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ORIGINAL PAPER

Seasonal characterization and quantification of municipal solid waste: energy content and statistical analysis

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ABSTRACT

Determining the seasonal and annual quantities and compositions of the municipal solid waste and assessing the present management conditions of three urban communities in the northwest of Iran were the core objectives of this study. Our findings revealed that the average daily per capita of municipal waste generation was 0.489–0.841 kg/cap-day. Organic and food waste comprised the largest part (56.46%) of the total generated waste in the studied cities, whereas paper and cardboard, plastics, metals, rubber, textiles, glass, woods, and other waste constituted 5.99, 12.62, 1.05, 0.95, 7.71, 1.63, 1.23, and 12.36%, respectively. More than 21% of the total generated waste was directly recyclable. Bulk density of the waste was determined as 182.53 kg/m^3. In addition, the moisture content and the chemical characteristics (food and organic fraction) of the generated waste including the amounts of carbon, nitrogen, phosphorous, ash, and C/N ratio were 67.44, 50.86, 1.67, 0.41, 34.91, and 30.61%, respectively. Waste composition in different seasons followed a variable pattern. In the present conditions, all the three studied cities were sending their waste to the municipal waste landfill sites that were actually used as a dump for waste. Hence, great concerns were raised from the public health and environmental viewpoints such as ground water, soil, and air pollution at the final disposal sites in the area. Implementation of source reduction, separation and recycling program, closing dump sites, and investing for new landfill sites according to the scientific and environmental approaches, were proposed.

Keywords: Urban area; Municipal solid waste; Quantification; Characteristics; Management

Introduction

According to the World Bank report, the urban population worldwide and that of Iran has increased from 47 to 53% and 64 to 69%, respectively, from 2000 to 2012.[1] Presently, about 3.73 billion of the world's population and 52.50 million of the Iranian population are living in the urban areas.[1] Rapid urbanization has intensified several environmental pressures including unorganized management and disposal of solid waste, in particular, in the economically developing countries.[2] Inappropriate management of solid waste, which can lead to contamination of water, soil, and atmosphere has a major impact on the public health.[3, 4] Municipal solid waste management systems and waste composition in the developed and developing countries have been reported in several researches in cities with high, medium, and low population.[2-16] Nevertheless, characterization, quantification, and management of household solid waste in the small urban communities have been less investigated and reported in both the developed and developing countries. Alternatively, for successful implementation of any waste management plan, having reliable and accurate data on both quantity and characteristics of the generated waste and the present management conditions, are the fundamental prerequisites.[17]

As there was insufficient information about solid waste generation, composition, and management condition of the small cities in our country, the present study aimed to determine the quantity and quality (composition) of the municipal solid waste in three small cities located in East Azerbaijan County. Furthermore, this study also aimed to monitor the present waste management conditions in all

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the three cities. Moreover, the seasonal variation of solid waste generation rate and composition was investigated in the studied cities. Eventually, to improve the present management actions, certain practical recommendations are suggested in this study.

Study Area

This study was conducted in three small cities including Azarshahr, Mamaghan, and Ilkhichi of the East Azerbaijan County in Iran. All three cities are located in the southwest of the County. These cities are at an altitude of 1357–1468 m above the sea level. The official reported population of Azarshahr, Mamaghan, and Ilkhichi, based on the national census in 2012, was above 41173, 13787, and 16037 people, respectively. The average population growth rate for Azarshahr and Mamaghan was about 1.5%, whereas it was 2.6 for Ilkhichi, which was higher than the other parts of East Azerbaijan, presumably due to the close proximity to Tabriz, the capital city of East Azerbaijan province, industrial development, availability of job opportunities in the area, and low life expenses in the region. The maximum and minimum average annual temperature and the relative humidity in the area were about 15.7 ºC, 6.8 ºC, and 68%, and 39%, respectively. The average annual precipitation of the area was estimated to be about 288 mm. Figure 1 presents the location of the three studied cities in East Azerbaijan.

