ANALYSIS OF MUNICIPAL SOLID WASTE MANAGEMENT IN AFGHANISTAN, CURRENT AND FUTURE PROSPECTS: A CASE STUDY OF KABUL CITY

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Abstract. In Asian countries like Afghanistan, the quantity of municipal solid waste (MSW) is rapidly increasing because of increasing population and economic developments. This increased MSW amount and its inappropriate management has severe impacts on Kabul city. The purpose of the current study was to find out the MSW sources, generation rate, physiochemical properties, current and future management practices in Kabul city, Afghanistan. A questionnaire survey of a total number with 1,150 questionnaires was conducted on the basis of stratified random sampling in January, 2021. Quantification/composition of waste was determined by using a standard method of ASTM-D5231-92. The average MSW generation ratio of four (04) categories of residential areas such as (high, middle, low income and rural areas) were considered and ranged from 0.28±0.10 kilograms per capita per day (kg/c/d) for low income or rural areas to 0.48±0.10 kg/c/d for high income areas with the maximum quantity of food waste (FW) at 52.4% of the total waste, followed by paper 20.3% and plastic 17.4% in residential areas. Hence, the total generation of MSW was 3,200 tons/day. The mean per capita FW production in Kabul city was 0.35 kilograms/day or 120.10 kilograms/year. MSW includes of fifteen (15) different types, with organic waste >70% as a major constituent of the MSW in the Kabul city. Outcomes of the current study might help the government to design and operate a complete municipal solid waste management (MSWM) structure for Kabul city and other growing cities all over the country.
Keywords: *solid waste, physiochemical analysis, solid waste management, 3R's approach, awareness*

Introduction

Proper solid waste management (SWM) is the most important method for environmental protection and resources management (Sandulescu, 2004; Ilyas et al., 2017). In SWM, the municipal solid waste management (MSWM) is a significant factor affecting the environment which is ignored in most of the Asian countries like Bangladesh, China, Nepal, Pakistan and Afghanistan (Murtaza and Rahman, 2000; Ghaforzai et al., 2021). In developed countries the generation amount of MSW is equal to collection amount, but in Asian countries like Afghanistan, Bangladesh, Pakistan and India etc., the situation is completely different and MSWM consist of only collection and open dumping (Ali et al., 2016).

There is little census data for Afghanistan but Afghanistan's Central Statistics Office (ACSO) assessed that Kabul city had a population of 720,000 in 1978, which has recently increased to 4 million in 2012 (Mack et al., 2013). The Kabul city population has increased to 4.8 and 5 million in 2015 and 2018 respectively, which shows a total 15% of Afghanistan population. According to United Nations report it is estimated that the population in the Kabul city will rise to about 9 million by the year 2057 (Mack, 2018). This is the maximum ratio of population in any one city in Central or South Asia. Due to this fast growth in population, that extending the boundaries of Kabul city and specifies greater waste generation quantity. This growing quantity of MSW is one of the key challenges to controlling organizations to keep the Kabul city clean (Mack, 2018).

Urbanization, developmental activities, population growth and current living standards are the basic causes behind the increasing growth in MSW generation in Kabul city (Khoshbeen et al., 2020). This increased solid waste total causes trouble in effective MSWM method (collection, storage, transportation and disposal) (Ozcan et al., 2016). Globally the amount and composition of MSW differs with area, climatic as well as socio-economic conditions (Ciuta et al., 2015). In many of the Afghanistan big cities and towns only 50% of the MSW is collected and stored and >80% of the collected MSW goes to open dumping sites around the cities (Khoshbeen et al., 2020). But, for the cities to be comparatively hygienic at least > 80% of the MSW should be collected.

The MSW generation in Kabul city in 2017 was about 0.4 kg/c/d with total amount of 2,000 tons per day (Haidaree and Lukumwena, 2017). In 2020, the MSW generation rate further increased to 0.5 kg/c/d with total amount of 2,563 tons/d. Moreover, it is expected that the sum of MSW generated within the Kabul city will be increase to 0.6 kg/c/d with total generation of 3,300 tons/d by the year 2025 (Khoshbeen et al., 2020). Consequently, the quantity of MSW is expected to rise extremely in the near future while there is no proper management system in Kabul Municipality (KM) to overcome with it. Absence of reliable facts, improper institutional measures, non-compliance of rules, inadequate resources (equipment and money), and absence of specialists are the main limitations for suitable MSWM in Kabul city. In Afghanistan throughout the last two decades due to migration of societies from rural to urban regions the household ratio in Kabul city has enlarged from 3.8-9.2%.

Currently, there is no well-designed and effective MSWM system, necessary data on the sources, generation rate, characterization and composition about MSW in Kabul city. Moreover, there is no well-planned landfill facility in the study area and all the MSW is dumped near to households and causes problems to human health, water quality both surface and underground and also sustainable development. The overall purpose of the current study was to develop a sound and sustainable MSWM for Kabul city. To achieve this purpose, the current MSWM systems have been examined and MSWM practices

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were found. All the important data about sources, generation rate, physiochemical properties, current and future prospects of MSWM in Kabul city of Afghanistan have been investigated.

Materials and Methods

Study area

Kabul city lies in the middle of Kabul province, with an expected population of 5 million with in 22 districts, with a total number of households are 694,756; commercial units 70,720 and administrative units are 761 (CSO, 2018). A comprehensive map of study area is available in *Figure 1*. KM is the organization in charge for all the hygienic actions in the Kabul city comprising regular collection, transport and dumping of MSW, as well as drainage cleaning and street sweeping under the control of Directorate of Sanitation (DoS). As of 2019, the DoS met challenges with insufficient technical manpower with a total number of officials are 119 for administration, with a total number of workers/staff 3,625 divided into three (03) sub units transportation, central unit and district offices in DoS. DoS collects the MSW from all the districts excluding district 14 from municipal collection bins. The DoS presently lacks technical staff to plan a well-designed a landfill and operate on international standards (Khoshbeen et al., 2020).

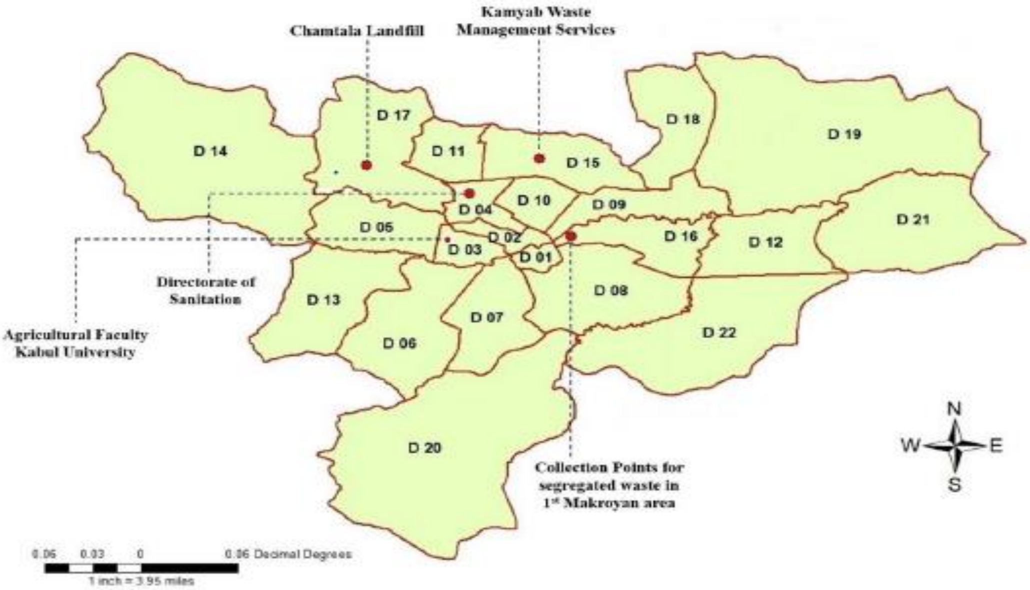

Figure 1. *Location of the study area with district boundaries & important locations of SWM. Map adopted from Khoshbeen et al. (2020)*

Sampling design

In current study MSW samples of the Kabul city were collected from both the main city and rural zones. The benefit of this sampling analysis was to measure the quantity of MSW produced and to identify its sources, generation rate, physiochemical properties and current management practices that will help to recommend a MSWM strategy/system. A total ten (10) sources of waste for the current study were considered, as shown in *Table 1*. Household sources were classified into four (04) main categories

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(high, medium, low income and rural families) for stratified sampling. For each source type a total 115 sampling points were selected see in *Table 1*, and waste quantity ratio to discharge was measured. The total sampling was done in ten (10) days (from 20th to 29th of January, 2021) and a total of 1,150 questionnaires and 750 waste samples were considered from all type sources for the current study. Out of the total 1,150 questionnaires about 600, 150, 120, 120, 100 and 60 from residential, markets, commercial, parks, institutions and street sweepings respectively. Moreover, the data about houses, individuals per family, number of staffs and total house area were collected from the questionnaire study.

