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Research Article

Municipal Solid Waste Status in Iran: From Generation to Disposal

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Abstract: The crucial step in policymaking and planning for local governments to select appropriate waste management methods and accomplish the required programs and projects is having comprehensive information on solid waste generation. Since there has not been a comprehensive study on waste management practices at a nationwide level in the last decade, this paper aims to present an overview of the current solid waste generation, characteristics, and disposal methods, covering all 31 provinces of Iran based on available information and regional integrated waste management plans. This study is applied research using the descriptive-case study method with quantitative data. The results show the average of solid waste generation (urban and rural) throughout the country is 0.63 kg/capita/day. Although this is 10% higher than its level in the past decade, it is still lower than the global average per capita (0.74 kg/day). Solid waste composition in Iran comprises primarily organic, with 70%, followed by paper and plastic, which account for 7% of the waste stream. In addition, on average, over 90% of the generated solid waste in Iran is still openly dumped, increasing health and environmental risks. To obtain accurate and reliable data, it is essential to establish a comprehensive waste monitoring plan at the national level. This plan should include the determination and periodic updating, through a standardized method, of waste composition and generation rates. According to the data from this research, planning and financial support for source separation can decrease environmental, economic, and social problems in current solid waste management systems.

Keywords: municipal solid waste, waste generation rate, waste composition, waste disposal method

1. Introduction

Population growth and urbanization, along with increasing per capita waste generation, make solid waste management (SWM) a challenging task in developing countries [1]. Besides, the challenges of SWM in developing countries are more complicated due to legal, technical, financial, institutional, economic, and social problems [2]. The adverse effects of solid waste on the environment and human health, along with the significant related costs imposed on societies, necessitate authorities to have a comprehensive plan on SWM. Thus, in addition to the technical aspects of SWM, health and environmental issues, as well as the economic and social aspects, should be considered. In Iran, waste management systems are subjected to an array of problems and challenges due to the lack of a national strategic plan setting out a roadmap for decision-makers. On the one hand, the rate of waste generation in Iran is increasing due to economic growth and urbanization, and on the other hand, changing lifestyle and consumption patterns can affect the waste composition. Drawing a roadmap for SWM systems and consequently selecting suitable methods for

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storage, collection, and disposal of solid waste requires a comprehensive characterization of the quantity and quality of the generated waste. SWM plans should be designed on a local or regional scale based on large-scale and nationwide policies. Therefore, waste characterization at the national level is crucial, and building up a strategic plan for SWM systems is necessary. It requires reliable data on waste composition and quantity in the current situation and anticipating its future trend [3]. Actually, waste characterization at the national level gives policymakers the opportunity to allocate enough funds and infrastructure to the local government, evaluate new waste-related technologies, and set up a field for collaboration between the local government, the private sector, and other stockholders.