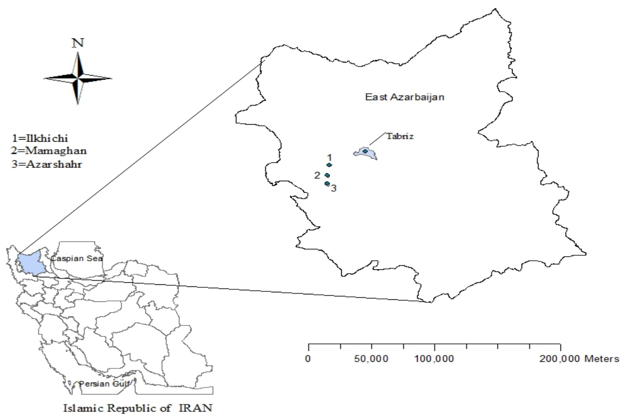

Fig. 1. Location of three studied cities in the East Azerbaijan

Materials and Methods

Site visit

Site visits were conducted in the three selected cities to obtain the required information and to evaluate the working conditions and present state of waste management conditions. To clarify the main objectives of the study, a training program was executed for all participants of the project, prior to commencement of the investigation. Importance of the hazards associated while working with the waste materials and the precise procedures for sorting and weighing these materials were considered in this course. The research team was provided with the necessary protective apparatus such as overalls, aprons, masks, gloves, and special boots.

Waste sampling

To balance out the daily and seasonal variations of the wastes, the study was scheduled for 7 days (1 week) of each season (spring, summer, autumn, and winter) during 2013. In order to determine the quantity and rate of waste generation, the entire generated waste was weighed on a daily basis in all the three cities during the investigation period. Solid waste generation rate (per capita basis) was calculated by dividing the total daily generated waste by the number of population of each city. A solid waste collection vehicle entering at the disposal site was randomly selected during the mentioned period (1 week per season).

Physicochemical analysis

To determine the physical composition of solid waste in the area, the entire waste content of the 84 (7 × 4 × 3) randomly selected collection vehicles, was unloaded. In order to obtain a representative sample, the unloaded solid waste was initially quartered. One part was selected for additional quartering until a sample size of about 110 ± 20 kg was obtained.[18] The bulk of solid waste was separately weighed on a suspension spring scale (±100 g) on a daily basis. Notably, the selected samples were sorted into nine major fractions including organic and food waste, plastics, metals, rubber, paper and cardboard, textiles, glass, woods, and other wastes (including materials, which could not be categorized in any of the aforementioned classes). These categories were weighed separately and the results were recorded. A special container with a volume of 210 L was used to determine the waste volume, which helped in calculating the uncompacted specific weight of the wastes, measured in kg/m^3.

Approximately, 1 kg of the organic waste fraction, on a daily basis, was collected in the polyethylene bags, brought to the laboratory, and was instantly analyzed in terms of moisture (according to wet weight) content. After determining the moisture content for 1 week per season, the dried samples were mixed, crushed, and stored at ambient temperatures before analyzing the carbon, nitrogen, and phosphor concentrations along with the ash percentage by the standard methods.

Statistical analysis

Correlation survey between different fractions of the wastes and also between the solid waste generations rates, along with other nine fractions, were implemented by binomial correlation test, using SPSS software (version 11.5) for windows. Correlation between the fractions is reported in three significant levels; that is, highly significant ($0.001 < p < 0.01$), moderately significant ($0.01 < p < 0.05$), and weakly significant ($0.05 < p < 0.1$). Other statistical and graphical analyses were performed by Microsoft excel.