Table 1. *Sampling design for solid waste generation sources in Kabul city*

Types		Questionnaire Survey for Solid Waste in Kabul City				
		Locations	**Samples/location**	**No of samples**	**Sampling days**	**Total samples**
Residential	High income	05	03	15	10	150
	Middle income	05	03	15	10	150
	Low income	05	03	15	10	150
	Rural areas	05	03	15	10	150
Commercial	Hotels	02	04	08	10	80
	Others	01	04	04	10	40
Markets		05	03	15	10	150
Institutions		05	02	10	10	100
Street sweepings		03	02	06	10	60
Parks		04	03	12	10	120
Total				115		1,150

Solid waste amount

For the determination of MSW generation rate in Kabul city, we used output technique or load count analysis (Ilyas et al., 2017), and it is reported from the literature that this technique requires less works and cost-effective as compared to Input method. Waste samples were collected in plastic bags from each source assigned with a different source code, and these waste samples were collected in specific allotted vehicles. MSW generation rate was measured by weighing the waste amount from each source (Di Maria et al., 2013; Suthar and Singh, 2015). To determine MSW generation rate the mean household size was used seven (07) persons. The relative proportion of each waste component was estimated as percent by weight on wet basis (Di Maria et al., 2015).

Analysis of solid waste composition

Physical properties of waste

Physiochemical properties of MSW show an important role in selection of suitable MSWM approach (Ilyas et al., 2017). For physical composition analysis of the MSW of the Kabul city a standard method ASTM-D5231-92 was used (ASTM, 2008). American Society for Testing Materials (ASTM) has termed this technique as ASTM-D5231-92 standard technique for the analysis of the MSW composition (Worrell and Vesilind, 2011). This method comprises unloading and analyzing the amount of MSW at a disposal

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location, in the absence of winds. A representative sample of size 100-200 kg resulting from the collection of waste in residential area is necessary for analysis.

Moreover, reduction process was done for huge MSW producing sources to get a sample of about 200 kg and the samples <200 kg segregation method was used directly. The physical composition percentage of each MSW sample in wet base, Xi (%), was measured as given below.

$$\text{Xi} = \frac{\text{Weight of each weight composition (kg)}}{\text{Total amount of each waste composition (kg)}} \times 100 \qquad \text{(Eq.1)}$$

Once the representative sample was prepared, the MSW is full into a plastic container. The plastic container containing the MSW is fallen 03 times to ground from a 30 cm of height, and then the volume is calculated using measuring tape and mass by a balance. The Apparent Specific Gravity (ASG) is calculated as follow.

$$\text{ASG} = \frac{\text{Weight of the MSW in container (kg)}}{\text{Volume of the MSW (m3)}} \qquad \text{(Eq.2)}$$

The waste samples were separated into fifteen (15) different physical components after measuring AGS, see in *Table 4*.

Chemical properties of waste

In the present study 100 samples of waste were collected from 20 different sources at Kabul city as shown in *Table 2*. Chemical composition analysis includes the analysis of carbon: nitrogen (C: N), moisture content (MC) of MSW, and three component analysis such as ash, combustible and moisture content were investigated. All analyses were carried out at Centralized Resource Laboratory (CRL), University of Peshawar, Pakistan. For the analysis of MC, minimum 1-1.5 kg of MSW was used of each composition. First of all, the samples were packed in a plastic bags to overcome the loss of MC and kept at a temperature range of 95-100°C for almost five to six (5-6) days in incubator (ASTM, 2008; Nadeem et al., 2016; Ilyas et al., 2017). Later MC was measured as given below.

$$\text{MC(\%)} = \frac{\text{Weight of sample before drying(kg)} - \text{Weight of sample after drying (kg)}}{\text{Weight of sample before drying (kg)}} \times 100 \qquad \text{(Eq.3)}$$

Table 2. *Number of samples for chemical composition survey for MSW in Kabul City*

Types		Chemical composition Survey for Solid Waste in Kabul City			
		Source of generation	**Moisture Content (MC)**	**Carbon: Nitrogen (C: N)**	**Three component analysis**
		Locations	**Samples/Location**	**Samples/Location**	**Samples/Location**
Residential	High income	05	5 × 5 = 25	5 × 5 = 25	5 × 5 = 25
	Middle income	05	5 × 5 = 25	5 × 5 = 25	5 × 5 = 25
	Low income	05	5 × 5 = 25	5 × 5 = 25	5 × 5 = 25
Markets (Fruits and Vegetables)		05	5 × 5 = 25	5 × 5 = 25	5 × 5 = 25
Total		20	100	100	100

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To analyze the Nitrogen ratio of MSW samples Total Kjeldahl Nitrogen method was used using Mercury (Hg) as a catalyst (Olsen et al. 1982). MC of combustible waste was calculated for MSW category (01, 02, 03, 04, 05 and 08); C: N ratio for (01, 02, 03 and 05) and three component analyses were carried out for (01 to 15). For three component analyses ash, combustible and moisture were analyzed for MSW types ranging from 01-15. For this purpose, 5-7 g of MSW was measured in crucible furnace of 150 ml. The samples were heated at a temperature of 820-850°C for almost two (02) hours and then kept in desiccator for 30-40 min to cool down and weighted. Then ash component (A) and combustible (V) were measured.

$$A(\%) = \frac{\text{Weight of sample after heating (g)}}{\text{Weight of sample (g)}} \times 100 \qquad \text{(Eq.4)}$$

$$V(\%) = \frac{\text{Weight of sample (g)} - \text{Weight of sample after heating (g)}}{\text{Weight of sample (g)}} \times 100 \qquad \text{(Eq.5)}$$

Data analysis

For MSW generation rate and its composition, 95% confidence interval of the means was calculated. Analysis of data was done using GraphPad Prism (GraphPad Software, Inc., San Diego, CA, USA) (Prism) and Microsoft Excel.

Results and Discussion

The outcomes of the current study show the sources, generation rate, physiochemical properties and current management practices of MSW from study area which is a combination of various constituents. The major ratio of the MSW in Kabul city is organic waste (compostable) more than 70%. Greater amount of this waste indicates a suitable idea for composting method, regular collection and removal of MSW from generation points.

Characterization of MSW in Kabul city

MSW generation, composition and characterization

The mean household size of low, middle, high and rural areas was seven (07) persons (Osama and Kajita, 2020). Average MSW generation rate of these 04 categories of residential parts ranged from 0.28±0.10 kg/c/d for low income or rural regions to 0.48±0.10 kg/c/d for high income regions as given in *Figure 2(a)*. High income areas generate more MSW as related to low income or rural regions; it reveals that living standard greatly affect the quantity of MSW generated.

In *Figure 2(b)* has shown the average MSW generation from commercial sources. Due to insufficient information about the exact number of individuals generating MSW in these regions we have to suggest the mean weight of MSW produced in 10 sampling days. In other sources of MSW, restaurants/hotels are the leading generator of MSW with a total amount of 12.2 kg/d following open parks with 8.4 kg/d of MSW amount. Street sweepings show less role and about 1.8 kg/d of MSW generated. Markets generate 2.5 kg/d of the MSW and institutes 5.3 kg/d individually. Also, MSW quantity study has been done in vegetable and fruit market places of Kabul city. There are some vegetables and fruit market places where KM has sited a communal container of 3 m^3. While other

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shops, which are illegal selling points of vegetables and fruits, are distributed in the Kabul city. Ten (10) major points were selected for the collection of samples in these selling places.

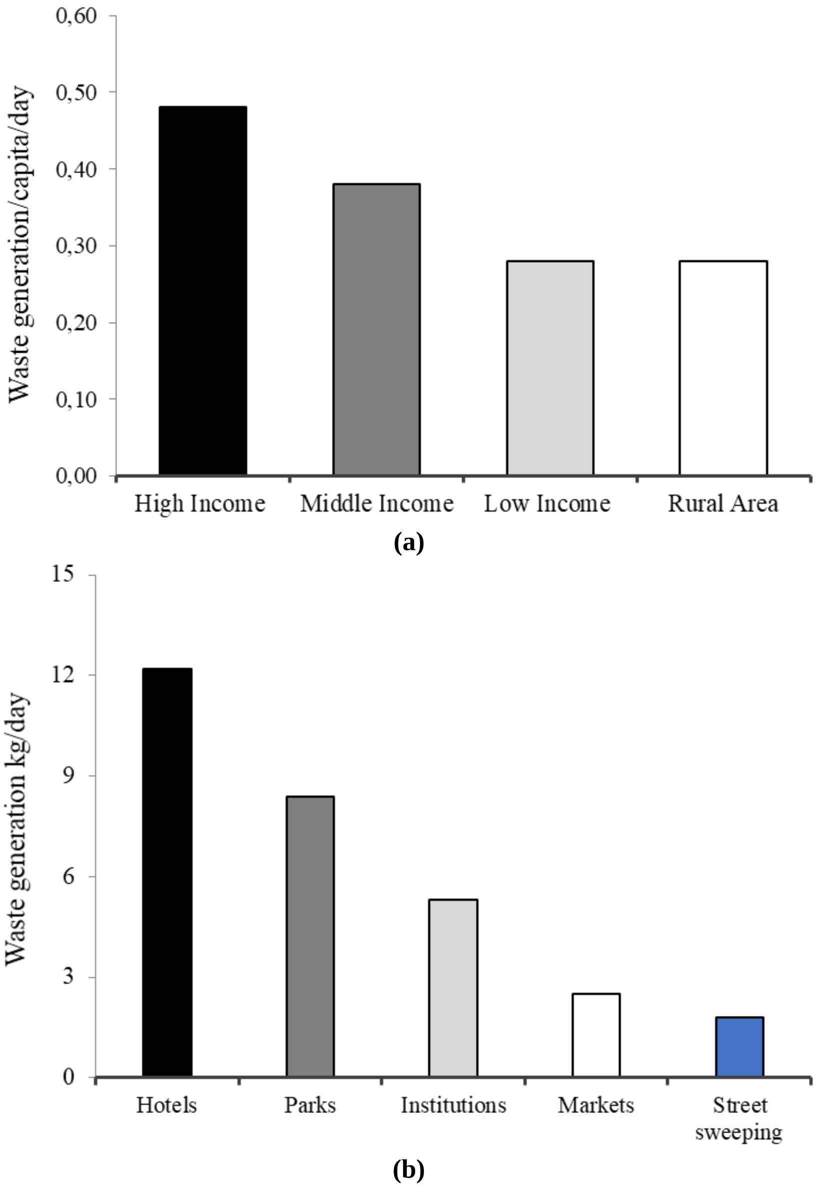

Figure 2. *Solid waste generation per capita per day (kg/d) in **(a)** residential areas and **(b)** in commercial areas*

