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Municipal solid waste characterization, quantification, and management: A case study in Shadegan International Wetland region, Iran

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ABSTRACT

The present study aimed to investigate the description and determination of municipal waste management in seven cities located in Shadegan wetland region, Iran. Some parameters were evaluated, including the waste generation rate, weight density rate, moisture content, pH, and carbon-to-nitrogen (C/N) ratio. In addition, the current status of waste management in the region was assessed using a simple questionnaire and via interviews with households and field surveys. According to the findings, the generation rate of solid wastes was 0.55-0.8 kg/capita/day. The wastes contained approximately 70% of corruptible materials, more than 12% of plastic, and approximately 9% of paper and paperboard. The density, moisture content, pH, and C/N were estimated at 3,242 kg/m, 72.7%, 5.6, and 23.4, respectively. In Shadegan wetland region, recycling was active through the informal sectors, while there was no definite program for source reduction and recycling. Daily collection operations were carried out with no specific programs and prioritization in determining the route of the vehicle and performed manually in optimal conditions. Moreover, the final disposal was observed to be poor and in the dumping form. The obtained results indicated that the wastes in the region had considerable potential for recycling and composting. Therefore, it is recommended that integrated waste management be applied through the improvement of the regulations, environmental education, development of source reduction programs, organized recycling, mechanization of waste collection, establishment of central composting plants, and selection and design of safe landfills in order to achieve optimal outcomes.

Keywords: Waste characteristics, Waste composition, Waste management, Shadegan wetland

Introduction

Waste management is considered to be a significant challenge for authorities in developing countries mainly due to the increased level of waste generation and the subsequent rise in the budget requests for municipalities for waste management.[1-4] In 1990, approximately 1.3×10^9 tons of municipal solid waste (MSW) were generated in the world, and the generation rate reached 1.6×10^9 tons in 2009.[5, 6] In many developing countries, inappropriate waste management has caused numerous environmental and health problems.

Wetlands are valuable and abundant

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sources of plant and animal life, which are currently exposed to environmental disasters due to poor waste management. Leachate of solid wastes contains high concentrations of toxic compounds (e.g., ammonia, organic matters, and heavy metals), which could cause severe damage to the ecosystem of wetlands.

Integrated solid waste management is a comprehensive approach to resource and environmental management,[7] which could be controlled based on multiple managerial guidelines, including source reduction, recycling of materials and energy, sanitary land-filling, and composting even in developing countries.[8-12]

The identification of the characteristics of wastes and estimation of their generation rate play a pivotal role in sustainable management systems in order to find the most effective solutions for MSW management. Unfortunately, the focus of waste management in many developing countries is solely on the collection of wastes regardless of their separation or disposal.[13] Many developed countries have achieved outstanding results in the comprehensive use of resources and solid waste management, thereby succeeding in maintaining their resources; such examples are Germany, Japan, Sweden, the United States, Turkey,[14-16] the Netherlands, and the United Kingdom.

In addition to its international value, Shadegan wetland in Iran has been a wildlife shelter and an eco-tourism site. However, the region is currently exposed to various threats, such as the non-principled disposal of solid wastes. The present study aimed to evaluate the quantity and quality of MSW and its management in the cities located within the Shadegan wetland region so as to provide proper managerial solutions for preventing the contamination of the wetland.

Materials and Methods

Studied region

Shadegan International Wetland is one of the natural, attractive landscapes located in Khuzestan province in the southwest of Iran (Fig.1). This wetland is located at the latitude of 30°00'-31°00'° north and longitude of 48°20'-49°20'°. The region is known as the largest wetland in Iran with the surface area of approximately 400,000 hectares. In this region, the temperature fluctuates within the range of 13-34 °*C* on the coldest and warmest days. With 167 millimeters of annual rainfall, this region has the lowest rate of rainfall compared to the other regions in Khuzestan province. Furthermore, it is considered to be the wettest climatic zone in this province, with the humidity of 45%. As such, the region is referred to as a low rainfall zone and has a lower average rainfall rate compared to other regions. In addition, the disposal site is located in the vicinity of Shadegan and Darkhoveyn cities.