Results and Discussion

Waste generation rates

Quantitative analysis of the generated waste in the studied cities is presented in Table 1. Waste generation rates in Azarshahr, Mamaghan, and Ilkhichi were compared with those obtained in other reported researches in Table 2.[5-7, 13, 15, 16, 19-24] Considering the data in Table 2, it is clear that the average per capita of household waste generation rates in Azarshahr, Mamaghan, and Ilkhichi was about 0.525, 0.841, and 0.489 kg/cap-day, respectively. Nevertheless, the generation rate of the nearby villages of the area was 0.259 kg/cap-day.[25]

The per capita household waste generation rates in the cities of East Azerbaijan province, Tehran, and Rasht along with an average for the whole country has been reported as 0.79, 0.84, 0.80, and 0.640 kg/cap-day, respectively (see Table 2).[5, 26] In addition, the solid waste generation rate in the urban areas of different parts of the world such as Kolkata (India), Chittagong (Bangladesh), Bangkok (Thailand), Chihuahua (Mexico), and Veles (Macedonia), along with an average of that in the USA has been determined to be between 0.250 and 2.038 kg/cap-day.[6, 7, 13, 15, 16, 20, 21] Considering these generation rates of various villages and cities at a global scale, it can be concluded that the amount of waste produced by each person varies in different urban communities, even inside a country, and waste generation rates of such societies are generally higher than that of the rural areas. In addition, the municipal solid waste generation rate in large and developed cities is greater than the smaller developing cities, due to the fact that the waste production and composition rates are related to several factors such as development stage; socioeconomic, climatic, geographical, and cultural conditions; and even to source reduction programs, food habits, and quality of supplied goods and food products.[5, 13, 22]

Table 1. The seasonal and annul amount of generated wastes in the studied cites

Generated waste	(ton/day)		
	Azarshahr	Mamaghan	Ilkhichi
Spring	18.43	7.14	8.99
Summer	23.18	9.28	8.26
Autumn	22.65	10.88	7.47
Winter	22.23	19.09	6.66
Average	21.62	11.59	7.84
Total in year (ton)	7891.30	2433.08	2862
Total population	41173	13787	16037
Generated waste per capita(kg/cap-day)	0.525	0.841	0.489

Table 2. The comparison of solid waste generation rates of the studied cities with the other reported researches in urban and rural areas

Urban communities	Generation rate (kg/cap-day)	Rural communities	Generation rate (kg/cap-day)
Azarshahr (This study)	0.525	Rural area of Babol.[22]	0.750± 0.18
Mamaghan (This study)	0.841	Rural area of Fars province (Iran).[27]	0.248
Ilkhichi (This study)	0.489	Rural area of Isfahan province (Iran).[27]	0.301
East Azerbaijan province (Iran).[26]	0.790	Tekanpur area (India).[23]	0.287
Tehran (Iran).[26]	0.840	San Quintín (Mexico).[24]	0.631
Rasht (Iran).[5]	0.800	Vicente Guerrero (Mexico).[24]	1.047
Average of Iran.[26]	0.640	Kétao (Togo).[28]	0.220-0.420
Kolkata (India).[20]	0.632	Average of Iran rural area.[27]	0.452
Chittagong (Bangladesh).[13]	0.250		
Bangkok (Thailand).[15]	1.5		
Chihuahua (Mexico).[7]	0.592		
Veles (Macedonia).[16]	1.06± 0.56		
Average of USA.[21,6]	2.038		