The ASG for each MSW type was analyzed and listed in *Figure 3*. The ASG of MSW from these four (04) residential areas reported 272 kg/m^3 for high income, 280 kg/m^3 for middle income and 278 kg/m^3 for low income areas while 260 kg/m^3 has been reported for rural areas, but commercial MSW from hotels have peak rate of ASG of around 550 kg/m^3. The mean per capita generation of MSW in Afghanistan was expected to be 0.44 and 0.61 kg/c/d in 2016 and 2018, respectively (Kaza et al., 2018). The major cause of this rapid growth is a consequence of current economic development in the Kabul city. With mean per capita MSW production of 0.61 kg/c/d, with expected 5 million population

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the total MSW production was approximately 3,050 tons/d. The per capita MSW generation in Bangkok and Delhi was reported 0.82 and 0.41 kg/c/d, respectively (Kumar et al., 2017; Khoshbeen et al., 2020). Significant, Bangkok city has mostly high to middle income families and thus the per capita generation of MSW was greater than Kabul city which generally has low and middle-income families. Remarkably, the high and middle-income families of Kabul city produced MSW at the equal ratio of the Bangkok city. Worldwide, MSW is consisting of 44% organic and food waste followed by cardboard and paper 17% both and plastics 12% (Kaza et al., 2018). A study by Marashlian and El-Fadel (2005) found that food waste grinders can reduce the total solid waste generation by 12 to 43%.

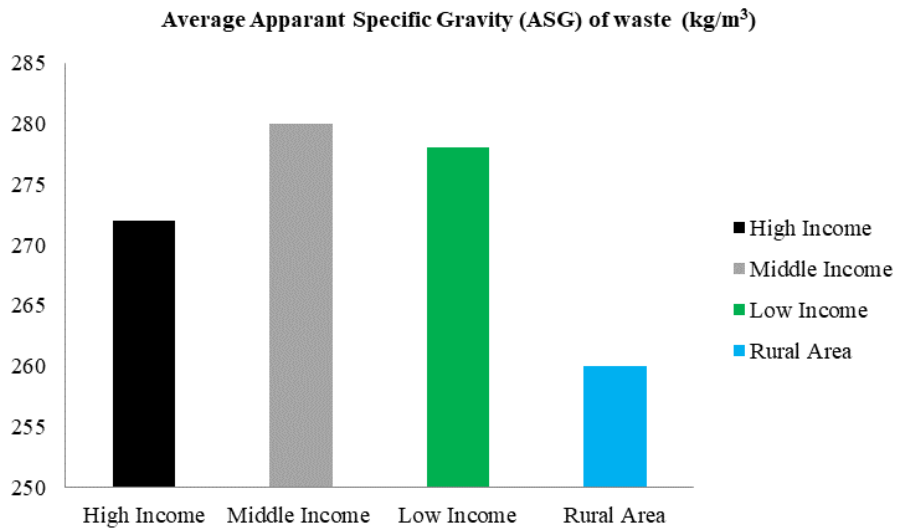

Figure 3. *The average (ASG) (kg/m^3) for residential areas*

Quantification and characterization of MSW generation are obligatory for effective management plan. Geographic area, living standards, food preferences, energy sources, industrial practices, and weather conditions all have an effect on MSW composition (Sahariah et al., 2015). Developing countries MSW contains more organic wastes, while developed countries MSW contains a greater proportion of plastics and paper. The proportion of organic constituents in MSW varies relatively between developed and developing countries like the United States (24%), the European Union (34%), China (67%), Malaysia (55%) and Japan (40%). Organic waste accounted for 60-70% of the total MSW in Indonesia (Sudibyo et al., 2017). Depending on the waste composition, different methods and MSW systems may be considered. Characterizing and classifying MSW for its suitable management requires knowledge of its physical composition. *Table 3* shows a complete list of MSW materials generated by various major cities in developed and developing countries, as classified by the USEPA and EUROSTAT. The important components in MSW produced by major cities in various developing countries do not always conform to the classifications developed by environmental agencies based in the United States and Europe. The composition of MSW generated in most of these cities was found to be dominated by FW and other decomposable materials. Moreover, some slowly decomposable materials like paper, wood, textiles, leather and rubber were reported in all cities, see in *Table 3*.

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Table 3. *Average composition of MSW in major cities in developed and developing nations*

S.No.	City/ (Country)	Food waste	Paper	Wood	Textile	Glass	Plastic	Rubber/ Leather	Metal	Others	References
01	Nottingham (UK)	21	32	-	2	9	11	-	8	10	Wang et al. (2018)
02	Mazowieckie (Poland)	38	8	0.04	1	10	8	-	2	6	Baran (2018)
03	Mexico City (Mexico)	28	12	-	-	5	17	-	3	33	Tsydenova et al. (2018)
04	Chengdu (China)	67	9	3	3	-	-	-	-	19	Huang et al. (2015)
05	Kolkata (India)	51	6	1.2	2	0.34	5	0.7	0.2	3	Paul et al. (2019)
06	Terengganu (Malaysia)	12	8	-	-	10	9	-	2	3	Jaafar et al. (2018)
07	Lampang (Thailand)	34	15	-	2	8	24	1	3	2	Outapa and na roiet (2018)
08	Kuala Lumpur (Malayasia)	55	13	1	4	2	19	-	3	3	Bashir et al. (2018)
09	Tehran (Iran)	-	7	-	6	-	6	-	-	-	Dehghanifard and Dehghani (2018)
10	Chittagong (Bangladesh)	21	2	-	4	-	-	1	1	-	Sarkar and Bhuyan (2018)
11	Muscat (Oman)	34	25	2	6	8	16	0.4	3	1	Baawain et al. (2017)
12	Jakarta (Indonesia)	35	11	18	3	14	14	4	4	7	Indrawati and Purwaningrum (2018)
13	Lagos (Nigeria)	10	12	-	3	-	6	-	9	4	Olukanni et al. (2018)
14	Kerbala (Iraq)	57	12	-	-	4	15	-	4	9	Abdulredha et al. (2018)
15	Kumasi (Ghana)	17	21	-	-	-	6	-	2	30	Edjabou et al. (2017)

It was also clear that the composition of MSW differed significantly between big cities and small towns. Organic components, for instance, about 55% of total MSW in Kuala Lumpur, Malaysia, related to 12.2% of total MSW in Terengganu, Malaysia, with a total population of 1.84 and 0.5 million people respectively (Jaafar et al., 2018). MSW in Qatar consisted primarily of organic components (60%) and recyclables (40%) (Rehrah et al., 2016).

FW generation rate, composition and characterization

FW is presently one of the biggest issue in the Kabul city. As explained previously, FW contributes 52.4% of total MSW produced in Kabul city. Hence, the total generation of MSW was 3,200 tons/d; the contribution of FW was 1,677 tons/d. The mean per capita FW production in Kabul city was 0.35 kg/d or 120.10 kg/y. According to Dung et al. (2014) the average FW generation in developing and devolped countries was about 56 and 107 kg/y respectivley obviously showing that the people in Kabul city are producing

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FW more than developing and devolped countries. FW was cosist of vegetables at maximum fraction of 35% followed by fruits 30%. Rice waste 20% was mostly produced at resturatnts and high income families. The whole constiuants of FW shows that the FW was mostly organic and thus appropriate for composting purposes.

The mean density of FW was reported 300 kg/m^3, greater than unsegregated waste, which was reported 221 kg/m^3. The mean MC of FW was reported 80% which may possibly generate leachate after dumping in adjecent landfills. Since MC of Kabul city FW was great, thus anaerobic digestion and composting are appropriate to get rid of FW.

Physiochemical properties of MSW

The physiochemical properties of MSW were analyzed for four residential areas. *Figure 4a*,*b*,*c* and *d* show the physical composition of waste for residentail areas includes the maximum quantity of food waste which was 52.4% of the total MSW, followed by paper 20.3% and plastic 17.4% see in *Table 4*. Metals are reported in fewer amounts due to segregation at household level (Batool et al., 2008). The physical composition of MSW in rural areas was changed from urban regions and includes of 36% of FW, followed by soil and stones 23% and wood and grass 12%. Recyclable plastic is less in low and rural areas waste which was associated with socio-economic situation of the region. Non-recyclable plastic and textile waste also reported in great quantity in household waste. The physical composition of wastes from commercial sources such as restaurants generated FW, paper and plastic 60%, 12% and 08% respectively.