Several studies have been carried out on the characterization of waste generated in different countries. Regarding annual reports, municipal solid waste (MSW) generation in different Polish cities varies from 0.65 to 0.85 kg/capita/day. This situation is affected by a number of factors, such as various methods and locations for waste sampling, several methods for field analysis, and different time spans for waste sampling [4]. In another study conducted in African countries, the waste generated in the main cities of Africa varies from 0.3 to 1.4 kg/capita/day, with a daily average of 0.78 kg/capita and a significant standard deviation. A comparison of the standard deviation per capita of waste generated in African cities with its corresponding value in developed countries shows that waste generation changes in developing countries are greater than in developed countries, which in turn makes long-term planning difficult in these countries [5]. In comprehensive research, waste management challenges were examined in more than 30 urban areas in 22 developing countries on four different continents. In this study, a combination of different methods was used to assess the factors influencing the performance of SWM in the cities. Different data about waste generation rate, collection and transportation frequency, and final disposal method were given. The studied cities were a mixture of cultures and included a variety of SWM systems. Presenting reliable data on the quality and quantity of MSW in this research helps authorities make proper and integrated waste management strategies. The financial support of the central government, the interest of the municipal leaders in waste management issues, the public participation, and the proper administration of the funds are essential for a modernized sustainable system [6]. Zhu et al. [7] published a paper on MSW management in China in 2021, which shows the quantity of MSW generation has dramatically increased in recent years. Data from 31 provinces from 2000 to 2017 showed that the amount of solid waste generated ranged from 0.08 to 2.34 kg/capita/day, with an average of 0.73 kg/capita/day in China. Waste composition in China is dominated by food waste (about 48% of the waste stream), followed by recyclables and landfill waste (26.7% and 24.9%, respectively). India is another country with a waste generation pattern similar to Iran. In India, per capita generation of MSW ranges from 0.40 to 0.45 kg/day. The estimates for biodegradable waste would be between 55 and 60% [8]. About 90% of MSW is disposed of unscientifically in open dumps and landfills, creating problems for public health and the environment. Such dumping has led to heavy metals rapidly leaching into the coastal waters [9]. In 2020, the waste generation rate in Malaysia was about 1.17 kg/capita/day [10]. In 2012, a comprehensive study on generation rate, composition, and waste management was conducted worldwide. It shows that on average, developed countries typically generate 1.43 to 2.08 kg/capita/day, while this amount is 0.3 to 1.44 kg/capita/day in developing countries. In both developing and developed countries, MSW is primarily disposed of through landfilling. However, there is a distinction in the way landfills are managed: developed countries conduct landfilling in a systematic manner, whereas developing countries rely mainly on open dumps [11]. In recent years, due to the low economic benefits of waste separation and recycling, resource recovery in the form of heat and electricity production has gained favor. In Asia and other developing countries, the composition of the generated MSW is around 40 to 80% organic waste, while in Europe and the developed American continents, an average of 30 to 40% of MSW consists of organic waste [12]. From a geographical point of view, the waste generation rate in Iran's neighboring countries varies significantly. For example, the average municipal waste generation rate in a wealthy country like Kuwait is 1.6 kg/capita/day [13], whereas the MSW generation rate by inhabitants of Basreh (the third-largest city in Iraq) located in the vicinity of Kuwait City is 0.65 kg/capita/day. Although the MSW generation rate increases in the other important Iraq's cities, such as Baghdad and Mosul, with 0.673 and 0.68 kg/capita/day, respectively, the amount of MSW generation decreases to 0.42 kg/capita/day in the northern city of Iraq, like Arbil [14]. Türkiye is another western neighbor of Iran, with approximately 83 million inhabitants and 1,390 municipalities. It is categorized as a developing country with an upper middle-income (UMI) and is very similar to Iran. The amount of MSW generation in different regions of Türkiye varies from 0.981 kg/capita/day in Southeast Anatolia to 1.48 kg/capita/day in the Aegean, with a total average of 1.16 kg/capita/day. So, the amount and components of MSW in Iran's neighbors are strongly linked to changes in people's consumption behavior, economic situations, and rapidly developing

technology [15].

Despite the importance of the waste management issue, in Iran there has been no integrated and comprehensive data about solid waste. Hassanwand et al. [16] published the latest research on the solid waste identification carried out by the Ministry of the Interior in 2004. This study reveals that the average MSW generation in the country was 0.64 kg/capita/day, and the waste composition was 72.04% organic material, 6.43% paper and cardboard, 7.77% plastic, 2.52% metals, 1.14% rubber, 2.86% textiles, 2.03% glass, 1.10% wood, and 4.11% other materials. Based on the results of this research, 10.3 million tons of MSW were generated in 2004, of which 6% was recycled, 10% was composted, and 84% was mostly unprocessed and dumped. Since MSW quantity and quality can be affected by economic development and degree of industrialization, it is expected that the quantity and composition of generated MSW in Iran have significantly changed through the last decade. However, no integrated study on the identification of Iran's generated waste has been carried out since 2004. The lack of documented information on waste characterization in Iran is evident even in international reports. For instance, the 2012 World Bank report on global MSW statistics relied on the research papers by Damghani et al. [17] to depict the waste generation status in Iran [11]. However, the information provided by Damghani et al. [17] is merely related to Tehran, and it is impossible to generalize the mentioned information to the whole country. In the latest edition of the World Bank report (published in 2018), an informal report by Abedini [18] was used as the source of information on Iran SWM [19]. Thus, it is necessary to examine SWM conditions in different parts of the country to produce much more reliable data on waste generation trends. On the other hand, according to Iran's Waste Management Act (approved in 2004), all cities with a population of more than one million inhabitants must have provided a comprehensive waste management plan by the end of 2011 [20]. Therefore, this paper presents an overview of the status of MSW generation and disposal methods by collecting data from different cities in the country reported in various sources. The results can help authorities make proper decisions on nationwide waste management strategies followed by relevant, feasible, viable, and practicable policies, plans, programs, and projects.

2. Background information

Iran is located in the southwest of Asia and in the Middle East, with 1,648,195 km² in size and a population of 89,172,767 inhabitants (based on the latest United Nations data 2023) [21]. Based on the latest divisions of the country in 2014, Iran consists of 31 provinces. The capital, the largest city and cultural, economic, political, and administrative center of Iran, is Tehran. Different cultures and weather conditions make the adoption of a waste management plan at the national level very complicated, and it will be impossible in the absence of sufficient information on waste characterization produced in various parts of the country. The present study has collected and analyzed data on waste generated in the capitals of all provinces. To this end, the existing reports were used for cities with a comprehensive waste management plan and available information, and in the absence of such data, information has been collected from other reliable sources and authorities. Table 1 shows general data on provincial capitals in Iran as well as the latest available references used for identifying waste produced in each region.