Waste composition and density

The result of the composition and density of the generated solid waste in different seasons of the year in the three studied cites is presented in Table 3. As indicated in the table, no significant difference was observed between the seasons, and in all of the seasons, maximum percentage of generated waste belonged to the organic and food wastes. According to Table 4, the annual rate of solid waste density in Azarshahr was 192.56 kg/m^3, which was higher than that of other cities; the solid waste density in Mamaghan and Ilkhichi was 172.96 and 182.06 kg/m^3, respectively; and the seasonal solid waste density for Azarshahr, Mamaghan, and Ilkhichi was 178.9–230.28, 131.64–209.31, and 166.43–223.61, kg/m^3, respectively. In all of the studied cities, the highest bulk density was observed in autumn. The main reason for the higher observed density in autumn might be the extreme humid atmosphere in this season. The annual average composition of waste in Azarshahr, Mamaghan, and Ilkhichi cities is demonstrated in Figure 2 and is compared with other reported studies presented in Table 4.[6, 7, 10, 15, 22, 26, 29] According to Figure 2 and Table 4, 54.31–57.82% of the total generated waste in the studied cities was organic and food waste, whereas paper and cardboard, plastics, metals, rubber, textiles, glass, woods, and other waste constituted 4.82–7.16, 11.76–13.72, 0.98–1.14, 0.26–1.41, 6.18–8.59, 1.55–1.68, 1.17–1.27, and 11.94–12.98%, respectively.

Table 3. Seasonal waste composition and density in 3 studied cities

Component (%)	Azarshahr				Mamaghan				Ilkhichi			
	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn	Winter	Spring	Summer	Autumn
Organic and food wastes	68.01	56.36	58.58	50.41	46.57	56.36	55.98	56.07	62.91	59.64	57.35	50.99
Paper and Cardboard	4.43	5.77	4.32	4.81	6.10	5.77	8.07	4.38	4.24	7.14	12.03	5.84
Plastics	10.70	13.55	12.26	10.82	17.36	13.55	15.56	10.02	11.72	19.11	7.89	11.18
Metals	1.37	1.07	0.90	0.88	1.70	1.07	1.12	0.86	0.85	0.67	1.00	1.30
Rubber	1.02	1.04	1.10	1.47	0.14	1.04	2.34	1.73	0.00	0.47	0.00	0.50
Textiles	4.95	8.50	10.97	9.57	9.80	8.50	6.64	8.83	5.43	5.49	4.50	8.51
Glass	2.08	2.13	1.72	0.99	2.51	2.13	1.55	0.80	1.47	1.17	2.00	1.55
Woods	0.42	2.02	2.38	0.12	1.34	2.02	0.36	1.26	0.53	0.50	0.85	2.73
Other waste	7.02	9.57	7.77	20.93	14.47	9.57	8.37	16.06	12.85	5.79	14.39	17.39
Total	100	100	100	100	100	100	100	100	100	100	100	100
Density (Kg/m^3)	178.9	174.19	186.86	230.28	131.64	174.19	176.71	209.31	173.31	166.43	164.90	223.61

The annual average of the recyclable wastes including paper and cardboard, plastics, metals, and glass indicted that Mamaghan with almost 22.51% ranked first, followed by 22.07% for Ilkhichi and 19.30% for Azarshahr. These values (21.29% as the average of three cities) were in accordance with those of some developing countries like Abuja city (Nigeria) with 24.2%, but were less than those of others like Bangkok city (Thailand). The obtained values were less than those of the developed countries like USA (average of the country) and Crete Island, Greece, with 60 and 47.07% recyclable portions. Among the recyclables, plastics with more than 11.76–13.72% revealed maximum percentages and metals with almost 0.98–1.14% indicated minimum percentages in all cities; however, considering the separation and recycling programs at the source can be extremely useful for reducing the waste generation and the related environmental and economical problems.