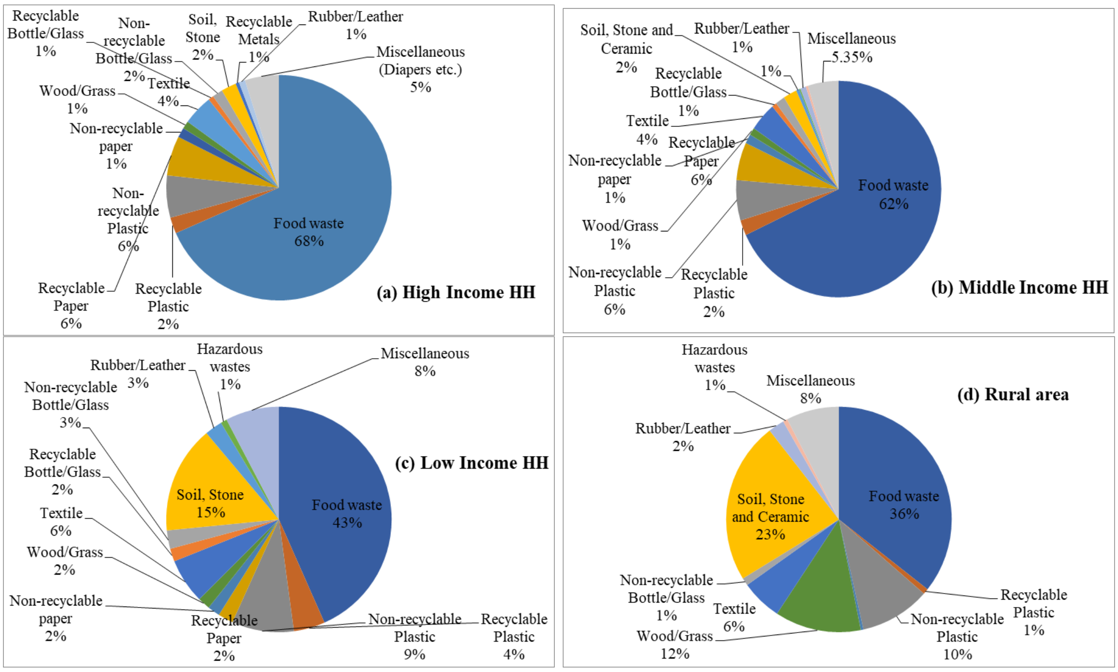

Figure 4. *Physical composition of waste generated from (a) high income household, (b) middle income household, (c) low income household, and (d) rural area*

Waste from commercial markets and shopping centers were mostly contained of FW 48%, followed by paper waste 42%, non-recyclable plastic 30% and wood and grass 25% each.

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Table 4. *Average physical composition of waste for residential areas in Kabul city*

S.No.	Physical components	High income areas	Middle income areas	Low income areas	Rural areas
		Average %	Average %	Average %	Average %
01	Food waste	68.02	62.10	43.98	35.5
02	Recyclable Plastic	2.30	2.60	4.56	0.80
03	Non-recyclable Plastic	6.02	6.75	9.02	10.05
04	Recyclable Paper	5.65	6. 03	2.2	0.00
05	Non-recyclable paper	1.40	1.10	1.8	0.38
06	Wood/Grass	1.10	1.50	1.8	12.32
07	Textile	4.32	5.12	6.55	5.85
08	Recyclable Bottle/Glass	0.75	1.80	1.87	0.00
09	Non-recyclable Bottle/Glass	1.50	0.55	2.68	1.10
10	Soil, Stone and Ceramic	2.15	4.75	15.65	23.15
11	Recyclable Metals	0.50	0.20	0.00	0.00
12	Non-recyclable Metals	0.20	0.10	0.42	0.35
13	Rubber/Leather	0.89	1.50	2.55	2.30
14	Hazardous wastes	0.35	0.55	0.92	0.65
15	Miscellaneous (Diapers etc.)	4.85	5.35	7.80	7.55
16	Total	100.00	100.00	100.00	100.00

Offices and institutions waste comprise 40% wood and grass, 28% soil, stones and ceramic and 10% paper waste. While in street sweeping 67% soil, stone and ceramic and 15% wood and grass, however park waste only contain wood and grass about 70% followed by recyclable plastic about 10% and FW 5% due to food stalls in the park area.

The chemical composition analysis of the MSW was carried out for MC, C: N ratio as well as three component analysis. Mean value for MC of the residential regions was reported 64%. The MC for MSW of high, middle, low-income and market areas were reported about 70.2%, 68.4%, 55.8% and 61.3%, respectively as shown in *Figure 5(a)*. The mean value for C: N ratio for MSW was reported to be 120.50. While C: N ratio for MSW of high, middle, low income region and market waste were 140.66, 130.44, 121.58 and 89.32 were observed respectively as given in *Figure 5(b)*.

For the three-component analysis; ash, combustible and moisture content were investigated. MC for MSW of high, middle, low income areas and market areas have detected about 73.2%, 65.5%, 67.6% and 70.2%, respectively as shown in *Figure 5(c)*, while the average value was found to be 69.2% in three component analysis for 100 samples. The mean value of combustible content (V) was detected about 81.8%, with maximum rate of 88.8% for high income region. In middle and low-income areas, (V) was observed to be comparable 80.6% and 81.2%, respectively, however lowest (V) was detected 76.4% in MSW of market areas. Likewise, the mean ash content (A) for the same samples were checked and found to be 14.2%. Maximum (A) is detected for market areas

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waste 20.4% and lower most for high income areas 8.3%. The values for (A) waste from middle and low-income areas were reported 13.5-14.6% respectively. *Table 5* shows the physiochemical properties of MSW produced in some big cities in several developing countries.

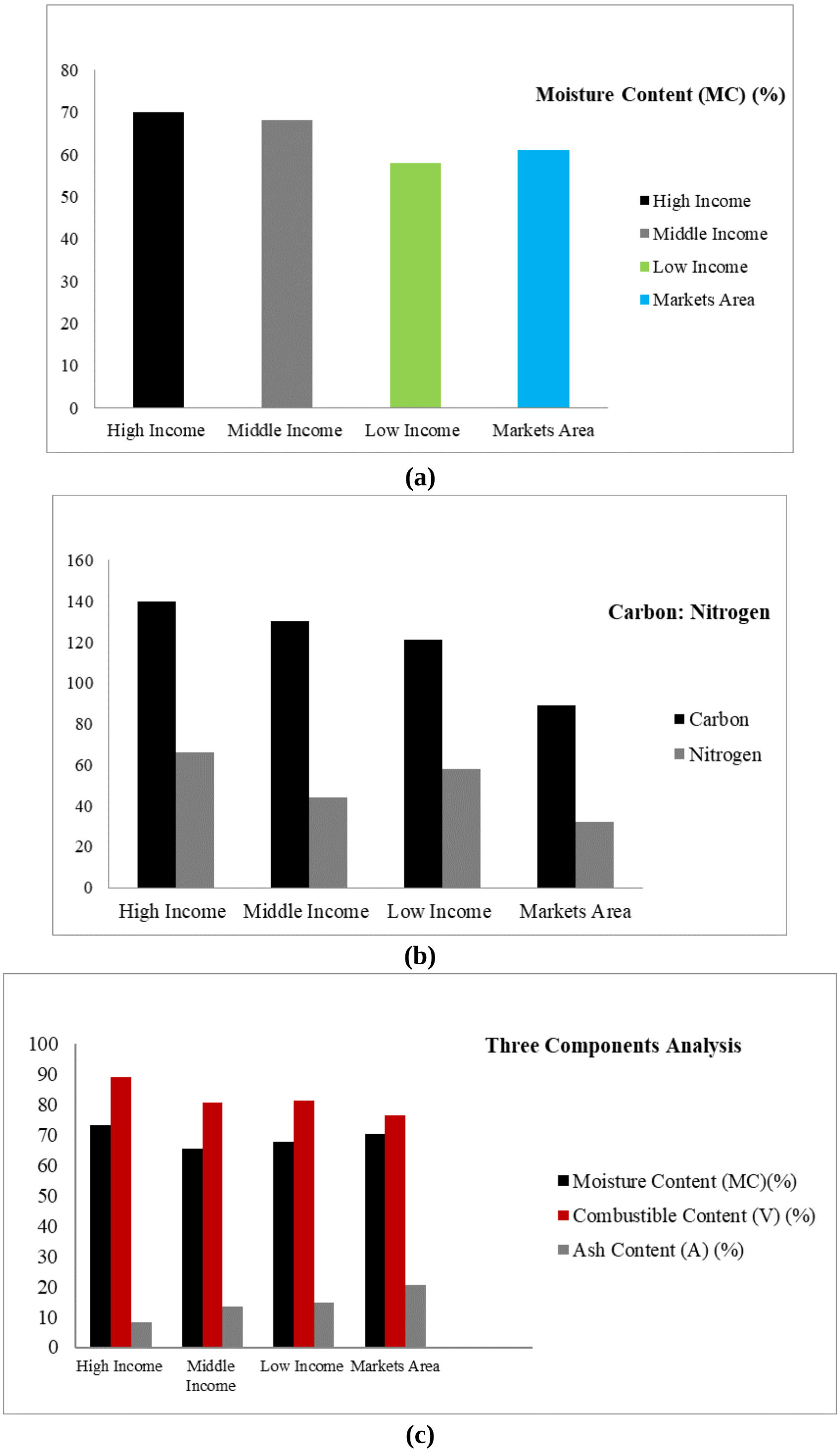

Figure 5. *(a) Average moisture content (MC) of the waste samples, (b) Average Carbon and Nitrogen (C: N) ratio of solid waste in Kabul city, and (c) Three components analysis of solid waste in Kabul city*