3. Waste generation

MSW generation rate is affected by economic situations, cultural conditions, eating habits, and the local climate. Therefore, the rate of waste generation in different parts of the country can be significantly different. Table 2 shows the per capita waste generation rate and the total amount of waste generation in municipal and rural areas of all provinces of Iran. As shown in Table 2, the average MSW generation rate is 0.70 kg/capita/day and the average rural solid waste (RSW) generation rate is 0.44 kg/capita/day.

Table 1. Provincial capital information and data collection resources

Province	Capital	General information on capital [22]					References used for waste identification
		Area (km^2)	Population (millions)	Density (per km^2)	Annual population growth rate (%)	Year	
Alborz	Karaj	162	1.94	11,978	-0.27	2013	[23]
Ardabil	Ardabil	111	0.53	4,796	1.86	2014	[24]
Bushehr	Bushehr	70	0.27	3,908	2.74	2007	[25]
Chaharmahal and Bakhtiari	Shahrekord	45	0.28	6,404	3.57	2012	[26]
East Azerbaijan	Tabriz	324	1.62	7,780	0.83	2006	[27]
Esfahan	Esfahan	551	2.11	3,834	2.23	2014	[28]
Fars	Shiraz	224	1.71	7,647	1.39	2008	[29]
Gilan	Rasht	60	0.74	12,478	1.22	2002	[30]
Golestan	Gorgan	40	0.36	9,142	1.25	2010	[31]
Hamedan	Hamedan	73.6	0.57	7,910	1.06	2005	[32]
Hormozgan	Bandar Abbas	80	0.54	6,790	3.86	2007	[33]
Ilam	Ilam	60	1.99	3,316	2.41	2014	[34]
Kerman	Kerman	185	0.63	3,417	0.12	2012	[35]
Kermanshah	Kermanshah	96	0.95	9,919	2.14	2011	[36]
Kohgiluyeh and Boyer-Ahmad	Yasuj	30	0.13	4,484	4.39	2012	[37]
Khuzestan	Ahvaz	185	1.19	6,445	1.27	2007	[38]
Kurdistan	Sanandaj	31	0.41	13,357	1.99	2006	[39]
Lorestan	Khorramabad	63	0.37	5,927	1.4	2008	[40]
Markazi	Arak	60	0.53	8,859	-0.19	2008	[41]
Mazandaran	Sari	30	0.31	10,400	0.88	2008	[42]
North Khorasan	Bojnord	36	0.23	6,495	2.76	2015	[43]
Qazvin	Qazvin	65	0.48	7,470	1.08	2008	[44]
Qom	Qom	123	1.22	7,257	2.26	2011	[45]
Razavi Khorasan	Mashhad	328	3.01	9,183	1.76	2012	[46]
Semnan	Semnan	40	0.18	4,628	3.79	2016	[47]
Sistan Baluchestan	Zahedan	90	0.59	6,588	0.94	2010	[48]
South Khorasan	Birjand	30	0.20	6,787	2.72	2010	[49]
Tehran	Tehran	750	8.69	11,591	1.28	2020	[50]
West Azerbaijan	Urmia	105	0.75	7,117	1.97	2013	[51]
Yazd	Yazd	99.5	0.61	6,145	1.72	2012	[52]
Zanjan	Zanjan	150	0.43	2,889	2.17	2009	[53]

Table 2. MSW and RSW generation rates in Iran [23-53]