Due to the higher percentages of food and organic contents (54.31–57.82 %) in the studied cities, use of composting facilities (as an organic fertilizer, natural, and healthy alternative for chemical fertilizers) can be recommended to reduce the generation rate of solid waste. Nevertheless, we observed noticeable differences between the results of this study with those of the other urban areas. For instance, as indicated in Table 4, the average amount of the organic and food waste in the present study was 56.46%, whereas it was 72.04% in all the Iranian cities,[26] 63.60 and 43% in Bangkok and Abuja cities of Thailand and Nigeria, respectively. Comparison of waste composition in the studied cities with other urban areas in Iran and other countries again indicated certain important differences. For example, paper and cardboard fraction for the selected cities of the present study was 4.82–7.16%; however, it was 6.43, 9.70, 12.10, 19.94, and 37% in the Iranian cities, Abuja (Nigeria), Bangkok (Thailand), Crete (Greece), and USA, respectively.[10, 15, 21, 26, 29] Moreover, the average density of the generated waste in the studied area was 172.96–192.56 kg/m^3, whereas it was reported as 240 kg/m^3 in Abuja (Nigeria).[10] Composition of the generated solid waste is a significant issue in the waste management planning in each society, since based on only the waste composition, the best methodology for reduction, recycling, processing, and disposal of waste can be selected and applied.[3, 21] According to the results in the related literature, it could be concluded that composition and density of the generated waste vary in different urban areas, which can be due to the variation in geographical, economic, cultural, and social conditions.

Table 4. Comparison of physical composition of analyzed solid wastes in study cities and other reported researches data (in rural and urban communities)

Component (%)	This study				Average of Iran cities 26	Abuja city (Nigeria)10	Bangkok (Thailand)15	Crete, Greece 29	Average of USA6
	Azarshahr	Mamaghan	Ilkhichi	Average of three cities					
Organic and food wastes	57.82	54.31	57.25	56.46	72.04	63.60	43	39.15	11
Paper and Cardboard	4.82	6.00	7.16	5.99	6.43	9.70	12.10	19.94	37
Plastics	11.76	13.72	12.38	12.62	7.77	8.70	10.90	16.85	11
Metals	1.04	1.14	0.98	1.05	2.52	3.20	3.50	4.95	8
Rubber	1.18	1.41	0.26	0.95	1.14	- A	2.60	- A	- A
Textiles	8.59	8.37	6.18	7.71	2.86	1.60	4.70	- A	7
Glass	1.68	1.65	1.55	1.63	2.03	2.60	6.60	5.33	6
Woods	1.17	1.24	1.27	1.23	1.10	- A	- A	- A	6
Other waste	11.94	12.16	12.98	12.36	4.11	10.60	16.60	13.78	14
Total	100	100	100	100.00	100	100	100	100	100
Density (Kg/m^3)	192.56	172.96	182.06	182.53	-A	240	-A	-A	-