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Table 5. *Physiochemical properties of MSW produced by major cities in developing nations (source: Das et al. (2019))*

S.No.	Parameters	Lahore	Dhaka	Numan	Kumasi	Delhi	Kuala Lumpur	Cap-Haïtien	Zanjan	Kolkata
01	pH	-	8.0	-	7.0	8.2	9.1	8.2	5.2	9.01
02	Carbon: Nitrogen (C: N)	44:3	10:1	-	37:1	-	-	31:1	14:1	32:2
03	Ash content (%)	11.7	-	1.50	11.2	5.5	9.3	21.0	6.8	24.0
04	Moisture content (%)	75	-	8.5	51	40	55	56	68	46
05	Organic matter (%)	67	-	-	14	24	-	-	58	-
06	Volatile matter (%)	80	-	-	60	28	32	79	-	-
07	Organic C (%)	-	-	4	-	8.4	-	53	45	22
08	Hydrogen (H) (%)	8.2	-	-	-	1.2	-	-	3.1	2.0
09	Potassium (K) (%)	-	0.6	-	-	0.9	-	1.1	-	0.5
10	Phosphorus (P) (%)	-	0.3	-	-	0.6	-	-	-	0.8
11	Oxygen (O) (%)	27	15	-	9	-	31	-	-	-
12	Total Nitrogen (N) (%)	0.6	0.9	0.04	1.0	0.9	1.3	0.9	-	0.8
13	Fixed carbon (%)	7.2	6.1	-	-	-	-	4.2	-	5.4
14	Sulphur (S) (%)	0.4	-	0.006	-	0.01	0.2	-	0.14	-
15	Lead (Pb) (ppm)	0.8	0.13	-	-	0.04	26	1.1	-	-
16	Zinc (Zn) (ppm)	33.08	0.3	-	-	0.4	-	9.1	-	4.2
17	Cadmium (Cd) (ppm)	1.1	-	-	0.8	0.2	8.8	-	3.9	-
18	Manganese (Mn) (ppm)	0.2	-	-	2.0	1.9	10.3	-	4.9	3.3
19	Mercury (Hg) (%)	0.3	-	-	-	-	1.0	-	-	-
20	Chromium (Cr) (%)	59.1	6.0	-	8.2	1.9	14.4	-	3.0	8.0

MSW collection and transportation in Kabul city

According to Khoshbeen et al. (2020) in the year 2019, there were approximately 4,273 MSW collection bins in the Kabul city. Out of the total MSW bins, 857 are 7 m^3, 1,116 are 1 m^3 and 2,300 are 0.1 m^3 bins. The 0.1 m^3 bins were set up at private points such as walkways, schools, markets, public parks, universities and hospitals etc., to avoid the problems of waste scattering. The information and facts collected from the weighing machine that were installed at Gazak 2 landfill in 2017 revealed that in working days

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(Saturday – Thursday) the mean MSW transported to Gazak 2 landfill was about 1,738 tons/d however in weekends (Thursday and Friday) the MSW transported was about 448 tons/d.

The collection efficiency was greatly minor on holidays as associated to working days, as the DoS does not assign period for employees on holidays as well as overtime payment for truck drivers. The DoS had only 477 vehicals in 2018 end and only 384 were active out of the total. Among the active vehicals, 374 were allocated for hygiene purposes though 10 were employed for organizational purposes. In May 2019, 76 new vehicals were added and it is estimated that the MSW transference to Gazak 2 landfill could rise to 2,500 tons/d. Vehicals with volume of 3,218 tons or lesser transported MSW to the handover station however vehicals of greater volume transported MSW to Gazak 2 landfill directly.

Disposal of MSW in Kabul city

For the final disposal of the MSW collected from the whole Kabul city by DoS is transported to Gazak 2 landfill. This Gazak 2 landfill was opened in 2012 for MSW disposal when the other 02 landfills such as (Gazak 1 and Chamtala landfills) were filled. The total area of Gazak 2 landfill is approximately 1, 60, 225 hectares and presently more than half is already filled. All the MSW are dumped collectively in the Gazak 2 landfill and the soil protection is barely obvious at landfill.

This Gazak 2 landfill is worked like a dumpsite, where the total MSW thrown openly neither dumped with soil cover or any proper compaction on daily basis. This MSW contain more MC hence leachate generated and enters to the ground water while the greenhouse gases are released into the air due to lack of treatment method. However, no communities close to landfill site up to 1 km range, the people living outside have been complaining about the bad odor, and other soical problems. With that the dumped leftover frequently catches fire, particularly in winter period, producing great quantity of smoke.

Current management practices of MSW in Kabul city

Recycling of MSW

The native scavengers in Kabul city including children, old men and drug addicts collected the MSW around the city. All these scavengers have personal two, three, or four-wheel carts to gather MSW. DoS predict that there could be about 2,250 to 2,750 scavengers in the Kabul city gathering approximately 215 to 320 tons of MSW/day that is about 9 to 12% of total MSW produced in the city. When the FW (Dry bread) is collected and vended to livestock farm. Even although this might aid to decrease the possibilities of FW stored in the landfill but it frequently causes health problems in the livestock (Leib et al., 2016). Recyclable MSW such as glass bottles, paper, plastic and aluminum can etc., are vended by these scavengers to the private recycling services natively called Kabar Khana (shops that purchase waste and recompense them with money). Previous studies reveals that that if FW, paper waste, HDPE and PET bottles, glass bottles and aluminum cans are vended on regular basis to the recycling services instead of transferring to landfill sites, it might generate an expected profit of around USD 182,590/day (Khoshbeen et al., 2020).

A well planned implementation of 3R’s technique of MSW turn into a responsibility via education, awareness, training and practice for better MSWM and cleaner environment (Azimi Jibril et al., 2012). This 3R’s approach are introduced to achieve

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synergistic effects with national polices and laws which aim control of GHG emissions, resources procurement and landfill prevention (Sakai et al., 2011). Hence, it is vital that a proper MSWM strategy for Kabul city should be focused on 3R's methods. Therefore, the current study suggested that the 3R's methods must be selected over the traditional method of collection, management and disposal.

Hospital waste management

According to previous studies about SWM in study area there was no perfect checking of hospital waste dumping both by DoS and by the Ministry of Public Health (MoPH). Maximum of the government hospitals used burners to burn all the hospital waste that is produced. While, the waste generated from private hospitals have managed by a private service named Kamyab Waste Management Services. More than five private hospitals were monitored and all of them confirmed that they refer their hospital waste to the private company for management. Though, it was also found via the survey that great quantity of hospital waste was mixed with MSW in the containers. It shows that private hospitals are transferring their hospital waste combine with MSW into the communal bins in Kabul city.

Construction and destruction waste

The fast-developmental growth in study area causing a rapid rise in the construction and demolition (C&D) waste. Till date no appropriate controlling of such type of wastes. The parts of steel bars are vended to industries where these parts are recycled. The timber waste that is usually not recyclable is vended to local people for heating and cooking purposes in winter period. The brick, stone and soil waste are recycled for houses filling. If not applied for filling purposes, then the construction companies pay to truck drivers for the removal afar from the Kabul city. Truck drivers move this C&D waste to the rural regions and used in the flood ways to safeguard farming land from flood disasters. But this method was not applied by wholly construction companies. Usually, this waste is discarded into the communal bins for final disposal or goes to drainage system. The soil and stone that go into the near streams and canals blocks the flow of water in heavy rainfalls and thus causes urban floods in Kabul city.

Role of private companies & public in MSWM

There are various private facilities in the Kabul city that offer Households (HH) waste collection facilities. In the current study, some of these companies were visited to evaluate their MSWM system. These facilities regularly collect waste from HH and get money in back. The selected companies that were visited charge about 100-200 AFN/month each HH. These facilities adopted Door-to-door collection approach for waste collection. Presently, around 51,347 HH are offered with this approach. Out of the total 52,570 HH, approximately 27,585 HH, 52.47%, 9,700 HH 18.45% and 5, 987 HH 11.38% willingly pays 100, 150 and 200 AFN/month respectively for Door-to-door collection facility.

Residents' willingness to pay

The MSW operations and management expenses are currently covered by the central government national treasury. For the MSWM, the DoS also receives international grants and loans. One of the most critical requirements for a well-developed SWM system is cost recovery. A cost recovery method has several phases, but the first and most important

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is determining the overall system's actual cost. *Table 6* shows the overall cost analysis of the present SWM scheme in the Kabul city.