Province	Total population (millions)	Urban population (millions)	MSW generation (tonnes/day)	MSW generation rate (kg/capita/day)	Rural population (millions)	RSW generation (tonnes/day)	RSW generation rate (kg/capita/day)
Alborz	2.71	2.50	1,733,788	0.69	0.19	69,882	0.35
Ardabil	1.27	0.86	536,941	0.62	0.40	133,447	0.33
Bushehr	1.16	0.83	543,371	0.65	0.32	208,582	0.63
Chaharmahal and Bakhtiari	0.94	0.60	206,531	0.34	0.34	177,306	0.52
East Azerbaijan	3.90	2.80	1,994,691	0.71	1.10	297,062	0.27
Esfahan	5.12	4.50	2,433,947	0.54	0.61	307,998	0.50
Fars	4.85	3.40	2,687,323	0.79	1.44	533,452	0.36
Gilan	2.53	1.60	1,603,026	1.00	0.92	760,689	0.82
Golestan	1.86	0.99	615,290	0.61	0.87	471,530	0.54
Hamedan	1.73	1.09	822,913	0.75	0.64	277,560	0.43
Hormozgan	1.77	0.97	758,021	0.78	0.80	466,664	0.58
Ilam	0.58	0.39	237,158	0.60	0.18	57,687	0.31
Kerman	3.16	1.85	1,263,839	0.68	1.30	382,696	0.29
Kermanshah	1.95	1.46	851,797	0.58	0.48	209,494	0.43
Kohgiluyeh and Boyer-Ahmad	0.71	0.39	270,273	0.68	0.31	97,833	0.31
Khuzestan	4.71	3.55	3,554,205	1.00	1.15	381,580	0.33
Kurdistan	1.60	1.13	703,222	0.62	0.46	180,950	0.38
Lorestan	1.76	1.13	703,643	0.62	0.62	277,829	0.44
Markazi	1.42	1.09	989,788	0.90	0.32	209,366	0.63
Mazandaran	3.28	1.89	1,713,206	0.90	1.38	959,350	0.69
North Khorasan	0.86	0.48	348,729	0.72	0.37	185,207	0.48
Qazvin	1.27	0.95	685,547	0.72	0.32	210,656	0.65
Qom	1.29	1.22	811,776	0.66	0.06	29,415	0.47
Razavi Khorasan	6.43	4.70	2,350,462	0.50	1.73	813,048	0.46
Semnan	0.70	0.56	375,536	0.67	0.14	60,006	0.42
Sistan and Baluchestan	2.77	1.34	497,888	0.37	1.42	414,518	0.29
South Khorasan	0.76	0.45	294,988	0.65	0.31	145,248	0.46
Tehran	13.26	12.42	9,463,695	0.76	0.81	358,779	0.44
West Azerbaijan	3.26	2.13	1,281,722	0.60	1.12	395,156	0.35
Yazd	1.13	0.97	582,813	0.60	0.16	54,166	0.32
Zanjan	1.05	0.71	490,712	0.69	0.34	179,721	0.51
Total or average	79.92	59.14	41,406,841	0.70	20.77	9,306,878	0.44

Figure 1 illustrates waste generation per capita by province (including both urban and rural), indicating the average daily per capita amount of waste generated within Iran. Accordingly, the annual waste generation rate in the country (municipal and rural) is 0.63 kg/capita/day. The largest per capita solid waste generation rates are found in Gilan and afterwards in Khuzestan, with an average of 0.93 and 0.83 kg/capita/day, respectively. Sistan and Baluchestan, with an average of 0.32 kg/capita/day, have the lowest waste generation among the provinces. The waste generation rate in

Tehran, the capital of Iran, is 0.76 kg/capita/day.