A: Was not reported

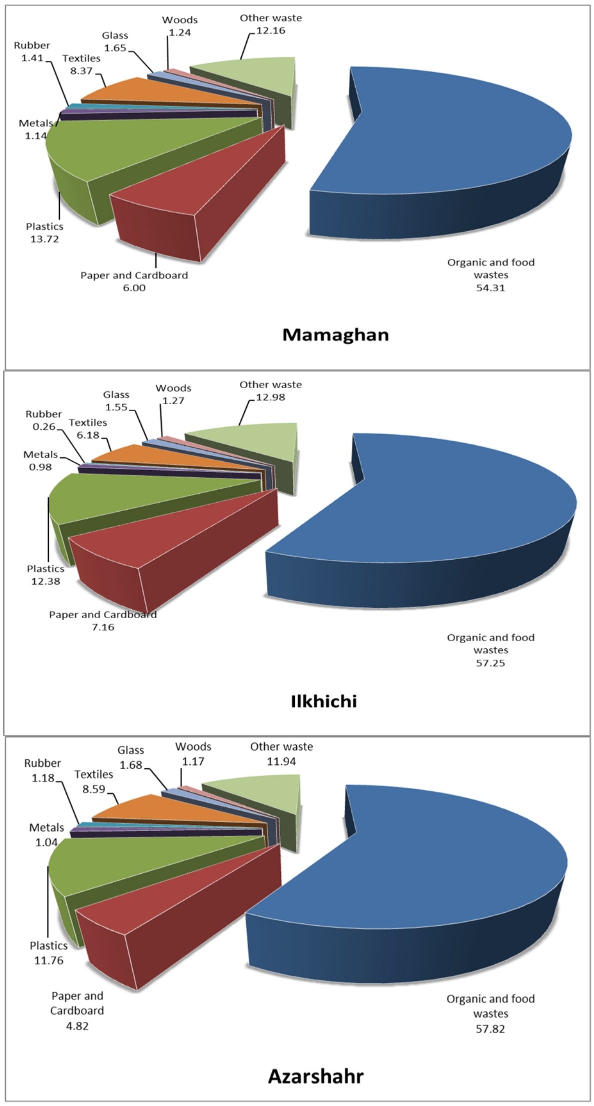

Fig. 2. The annual average of waste compositions at 3 studied cities

Moisture and chemical characteristics of organic and food wastes

In order to evaluate the solid waste potential for composting, determining the moisture content and chemical characteristics of waste including carbon, nitrogen, phosphor, and C/N ratio etc., are necessary. Chemical characteristics and moisture content of the solid waste generated in the studied areas are listed in Table 5. Notably, the annual average amount of moisture content was 71.59, 64.29, and 66.44% in Azarshahr, Mamaghan, and Ilkhichi, respectively. The amount of moisture in the organic and food waste was reported as about 50–80% in the previous studies in urban areas.[21] Hence, the amount of the moisture content obtained in this study was in accordance with that of the other reports. No regular trend was observed for the moisture variation in the four seasons. In Azarshahr, for example, the maximum (79.67%) and minimum (66.82) moisture contents were measured in autumn and winter, respectively; whereas, in the case of Mamaghan, although the maximum moisture content was determined in autumn, the minimum value was recorded for summer. Maximum moisture content in Ilkhichi was measured in winter, whereas the minimum moisture was observed in spring.

Furthermore, the average amount of carbon in the organic and food waste in this study was in accordance with that reported by Tchobanoglous and Kreith (2002) (48%); nevertheless, the nitrogen amount was not in accordance with that report (2.6%). Moreover, the average ash amount in this study was 34.91%, which was considerably higher than the 5% reported by the aforementioned study.[21] C/N ratio in the studied cities of Azarshahr, Mamaghan, and Ilkhichi were 34.76, 30.74, and 26.39, respectively; in Azarshahr, it was slightly higher than the initial optimum ratio of 25–30 for composting;[30, 31] hence, the ratio should be modified by adding compounds with high nitrogen, like waste sludge of wastewater treatment plants. Nevertheless, in Mamaghan and Ilkhichi, the C/N ratio was in accordance with the optimum range for composting.

Correlations between waste generation rates and waste fractions

Spearman correlation coefficients and their significance level among the solid waste components with waste generation rate (WGR) as well as between the individual fractions of solid waste are presented in Table 6. It is clear from this table that WGR negatively correlated with the organic matter, rubber, and wood, and it positively correlated with paper, plastics, metals, textiles, glass, and other fractions; however, all of these correlations were statistically insignificant except for the correlations between WGR with the organic and metal fractions, which are significant at the level of 0.1 and 0.05, respectively. This suggests that when the amount of WGR decreases, the organic waste fraction increases consequently.

Table 5. Moisture content and chemical characteristics of organic and food wastes at studied cities in different seasons

City		Component %					
		Moisture	Carbon	Nitrogen	Phosphor	Ash	C/N
Azarshahr	Winter	66.82	54.65	1.72	0.635	20.20	30.02
	Spring	71.35	58.89	1.84	0.270	19.40	32.00
	Summer	72.52	58.5	1.75	0.265	29.6	33.42
	Autumn	79.67	53.22	1.16	0.321	27.2	45.87
	Average	71.59	56.32	1.62	0.37	24.1	34.76
Ilkhichi	Winter	72.44	54.21	1.73	0.918	27.5	31.33
	Spring	56.49	37.44	1.83	0.223	61.2	20.45
	Summer	70.55	52.62	1.82	0.385	57.4	28.91
	Autumn	66.93	41.52	1.64	0.324	39.2	25.31
	Average	66.44	46.45	1.76	0.46	46.33	26.39
Mamaghan	Winter	62.76	51.48	1.83	0.441	28.4	28.08
	Spring	55.29	39	1.69	0.265	55.4	23.07
	Summer	54.95	56.14	1.76	0.561	26.8	31.89
	Autumn	84.16	52.62	1.2	0.334	26.6	43.85
	Average	64.29	49.81	1.62	0.4	34.3	30.74
Average of 3 cities		67.44	50.86	1.67	0.41	34.91	30.63