Table 6. *Cost of different components in SWM of Kabul city*

Amount of MSW	Component	Cost in AFN	Cost in USD
For 1,850 tons of MSW that is presently collected	Collection and transfer cost/ton	700	8.93
	Disposal cost/ton	15	0.19
	Additional cost/ton	550	7.02
	Total cost/ton	1265	16.14
	Total cost/ton/month	70.20 million	0.90 million
	Total cost/ton/year	842.40 million	10.75 million
For 100 % collection efficacy (3,200 tons of MSW)	Total cost/ton/month	121.44 million	1.55 million
	Total cost/ton/year	1457.28 million	18.59 million

For the calculation of per ton collection and transferring expense, the cost of fuel consumed by vehicles that collect and transfer waste from collection points, as well as the wages of sanitation workers who were directly involved in waste collection and transportation, were taken into account.

The cost of fuel consumed by disposal site vehicles such as excavators and compactors, as well as the wages of sanitation staff (disposal officers, workers, guards, and so on) is factored into the per ton disposal cost estimate. The cost of fuel consumed by administrative vehicles, the wages of sanitation staffs engaged in administrative work, and the extra costs incurred from GPS, power bills, spare parts, repairs, hydraulics, and other factors were taken into account.

The cost of transporting one ton of waste is 1,265 AFN, as shown in *Table 6*. The overall transfer cost is 70.20 million AFN because only 1,850 tons of waste are collected and transferred each month. The overall monthly cost of transferring the waste produced, which is 3,200 tons per day, rises to 121.44 million AFN, with a per year cost of 1457.28 million AFN. People's willingness to pay for services was examined. Municipalities should impose a tax on solid waste collection in Kabul city.

On the application of the levy, 80% and 20% (920 and 230 respondents) were agreed and disagreed respectively, while high-income HH said they were willing to pay more than 200 AFN.

The lower ranges, 50-100 AFN and 100-150 AFN, were mostly chosen by low-income households, while the higher ranges, 150-200 AFN and more than 200 AFN, were mostly chosen by high-income, middle-income, and commercial units, as shown in *Figure 6*.

MSWM plan for Kabul city

All the major issues and challenges regarding to MSWM in study area were noted in this current study. Various risks to local public, climate, aesthetics values and environment, and thus demand for a proper MSWM strategy to effectively control the MSW of the Kabul city. The main aim of this MSWM strategy is the preparation and operation of a safe, sound and sustainable MSWM system to change the Kabul city in to a smart and clean city.

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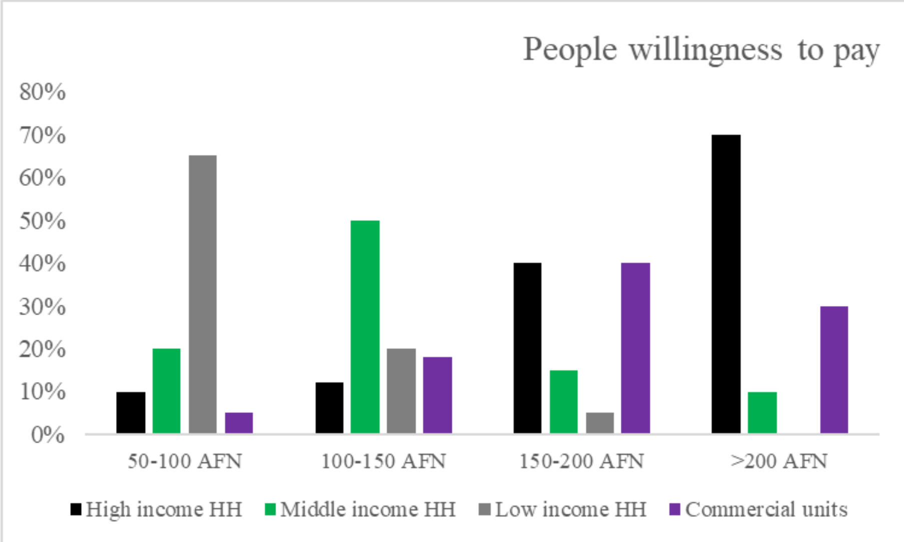

Figure 6. *People willingness to pay for SW collection in Kabul city*

Proper awareness programs

Unawareness and absence of environmental interests leads to the failure of MSWM strategies in South Asia countries (Visvanathan et al., 2003). A proper awareness program should be planned and focus on social changes of residents to suitable MSWM practices like reduction of waste, separation of waste at household level, not burning or scattering waste onto roads and sewage, willingness to pay for collection services and finally implementation of 3R's approach. Hospitals should separate their wastes in to three (03) types such as hazardous, wet and dry wastes. Door-to-door collection facility will improve collection and recycling efficacy, as well as generate revenue. DoS must monitor MSWM services at district level. Scavengers must be listed and observable. For better capacity building proper trainings and seminar sessions must be organized at regular intervals of time in Kabul city.

Implementation of 3R's approach

The principle of waste minimization reduces the quantity and negative consequences of waste generation by decreasing waste volume, reusing waste products with easy treatments, and recycling wastes by using them as tools to generate the same or changed products (Obi et al., 2016).This approach commonly called the '3R's'process. Some waste materials may be used as tools for the manufacture of other goods or the same product, implying that the same resource can be recycled. This decreases the waste production and reduces the exploitation of fresh resources.

Overall, the 3R's method save new resource utilization and exploitation, bring value to resources that have already been used, and, most significantly, reduce waste quantity and its negative effects individually and collectively. The 3R's theory seeks to achieve effective waste minimization by reducing waste, reusing and recycling waste products and resources by: (a) to minimize the amount of waste produced, choose to use products with care. (b) usage of substances or parts of substances that are still available on a regular basis. (c) using waste as a resource itself.

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3R's obstacles and constraints

However, there are several limitations and barriers that produce problems in the implementation of 3R's approach. From survey it was reported that the household's willingness to contribute in 3R's approach was comparatively low and need much improvement. High cost for the transportation limited the recycling and reusing rate of recycled and reused materials in the Kabul city. Local people are unaware of which materials might be reuse, or recycled and which might be vended to scavengers. Demand for these materials is also low in market places and thus leads to the limitation of 3R's approach. Absence of specialists to run and sustain the recycling technologies is also a major concern and no one ready to invest in large recycling technologies. A total 500 households were interviewed for this purpose, and out of the total 70% claimed that they are known of this 3R's programs while 30% claimed that they are unaware of the 3R's approach. This shows a good sign for the adaptation of 3R's approach because most of households are known of the profits of 3R's programs and only few numbers of households need to adopt this approach.

Therefore, DoS need to take some proper steps for 3R's approach. The usage of cloth or paper bags should be prioritized over plastic bags in the markets and local shops. Number of waste collection bins should be increased to a larger number around the city to overcome the MSW issues. DoS must conduct awareness campaigns in the Kabul city to aware the households about wet and dry MSW separation. DoS need to install the GPS system in all running vehicles to monitor the landfill routes and to resolve the fuel stealing problems. As well as, suitable MSWM practices should be initiated to overcome the scattering of MSW by residents along roadsides and canals to control urban floods. Hospital waste and C&D waste should be dumped separately from other waste and MSW must be disposed suitably in to communal containers at each collection points. Burning of MSW should be banned in Kabul city to avoid the issues of air pollution.

Policy enhancement and implementation for SWM in Kabul city

The amount of MSW produced in urban regions of developing countries is low as compared to developed countries though, the system of MSWM is not good and sustainable. Problems includes lack of appropriate policies, encouraging regulations, insufficient collection facilities, open dumping without any treatment and open burning of MSW are at the major roots of waste management issues (Khajuria et al., 2008; Manaf et al., 2009). The above-mentioned problems have been reported in various under and developing counties such as: Asia (Agamuthu et al., 2009), Afghanistan (Haidaree and Lukumwena, 2017), Bangladesh (Shams et al., 2017), Cameroon (Manga et al., 2008), Kenya (Henry et al., 2006), Malaysia (Manaf et al., 2009), Pakistan (Batool et al., 2008), Palestinian (Al-Khatib et al., 2007) and South Africa (Simatele et al., 2017).

Mostly Asian and developing countries have applied laws and policies cover MSWM but their function showed to be unreliable and insufficient, such as Afghanistan (Khoshbeen et al., 2020), Bangladesh (Shams et al., 2017), Cameroon (Manga et al., 2008), Kenya (Henry et al., 2006), Pakistan (Ilyas et al., 2017) and South Africa (Simatele et al., 2017). These laws and policies covering a series of works and efforts to take improvements for human health and environmental sustainability. However, even with the approved quality and significance, the regulations implementation still doesn't ensure the enhancements in MSWM. To guarantee all these objectives of MSWM laws and policies are have been attained, now it is compulsory to observe and monitor its outcomes

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to find out the requirements for other significant management involvements. Like other laws and policies, same these policies should be evaluated and enhanced through the object of achievement and appropriate standards and measures (Crabbe and Leroy, 2008).