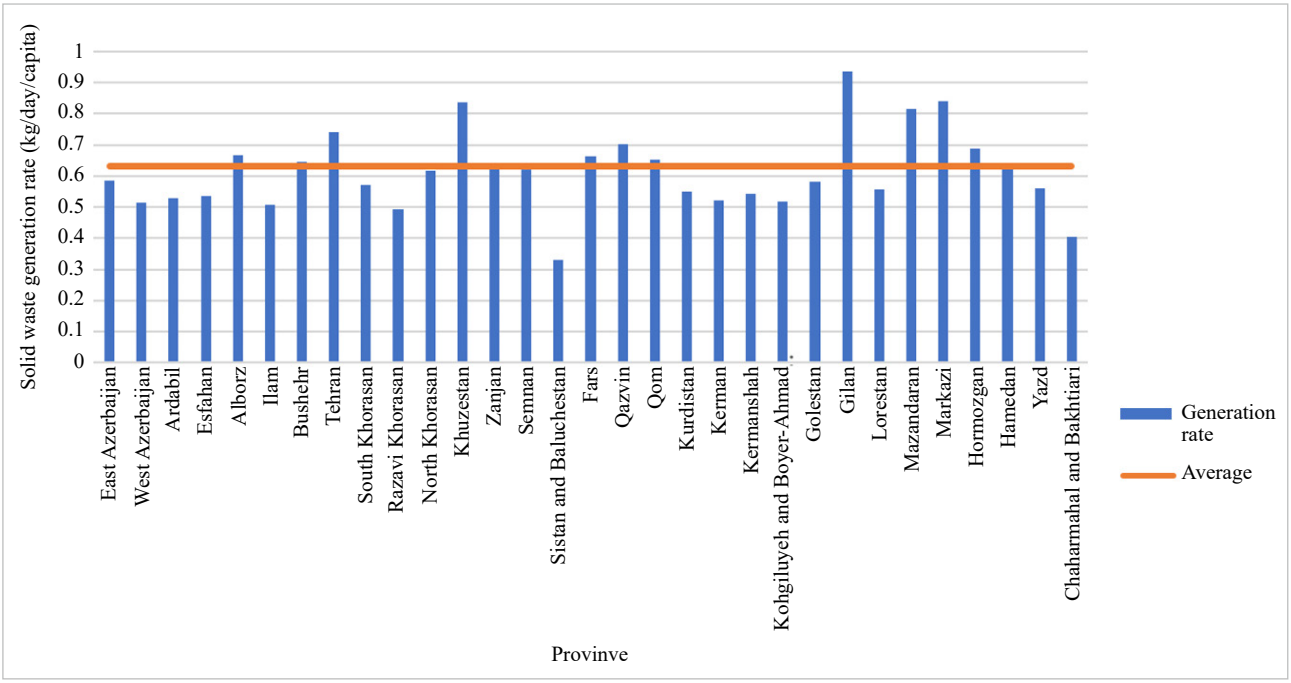

Figure 1. Solid waste generation rate in Iran [23-53]

According to the latest report from the World Bank, the average MSW generation in the world (based on available data in 217 countries) is 0.74 kg/capita/day [19]. Income level and location are two important criteria used to compare MSW generation in Iran with the corresponding global values. The waste generation rate in UMI countries is averagely 0.69 kg/capita/day. On the other hand, per capita waste production in the Middle East and North Africa (MENA) region is 0.81 kg/day. Therefore, the average per capita waste generation in Iran is less than the corresponding value in countries where the economic and regional view is similar to Iran. Different factors can be responsible for the low waste generation rate in Iran compared to countries with similar economic and geographical situations. The main reason for the reduction in waste generation is lower consumption in Iranian families, which has been directly affected by the high inflation rate in recent decades. In addition, the unofficial sector (i.e., waste scavengers) plays an important role in the separation of recyclables from the waste stream, which decreases the amount of waste sent to centers under the supervision of municipalities [54].

4. MSW composition

Waste composition is one of the most important parameters considered when selecting suitable methods for collection, processing, transportation, and final disposal. Different factors, such as income level, consumption pattern, geographic location, source of energy, and climate, influence waste composition. Investigating waste composition allows local governments to select appropriate management methods and treatments for MSW.

The determination of the waste composition is usually done by the American Standard Test Method (ASTM) D5231. MSW composition is classified as organic material (including vegetables, food, and garden waste), paper and cardboard (including paper, wrapper, and packaging paper), plastics (including plastic bags, plastic bottles, and packaging material), glass and ceramics (including glass bottles, broken glass, pottery items, and earthen pots), metals (cables, foils, ferrous and nonferrous material), and others (including textiles) [55]. Table 3 shows the waste composition of different cities in Iran. In general, waste composition in Iran is dominated by a high organic and moisture content.

Among the different compositions in MSW, organic material contributes a higher percentage, which was 69.8%. In the next steps, plastic with 7.8% and paper and cardboard with 7.4% comprise the highest amount. Glass and metal, with the same percentage (2%), have the lowest share among the waste compositions in Iran.

Table 3. MSW composition in provincial capitals in Iran [23-53]