Overall, it is obvious that the individual solid waste fractions varied independently, and the estimation of waste composition from WGR is not a feasible action.[32] The proportion of glass and metals were positively and significantly correlated (r = 0.724). Alternatively, the correlation between paper and plastic fractions, and wood and textiles were negative at the 0.05 significance level. A weak negative correlation, at the level between 0.05 and 0.1, was also revealed among plastics and other wastes.

Table 6. Correlation matrix between MSW components from Spearman's correlation

	Organic	Paper	plastics	Metals	Rubber	Textiles	Glass	Wood	Other	WGR
Organic	1					*			*	+
Paper	-0.248	1	*							
plastics	-0.201	0.629	1						+	
Metals	-0.280	0.2514	0.0009	1			**			*
Rubber	0.0404	0.242	-0.197	-0.130	1					
Textiles	-0.643	-0.351	-0.046	-0.076	0.034	1		*		
Glass	-0.028	0.1074	0.2859	0.724	-0.322	0.039	1			
Wood	-0.316	-0.235	-0.099	0.074	0.259	0.6354	0.257	1		
Other	-0.641	-0.208	-0.489	0.169	-0.066	0.3157	-0.333	0.033	1	
WGR	-0.563	0.2313	0.3628	0.602	-0.137	0.265	0.389	-0.015	0.217	1

**High significance probability between 0.001 and 0.01.
* Medium significance, probability between 0.01 and 0.05.
(+) weak significance-probability between 0.05 and 0.10.

Energy Content and potentially recyclable waste

Energy content of the generated solid wastes in the three studied cities was calculated as lower heating value (LHV) using Equation 1 for wet physical composition of solid waste, as suggested by Lin et al. .[33] According to this equation, LHV in Azarshahr, Ilkhichi, and Mamaghan was 4179, 4307, and 4811 kJ/kg, respectively.

$$LHV=219\times P_{pl}+109\times(P_{pa}+P_{wo}+P_{Te}) \quad \text{Eq. (1)}$$

The LHV of 1700 kcal\kg (7140 kJ\kg) is the minimum criteria suggested for the energy recovery from solid waste incineration. Therefore, based on this criterion, the solid wastes generated in the aforementioned three cities are not suitable for energy recovery and incineration.

Annual average of the recyclable wastes

including paper and cardboard, plastics, metals, glass, and wood are presented in Figure 3. It is inferred from this figure that Mamaghan, with almost 30% recyclable waste, holds the first position, followed by Azarshahr (20%), and Ilkhichi (18.81%). Among the recyclables, plastics with more than 12% revealed the highest percentages and metals with nearly 1% indicated the lowest percentage in all cities. These values are low when compared to the other developing countries like Mostaganem/Algeria (31.1%),[34] Amman/Jordon (31%),[35] and Istanbul/Turkey (34%).[36]