National Environmental Protection Agency (NEPA) of Afghanistan made the law and policy of waste management of Afghanistan in 2010. Since 2010 no improvements have been made in that law which required important modifications. There should be a separate law and policy for plastic bags. The ban of plastic bags must be extended from bread shops to stores and pharmacies and finally to market places. With that, efforts are required to be applied to avoid the MSW imported from another nation. The disposing of hospital waste and C&D waste together with MSW must be banned strictly and persons who not obeying must be charged. Scattering of such type of wastes onto roadsides or sewage must be banned immediately. All those construction companies who's produce C&D waste of >20-25 tons/day or 300-350 tons/project/month must to submit a MSWM plan and to get proper approvals from local government authorities before starting of work. Moreover, MSWM laws and policies should be regularly improved through outputs (policies, plans, programs and capitals) and outcomes efficiency evaluations. Through this method, targets might be recognized and updated rules and instruments such as reduce, reuse and recycle (3R's) waste to energy (WTE), waste disposition charge (WDC) and extended producer responsibility (EPR) principle might be adopted.

Composting method for MSW in Kabul city

Composting is basically a method that is done by a series of microbes related with several decomposition methods (López-González et al., 2015). Switching organic waste of MSW from landfills to composting has several environmental values. Amongst them, reduction of greenhouse gases from landfills and enhancement of soil quality via composting method have been reported (Bernstad et al., 2016). The efficiency of the composting method is mainly affected by some factors like oxygen (O_2) amount, temperature, MC, pH, C: N, compaction and particle size (Li et al., 2013). Suitable O_2 amount is the significant factor to be count in composting method; hence, aeration is significant. The effectiveness of this method is greatly influenced by O_2 amount as this method is completely linked with bacterial population (Nakasaki and Hirai, 2017).

Luckily, the MSW of Kabul city is mainly consisting of approximately more than 70% of organic waste mainly consist of food waste, paper and wood and grass which is compostable, hence, composting turns out to be a significant part of the MSWM strategy. Meanwhile aerobic composting is efficient, easy to use and cost-effective method as compared to anaerobic composting, however, the suitable option of MSW composting in Kabul city might be aerobic composting. The Gazak 2 landfill which is currently operative must be improved in to a sanitary landfill. If the government of Afghanistan implements MSWM strategy, about 5-11% (125–300 tons/day) of the total waste, mostly non-recyclable waste, will be ends up into Gazak 2 landfill related to the present condition in which approximately more than 85% of the MSW is openly dumped in the Gazak 2 landfill.

Conclusion

Solid waste sources, generation rate, physiochemical properties and its management practices in Kabul city had revealed some interesting results. The average household size in Kabul city was seven (07). MSW generation rate ranged from 0.28±0.10 kg/c/d for

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low-income or rural areas to 0.48±0.10 kg/c/d for high-income in residential areas. Also, waste generation rate from commercial sources reported as 12.2 kg/d, 8.4 kg/d, 5.3 kg/d, 2.5 kg/d and 1.8 kg/d for restaurants/hotels, parks, institutions, shops and street sweeping respectively. Results revealed that ASG of MSW from four (04) residential areas reported as 272 kg/m^3, 280 kg/m^3, 278 kg/m^3 and 260 kg/m^3 for high, middle, low-income areas and rural areas respectively, however, commercial MSW from hotels/restaurants have a peak value of ASG of about 550 kg/m^3. The average value for MC, C:N ratio, combustible and ash content were reported to be 64%, 120.50%, 81.8% and 14.2%, respectively. This study shows that MSW generated from the Kabul city has maximum possibility for composting because >70% of the MSW was consist of organic wastes. Moreover, there is no proper management of MSW in Kabul city, hence, it is important that a proper MSWM strategy for Kabul city should be focused on 3R's approach. Therefore, the current study suggested that the Kabul city must take initiatives such as awareness programs, policy enhancement and implementation, composting method and 3R's approach must be selected over the traditional method of solid waste management in Kabul city and other growing cities around the country.

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REFERENCES

[1] Abdulredha, M., Kot, P., Alkhaddar, R., Jordan, D., Abdulridha, A. (2018): Investigating Municipal Solid Waste Management System Performance during the Arba'een Event in the City of Kerbala, Iraq. – Environment, Development and Sustainability 22: 1431-1454. https://doi.org/10.1007/s10668-018-0256-2.

[2] Agamuthu, P., Khidzir, K. M., Hamid, F. S. (2009): Drivers of sustainable waste management in Asia. – Waste Manag. Res. 27: 625-633. https://doi.org/10.1177/0734242X09103191.

[3] Al-Khatib, I. A., Arafat, H. A., Basheer, T., Shawahneh, H., Salahat, A., Eid, J., Ali, W. (2007): Trends and problems of solid waste management in developing countries: a case study in seven Palestinian districts. – Waste Manag. 27: 1910-1919. https://doi.org/10.1016/j.asman.2006.11.006.

[4] Ali, M., Wang, W., Chaudhry, N. (2016): Management of wastes from hospitals: A case study in Pakistan. – Waste Management & Research 34(1): 87-90.

[5] ASTM Committee D-34 on Waste Management (2008): Standard test method for determination of the composition of unprocessed municipal solid waste. – ASTM International.

[6] Azimi Jibril, J. D., Sipan, I. B., Sapri, M., Shika, S. A., Isa, M., Abdullah, S. (2012): 3R's critical success factor in solid waste management system for higher educational institutions. – Procedia-Social and Behavioral Sciences 65: 626-631.

[7] Baawain, M., Al-Mamun, A., Omidvarborna, H., Al-Amri, W. (2017): Ultimate composition analysis of municipal solid waste in Muscat. – J. Clean. Prod. 148: 355-362. https://doi.org/10.1016/j.jclepro.2017.02.013.

[8] Baran, J. (2018): Municipal Waste Management in Rural Areas in Poland. – https://doi.org/10.22616/ESRD.2018.113.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2003_24852507

[9] Bashir, M., Tao, G., Abu, S., Amr, T. (2018): Public concerns and behaviors towards solid waste minimization using composting in Kampar district, Malaysia. – Global NEST J. 20: 316-323.
[10] Batool, S. A., Chaudhry, N., Majeed, K. (2008): Economic potential of recycling business in Lahore, Pakistan. – Waste Management 28(2): 294-298.
[11] Bernstad, A., Wenzel, H., la Cour Jansen, J. (2016): Identification of decisive factors for greenhouse gas emissions in comparative life cycle assessments of food waste management – An analytical review. – Journal of Cleaner Production 119: 13-24.
[12] Central Statistic Organization (CSO) (2018): Analysis of population projections 2017-18. – Available at: http://cso.gov.af/en/page/demography-and-socile-statistics/demograph-statistics/3897111. Accessed on May 2019.
[13] Ciuta, S., Apostol, T., Rusu, V. (2015): Urban and rural MSW stream characterization for separate collection improvement. – Sustainability 7(1): 916-931.
[14] Crabbe, A., Leroy, P. (2008): The Handbook of Environmental Policy Evaluation. – Earthscan, London, 202p.
[15] Das, S., Lee, S. H., Kumar, P., Kim, K. H., Lee, S. S., Bhattacharya, S. S. (2019): Solid waste management: Scope and the challenge of sustainability. – Journal of cleaner production 228: 658-678.
[16] Dehghanifard, E., Dehghani, M. H. (2018): Evaluation and Analysis of Municipal Solid Wastes in Tehran, Iran. – MethodsX 5: 312-321. https://doi.org/10.1016/j.mex.2018.04.003.
[17] Di Maria, F., Sordi, A., Micale, C. (2013): Experimental and life cycle assessment analysis of gas emission from mechanically–biologically pretreated waste in a landfill with energy recovery. – Waste Management 33(11): 2557-2567.
[18] Di Maria, F., Micale, C., Morettini, E., Sisani, L., Damiano, R. (2015): Improvement of the management of residual waste in areas without thermal treatment facilities: A life cycle analysis of an Italian management district. – Waste management 44: 206-215.
[19] Dung, T. N. B., Sen, B., Chen, C. C., Kumar, G., Lin, C. Y. (2014): Food waste to bioenergy via anaerobic processes. – Energy Procedia 61: 307-312.
[20] Edjabou, M. E., Martín-Fernandez, J. A., Scheutz, C., Astrup, T. F. (2017): Statistical analysis of solid waste composition data: arithmetic mean, standard deviation and correlation coefficients. – Waste Manag. 69: 13-23. https://doi.org/10.1016/j.wasman.2017.08.036.
[21] Ghaforzai, A., Ullah, S., Asir, M. (2021): Household waste management in formal housing developments in Afghanistan: a case study of Kabul city. – Aust. J. Eng. Innov. Technol. 3(4): 64-72. https://doi.org/10.34104/ajeit.021.064072.
[22] Haidaree, G. H., Lukumwena, N. (2017): Solid waste management challenges and possible solution in Kabul city. – Int J Environ Chem Ecol Geol Geophys Eng 11: 262-266.
[23] Henry, R. K., Yongsheng, Z., Jun, D. (2006): Municipal solid waste management challenges in developing countries: kenyan case study. – Waste Manag. 26: 92-100. https://doi.org/10.1016/j.wasman.2005.03.007.
[24] Hidayat, O., Kajita, Y. (2020): Influences of Culture in the Built Environment; Assessing Living Convenience in Kabul City. – Urban Science 4(3): 44.
[25] Huang, H., Singh, V., Qureshi, N. (2015): Butanol production from food waste: a novel process for producing sustainable energy and reducing environmental pollution. – Biotechnol. Biofuels 8: 147. https://doi.org/10.1186/s13068-015-0332-x.
[26] Ilyas, H., Ilyas, S., Ahmad, S. R., Nawaz, M. (2017): Waste generation rate and composition analysis of solid waste in Gujranwala city, Pakistan. – Int. J. Waste Resour 7(3): 97.
[27] Indrawati, D., Purwaningrum, P. (2018): Identification and analysis the illegal dumping spot of solid waste at Ciliwung segment 5 riverbanks. – IOP Conf. Ser. Earth Environ. Sci. 106: 012043.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2003_24852507