City	Year	Urban population (millions)	Organic (%)	Paper and cardboard (%)	Plastics (%)	Glass (%)	Metals (%)	Other (%)
Ahvaz	2007	1.14	62.1	10.5	12.1	3.3	1.8	10.3
Arak	2006	0.44	66.8	6.8	2.9	2.4	1.1	19.9
Ardabil	2014	0.48	75.2	4.2	8.7	2.4	1.7	7.8
Bandar Abbas	2006	0.37	76.1	6.5	7.6	2.4	2.5	4.9
Birjand	2010	0.18	77.0	7.4	5.6	2.2	1.5	6.4
Bojnord	2015	0.20	77.5	5.7	5.5	1.0	2.1	8.1
Bushehr	2012	0.20	70.0	6.9	8.3	2.6	4.2	8.0
Esfahan	2008	1.60	79.6	3.9	8.7	1.0	0.5	6.3
Gorgan	2008	0.27	71.0	10.0	7.0	2.3	1.3	8.4
Hamedan	2007	0.49	78.8	3.9	5.5	1.2	1.6	9.0
Ilam	2006	0.17	74.1	5.8	7.8	2.0	1.8	8.5
Karaj	2013	1.61	78.4	5.9	6.1	1.6	1.5	6.5
Kerman	2009	0.53	72.3	8.7	8.9	3.0	2.1	5.0
Kermanshah	2013	1.94	66.6	7.2	9.8	1.3	1.1	14.0
Khorramabad	2008	0.34	86.6	5.1	5.2	0.3	0.9	1.8
Mashhad	2012	2.74	46.7	10.8	9.7	5.0	6.8	21.0
Qazvin	2008	0.36	79.8	7.8	5.1	1.3	1.0	5.1
Qom	2011	1.07	67.0	4.0	9.0	2.0	2.0	16.0
Rasht	2009	2.45	65.3	8.8	11.0	1.7	1.2	12.1
Sanandaj	2006	0.37	71.0	6.0	8.0	2.0	1.0	12.0
Sari	2008	0.26	76.0	8.0	8.4	1.1	1.3	5.2
Semnan	2011	0.15	72.2	7.6	7.1	2.6	2.1	8.4
Shahrekord	2017	0.29	75.6	7.9	4.7	4	2.4	5.4
Shiraz	2008	1.22	66.3	5.4	10.7	2.4	1.8	13.5
Tabriz	2006	1.30	69.4	6.4	3.1	1.7	1.0	18.4
Tehran	2020	8.94	58.0	9.0	20.0	3.0	1.0	9.0
Urmia	2013	0.71	75.2	3.8	9.0	2.4	1.7	7.9
Yasuj	2010	0.11	76.6	4.8	7.9	2.4	1.4	6.9
Yazd	2009	0.48	66.8	5.0	8.5	2.1	1.6	16.0
Zahedan	2010	0.46	48.2	2.1	2.7	2.0	2.4	42.7
Zanjan	2009	0.35	74.6	5.0	6.3	2.0	2.5	9.6

Figure 2 illustrates the difference in waste composition in Iran with the corresponding global values. While the average production of organic wastes in the world is 44%, the share of organic wastes in the MSW composition in Iran is about 1.6 times the global average. The amount of organic waste in UMI and MENA countries is about 54% and 58%, respectively. However, Iran is among the UMI countries, but the pattern of consumption in this country is almost similar to that of low-income countries. In addition, by comparing the average waste composition of Iran with the countries of

the MENA region, the amount of organic waste production is higher than in the countries of this region. The average production of paper waste in the countries of this region is about 13.2%, and the average production of plastic waste is 11.7%, but in Iran, these two elements are close together at about 7%. World Bank reports on worldwide waste composition show that the amount of plastic in generated waste has increased from 10% to 12% over the past five years [11, 19].

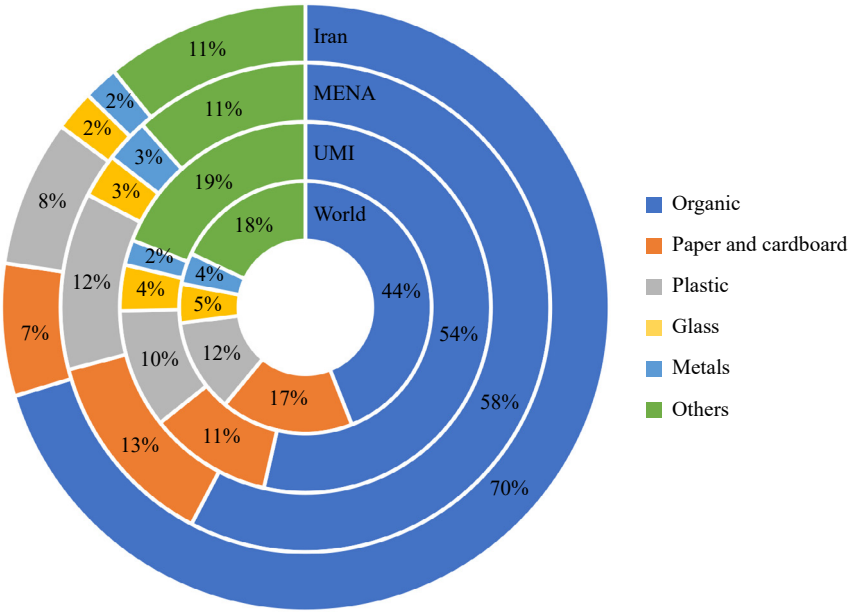

Figure 2. MSW composition in Iran, MENA countries, UMI countries, and the world [11, 23-53]

5. Final disposal

Table 4 shows different disposal methods used in provincial capitals in Iran in the last decade. In general, open dumping is the most prevalent disposal method in the majority of Iran's cities, particularly small towns. In this method, wastes are disposed of in a manner that does not protect the environment, are susceptible to open burning, and are exposed to the elements, vectors, and scavengers. The other cities (especially large cities) use controlled landfills, which is a significant improvement on the communal open dump. The area is fenced to control access, and the waste is covered with soil at the end of each day. This prevents the waste from being blown around, stops flies from breeding on the waste, makes it less accessible to scavenging animals, and prevents the waste from catching fire. A controlled landfill site is staffed, and some machinery (such as a loader) is available to spread, compact, and cover the waste with soil. The other methods (recycling, composting, and incineration) have a very small share of the current waste management system in Iranian cities due to a lack of effective source separation plans.

