, road construction material, energy recovery and gold recovery specially from e-waste.

Authors' contributions

Conceived and designed the experiments: A Afzal & SAfsar, Performed the experiments: A Afzal, Analyzed the data: A Afzal, Contributed materials/ analysis/ tools: A Afzal & SAfsar, Wrote the paper: A Afzal & AH Lahori.

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