[28] Jaafar, I., Ibrahim, T., Awanis Ahmad, N., Abdul Kadir, K., Tomari, R. (2018): Waste Generation and Characteristization: Case Study of Seberang Takir. Kuala Nerus, Terengganu, Malaysia. – Journal of Physics 1049: 012029. https://doi.org/10.1088/1742-6596/1049/1/012029.
[29] Kaza, S., Yao, L., Bhada-Tata, P., Van Woerden, F. (2018): What a waste 2.0: a global snapshot of solid waste management to 2050. – World Bank Publications.
[30] Khajuria, A., Yamamoto, Y., Morioka, T. (2008): Solid waste management in Asian countries: Problems and 531 issues. – WIT Trans Ecol Environ 109: 643-653.
[31] Khoshbeen, A. R., Logan, M., Visvanathan, C. (2020): Integrated solid-waste management for Kabul city, Afghanistan. – Journal of Material Cycles and Waste Management 22(1): 240-253.
[32] Kumar, S., Smith, S. R., Fowler, G., Velis, C., Kumar, S. J., Arya, S., Rena, Kumar, R., Cheeseman, C. (2017): Challenges and opportunities associated with waste management in India. – Royal Society open science 4(3): 160764.
[33] Leib, E., Balkus, O., Rice, C., Maley, M., Taneja, R., Cheng, R., Civita, N., Alvoid, T. (2016): Leftovers for livestock: a legal guide for using food scraps as animal feed. – FLPC, in partnership with the Food Recovery Project.
[34] Li, Z., Lu, H., Ren, L., He, L. (2013): Experimental and modeling approaches for food waste composting: A review. – Chemosphere 93(7): 1247-1257.
[35] López-González, J., Vargas-García, M., López, M., Suárez-Estrella, F., Jurado, M., Moreno, J. (2015): Biodiversity and succession of mycobiota associated to agricultural lignocellulosic waste-based composting. – Bioresource Technology 187: 305-313.
[36] Mack, T. J. (2018): Groundwater Availability in the Kabul Basin, Afghanistan. – In: Groundwater of South Asia, Springer, Singapore, pp. 23-35.
[37] Mack, T. J., Chornack, M. P., Taher, M. R. (2013): Groundwater-level trends and implications for sustainable water use in the Kabul Basin, Afghanistan. – Environment Systems and Decisions 33(3): 457-467.
[38] Manaf, L. A., Samah, M. A. A., Zukki, N. I. M. (2009): Municipal solid waste management in Malaysia: practices and challenges. – Waste Manag. 29: 2902-2906. https://doi.org/10.1016/j.wasman.2008.07.015.
[39] Manga, V. E., Forton, O. T., Read, A. D. (2008): Waste management in Cameroon: a new policy perspective? – Resour. Conserv. Recycl. 52: 592-600. https://doi.org/10.1016/j.resconrec.2007.07.003.
[40] Marashlian, N., El-Fadel, M. (2005): The effect of food waste disposers on municipal waste and wastewater management. – Waste management & research 23(1): 20-31.
[41] Murtaza, G., Rahman, A. (2000): Solid waste management in Khulana City and a case study of a CBO: Amader Paribartan. – Maqsood Sinha, A. H. Md., Enayetullah, I. (eds.) Community Based Solid Waste Management: The Asian Experience. Waste Concern, Dhaka, Bangladesh.
[42] Nadeem, K., Farhan, K., Ilyas, H. (2016): Waste amount survey and physio-chemical analysis of municipal solid waste generated in Gujranwala-Pakistan. – International Journal of Waste Resources 6: 196.
[43] Nakasaki, K., Hirai, H. (2017): Temperature control strategy to enhance the activity of yeast inoculated into compost raw material for accelerated composting. – Waste Management 65: 29-36. Available on-line: doi: 10.1016/j.wasman.2017.04.019.
[44] Obi, F. O., Ugwuishiwu, B. O., Nwakaire, J. N. (2016): Agricultural waste concept, generation, utilization and management. – Nigerian Journal of Technology 35(4): 957-964.
[45] Olsen, S., Sommers, L., Page, A. (1982): Methods of soil analysis, Part 2. – Soil Science Society of America, Inc., pp. 403-430.
[46] Olukanni, D., Aipoh, A., Kalabo, I. (2018): Recycling and Reuse Technology: Waste to Wealth Initiative in a Private Tertiary Institution, Nigeria. – Recycling 3(3): 44. https://doi.org/10.3390/recycling3030044.

[47] Outapa, P., Na Roiet, V. (2018): Evaluation of greenhouse gas emissions from municipal solid waste (MSW) management: case study of Lampang municipality, Thailand. – Appl. Environ. Res. 40: 46-56.
[48] Ozcan, H. K., Guvenc, S. Y., Guvenc, L., Demir, G. (2016): Municipal solid waste characterization according to different income levels: A case study. – Sustainability 8(10): 1044.
[49] Paul, K., Chattopadhyay, S., Dutta, A., Krishna, A. P., Ray, S. (2019): A comprehensive optimization model for integrated solid waste management system: a case study. – Environ. Eng. Res. 24: 220-237. https://doi.org/10.4491/eer.2018.132.
[50] Prism, G., 5.0. GraphPad Software Inc., San Diego, CA, USA.
[51] Rehrah, D., Bansode, R. R., Hassan, O., Ahmedna, M. (2016): Physico-chemical characterization of biochars from solid municipal waste for use in soil amendment. – J. Anal. Appl. Pyrolysis 118: 42-53. https://doi.org/10.1016/j.jaap.2015.12.022.
[52] Sahariah, B., Goswami, L., Farooqui, I. U., Raul, P., Bhattacharyya, P., Bhattacharya, S. (2015): Solubility, hydrogeochemical impact, and health assessment of toxic metals in municipal wastes of two differently populated cities. – J. Geochem. Explor. 157: 100-109. https://doi.org/10.1016/j.gexplo.2015.06.003.
[53] Sakai, S. I., Yoshida, H., Hirai, Y., Asari, M., Takigami, H., Takahashi, S., Tomoda, K., Peeler, M. V., Wejchert, J., Schmid-Unterseh, T., Douvan, A. R. (2011): International comparative study of 3R's and waste management policy developments. – Journal of Material Cycles and Waste Management 13(2): 86-102.
[54] Sandulescu, E. (2004): The contribution of waste management to the reduction of greenhouse gas emissions with applications in the city of Bucharest. – Waste Management & Research 22(6): 413-426.
[55] Sarkar, M., Bhuyan, M. (2018): Analysis of physical and chemical composition of the solid waste in Chittagong city. – Jr. Ind. Poll. Control 34: 1984-1990.
[56] Shams, S., Sahu, J. N., Rahman, S. M. S., Ahsan, A. (2017): Sustainable waste management policy in Bangladesh for reduction of greenhouse gases. – Sustain. Citie. Soc. 33: 18-26. https://doi.org/10.1016/j.scs.2017.05.008.
[57] Simatele, D. M., Dlamini, S., Kubanza, N. S. (2017): From informality to formality: perspectives on the challenges of integrating solid waste management into the urban development and planning policy in Johannesburg, South Africa. – Habitat Int. 63: 122-130. https://doi.org/10.1016/j.habitatint.2017.03.018.
[58] Sudibyo, H., Majid, A. I., Pradana, Y. S., Budhijanto, W., Deendarlianto, Budiman, A. (2017): Technological evaluation of municipal solid waste management system in Indonesia. – Energy Procedia 105: 263-269. https://doi.org/10.1016/j.egypro.2017.03.312.
[59] Suthar, S., Singh, P. (2015): Household solid waste generation and composition in different family size and socio-economic groups: A case study. – Sustainable Cities and Society 14: 56-63.
[60] Tsydenova, N., Vazquez Morillas, A., Cruz Salas, A. A. (2018): Sustainability assessment of waste management system for Mexico City (Mexico) based on analytic hierarchy process. – Recycling 3: 45. https://doi.org/10.3390/recycling3030045.
[61] Visvanathan, C., Trankler, J. (2003): Municipal Solid Waste Management in Asia: A Comparative Analysis. – Presented at the National Workshop on Sustainable Solid Waste Landfill Management in Asia, Bangkok, Thailand.
[62] Wang, D., He, J., Tang, Y.-T., Higgitt, D. (2018): The EU Landfill Directive Drove the Transition of Sustainable Municipal Solid Waste Management in Nottingham City, UK. – 7th International Symposium on Energy from Biomass and Waste, Venice.
[63] Worrell, W., Vesilind, P. (2011): Solid Waste Engineering. – SI Version. Nelson Education.

http://www.aloki.hu ● ISSN 1589 1623 (Print) ● ISSN 1785 0037 (Online)
DOI: http://dx.doi.org/10.15666/aeer/2003_24852507