Table 4. Final disposal methods of MSW in provincial capitals in Iran [23-53]

City	Year	Open dump (%)	Landfills (%)	Compost (%)	Recycled (%)	Incineration (%)	Other (%)
Ahvaz	2007	100.0	0.0	0.0	0.0	0.0	0.0
Arak	2006	100.0	0.0	0.0	0.0	0.0	0.0
Ardabil	2014	100.0	0.0	0.0	0.0	0.0	0.0
Bandar Abbas	2006	100.0	0.0	0.0	0.0	0.0	0.0
Birjand	2006	100.0	0.0	0.0	0.0	0.0	0.0
Bojnord	2007	100.0	0.0	0.0	0.0	0.0	0.0
Bushehr	2012	98.0	0.0	0.0	2.0	0.0	0.0
Esfahan	2008	0.0	50.3	47.0	2.7	0.0	0.0
Gorgan	2008	0.0	90.0	10.0	0.0	0.0	0.0
Hamedan	2007	0.0	99.0	0.0	1.0	0.0	0.0
Ilam	2006	100.0	0.0	0.0	0.0	0.0	0.0
Karaj	2013	100.0	0.0	0.0	0.0	0.0	0.0
Kerman	2009	0.0	85.0	15.0	0.0	0.0	0.0
Kermanshah	2006	0.0	0.0	75.0	7.0	0.0	20.0
Khorramabad	2008	100.0	0.0	0.0	0.0	0.0	0.0
Mashhad	2006	80.0	0.0	20.0	0.0	0.0	0.0
Qazvin	2008	0.0	95.5	0.0	0.5	0.0	0.0
Qom	2011	95.0	0.0	0.0	5.0	0.0	0.0
Rasht	2002	66.6	0.0	25.0	8.3	0.0	0.0
Sanandaj	2006	36.0	0.0	0.0	64.0	0.0	0.0
Sari	2008	100.0	0.0	0.0	0.0	0.0	0.0
Semnan	2011	100.0	0.0	0.0	0.0	0.0	0.0
Shahrekord	2017	100.0	0.0	0.0	0.0	0.0	0.0
Shiraz	2008	0.0	98.8	0.7	0.5	0.0	0.0
Tabriz	2006	99.0	0.0	0.0	1.0	0.0	0.0
Tehran	2020	0.0	45.0	15.0	40.0	0.0	0.0
Urmia	2013	100.0	0.0	0.0	0.0	0.0	0.0
Yasuj	2010	0.0	100.0	0.0	0.0	0.0	0.0
Yazd	2009	100.0	0.0	0.0	0.0	0.0	0.0
Zahedan	2012	100.0	0.0	0.0	0.0	0.0	0.0
Zanjan	2009	50.0	30.0	20.0	0.0	0.0	0.0

There is no accurate information about disposal methods in developing countries, which generally rely on open dumps. In high-income countries, the most common method for MSW management is landfilling and recycling. According to the global average, solid waste is almost always disposed of in landfills, followed by compost, recycling, and incineration. Figure 3 compares the waste disposal methods in Iran with the global average, UMI, and MENA countries. As shown in Figure 3, different types of landfills (i.e., open dump, controlled landfill, engineered landfill, etc.) are prevalent in Iran, MENA, and UMI countries. In UMI countries, however, sanitary landfills and recycling are more common methods; in MENA countries (including Iran), open dumping is the most popular method for waste disposal [19].

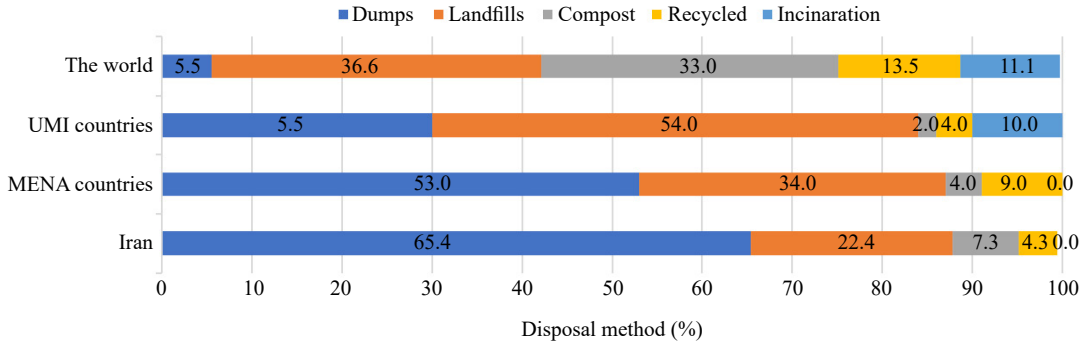

Figure 3. Solid waste disposal methods in Iran, UMI, MENA countries, and the world [11, 23-53]