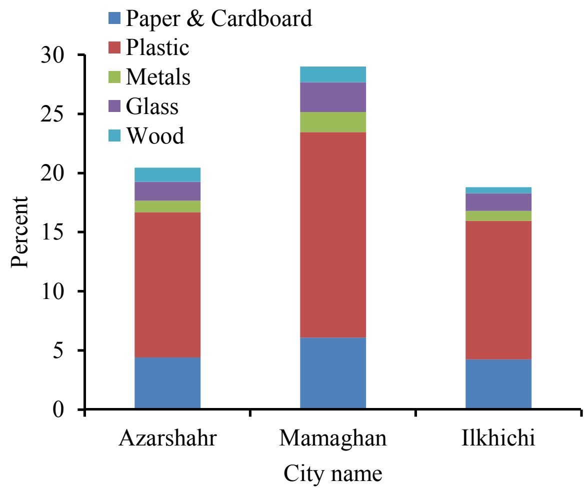

Fig. 3. Annual average of recyclable wastes in the studied cities

Present state of solid waste management

Source separation of waste, in particular, the organic and recyclable portion, not only has direct and undirected environmental and health benefits but also has great economical advantages. Hence, implementing the correct method of waste handling and separation/processing at the source is an essential step to minimize the health and environmental and economic problems related to the waste management. Unfortunately, no systematic source separation program existed for solid wastes (including food waste, plastics, paper and board, metal, and glass) in the studied cities including Azarshahr, Mamaghan, and Ilkhichi during this study. Often, the solid waste was being recycled legally or illegally under the unorganized conditions by individuals or small private companies using a low level of technology. In all of the studied cities, the respective municipalities were completely responsible for waste collection both directly, using their own infrastructure, and indirectly, through private sector contracts. Moreover, the mechanical and manual methods were generally used to collect waste. Collection of solid waste is a difficult and complex task; organic parts of the waste can be easily degraded, which causes offensive odors and leachate in storage containers.[5] The waste that is collected by vehicles like small tracks and vans is directly transferred to the disposal sites (landfill). Safe and reliable long-term disposal of waste considering health, environmental, and economic aspects is an important component of integrated solid waste management. In the present conditions, for all the three studied cities, the waste was sent to the municipal waste landfill for final disposal. The municipal solid waste landfills were located at a distance of about 7, 6, and 3 km from Azarshahr, Mamaghan, and Ilkhichi cities, respectively. Neither selection nor designing and operating of the sites were scientific and they did not meet the criteria of a sanitary landfill. The landfill sites were actually used as a dump for waste; moreover, the waste recycling and feeding of livestock were illegally carried out, and only occasionally, the waste was covered with a layer of soil. Hence, great concerns arised from the environmental and public health viewpoints like ground water, soil, and air pollution, etc. in the final disposal sites in these areas. In addition to the aforementioned technical and environmental issues, small cites generally face financial problems in terms of new investment in the municipal waste management field.

Conclusion

According to the results and review of the related literature, it could be concluded that the amount of solid waste production per capita varies in different urban communities. Waste generation rates of the urban communities in economically developing countries like Iran are less than those of the developed nations. Physical characterization of municipal solid waste in the studied cites indicated that it contained a high proportion of degradable organic matter, representing the existence of a vital scope for the development of composting facilities and converting the generated waste into the fertilizer. Overall, no significant differences were observed between the components of each city during different seasons. Furthermore, in the studied areas, no practical systems were available for source reduction and separation of generated waste. The entire waste was sent to the open dumping sites for final disposal, which may create considerable public health and environmental hazards.

Recommendations

- ✓ Employing skilled personnel like environmental health engineers in the municipalities, especially in waste collection, disposal, and management departments
- ✓ Implementing source reduction, separation, and recycling programs for the generated solid waste (including food waste, paper and board, plastic, metal, and glass)
- ✓ Receiving direct waste collection fee according to the amount of generated waste by citizens for encouraging them to reduce their own produced waste (during this study, the cost of waste management was received from people indirectly via different taxes)
- ✓ Using new and scientific methods and implementing an integrated waste management program
- ✓ Closing all the open dumping sites to avoid environmental, health, and esthetic problems
- ✓ Selecting and operating the final disposal sites according to the scientific approaches
- ✓ Preparing stable and reliable financial and capital sources for new investment in the final disposal sites including sanitary landfills, composting facilities, etc.

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