The most important bottlenecks and shortages of waste disposal systems in Iran can be categorized as follows:

- Lack of precision and data on waste characterization (especially waste composition)
- Inefficient source separation systems, which in turn hinder the utilization of methods with a high rate of material recovery (especially recycling and composting)
- Insufficient financial sources to cover the cost of new technologies
- Inappropriate supervision of waste disposal sites by Iran's Department of Environment as a supreme authorized organization
- Absence of reasonable and scheduled national targets for landfill diversion

The simplicity of implementation and operation, as well as the lower cost, have made landfilling the main method of waste disposal in Iran (about 88%). However, new treatment and disposal technologies must be considered to move toward landfill diversion. New process and treatment technologies must be selected based on waste characterization and current bottlenecks and shortages in municipal SWM systems in each area. The heterogeneous nature of generated waste in cities and the failure of source separation plans necessitate using preprocessing technologies at the entrance of waste disposal complexes. It must be considered that the insufficient efficiency of these facilities does not allow the use of highly sensitive technologies against mixed waste streams such as plasma or pyrolysis. But different kinds of sieves with various hole sizes can be helpful to separate recyclables from putrescible waste. Regarding the high percentage of organic materials in the waste stream (about 70%), a digestion-based method such as compost or anaerobic digestion can be used as the main method for putrescible waste (such as food waste). However, land requirements can restrict these methods in some regions (e.g., the north of Iran) due to limitations on land availability. In this situation, thermal technologies such as incineration can be considered as a solution to avoid landfilling and convert waste to energy. In this regard, biodrying can be applied as an appropriate preprocess method to reduce water content and increase the calorific value of municipal waste before feeding incinerators. Refuse derived fuel (RDF) from non-organic waste is another notable technology that helps increase landfill diversion as well as decrease consumption of non-renewable fossil fuels in different industries, such as cement factories. Clearly, a final decision on the selection of suitable technologies for MSW disposal must be made based on the socioeconomic and physical situation in each city.

6. Conclusion

A thorough analysis of waste management conditions in Iran was done using available and reliable data in order to identify the strong and weak points of the existing system and set a platform for developing a long-term comprehensive plan. Thus, the characterization and analysis of three important factors of waste specification (i.e., quality, quantity, and disposal method) have been taken into account in the provincial cities. In terms of quantity of waste generation, results show that the per capita waste generation in Iran is not only lower than the global average but even lower than that of Iran's counterpart countries geographically and economically. The data indicates that although waste reduction programs should be pursued, the focus should be on promoting waste separation plans along with encouraging disposal methods with the approach of maximum material and energy recovery. An investigation of waste composition in Iran's

cities indicated that a major part of the citizens' waste composition (more than 70%) is putrescible waste. Affordable food products in comparison with other goods and the unique consumption pattern in Iran (as compared with other countries) are the main reasons for the large amount of organic waste. In addition, informal recycling systems and widespread dumpster diving in megacities are effective parameters for removing recyclables from waste streams and, in consequence, increasing the ratio of putrescible elements in waste composition. In other words, lack of proper supervision of the waste storage and collection process results in dramatic increases in scavengers, which in turn leads to the removal of a major part of dry recyclable trash (e.g., plastics, paper, cardboard, metals, etc.). Therefore, besides planning for regular waste sampling and analysis, the strong recommendation is to organize informal recycling systems to obtain real statistics on the generated waste quantity and quality. With respect to waste disposal methods, results show that open dumps are still the prevailing method of urban waste disposal throughout the country. This issue is basically related to a lack of national standards on the avoidance of open dumping as well as the weakness of Iran's environmental organizations, which have no sound perception of a nationwide policy on solid waste disposal emphasizing landfill diversion. Although the present paper provides a general framework for waste generation and disposal methods throughout the country by collecting, classifying, and analyzing available data, we need to adopt a comprehensive monitoring plan for the waste management system. A systematic data gathering platform on the quality and quantity of generated waste should be designed based on standard sampling methods to produce reliable information within specific time intervals for all of Iran's cities in order to adopt mid-term and long-term strategic plans through identifying potential and reviewing the process of change.

Conflict of interest

There is no conflict of interest in this study.

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