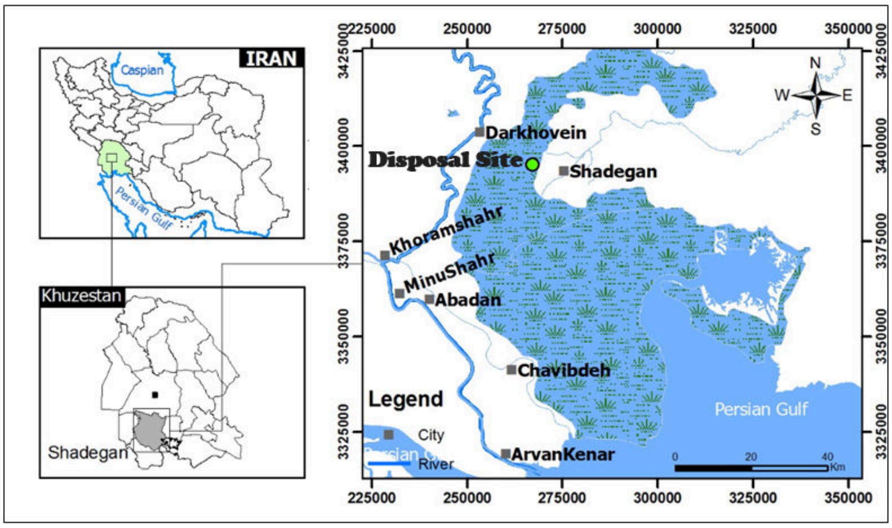

Fig. 1. Location of cities and final disposal site in Shadegan wetland region

Sampling and determination of solid waste characteristics

In the present study, sampling was performed based on standard methods in summer and winter in order to determine the quality and composition of wastes in the middle of each season for seven consecutive days in various cities located in the studied region.[17] In order to determine the physical and chemical characteristics of the municipal wastes in the studied region, the waste sampling program was implemented in 50-60 generation points in each city, which were selected in a completely randomized manner from the entire city.[4]

Quantity was determined based on counting and weighing analysis. The weighing of the wastes in the cities was performed independently in each city for one month in each season. The generation rate in each city was calculated using the following formula:

$$\text{Per capita waste generation} = \frac{\text{Weight of MSW generated at every city} \times 100}{\text{Total number of persons in the city-total number of generation days}} \quad (1)$$

The density of the waste samples was determined using a 500-liter barrel. After the removal of the bags, the samples were divided into four equal parts in the barrel, and specific amounts of waste collected from each part were poured into the container. Without compaction and after the shaking of the container repeatedly, the volume occupied by the samples was measured, and the density of the samples was calculated after weighing. Finally, the average of the four obtained values was reported as the total density of the vehicle.

At the next stage, the waste was separated into the components and the rate of the composition of waste fraction was determined manually.[17] The components of the wastes consisted of 14 groups, including food wastes, plastic (e.g., polyethylene [PE], polypropylene [PP], and polyethylene terephthalate [PET]), paper and paperboard, rubber, leather, wood, glass, textiles, ferrous metals, non-ferrous metals, construction and demolition wastes, hazardous household wastes, and other materials. The rate of the composition of waste fraction was calculated using the following formula:

$$\text{Percentage composition of waste fraction} = \frac{\text{Weight of separated waste} \times 100}{\text{Total of mixed waste sampled}} \quad (2)$$

To determine the moisture content, the evacuated wastes from each vehicle were separated into four parts, and three kilograms of a sample of fresh compostable waste was separated from each part and combined. In addition, a three-kilogram sample was obtained from the combined waste in triplicate and transferred to the laboratory. Following that, the samples were dried in an oven at the temperature of 105 °C for 24 hours. The samples were preserved in the desiccator until reaching the room temperature. The initial weight loss of the samples after drying was equivalent to their moisture content.

In the present study, the pH of the samples was measured using EPA-9045-D. Moreover, the carbon and nitrogen rates were determined using standard methods, and the carbon-to-nitrogen (C/N) ratio was calculated as well.

Results and Discussion

Status and problems of waste management

Storage, processing, and separation at the source

In the studied region, with the exception of the cases where some households recycled their wastes depending on their needs, there was no activity for the separation of the wastes at the source, and the wastes were collected in the combined form. Compared to India, waste management in Iran (treatment and disposal) is not yet properly performed due to the heterogeneous nature of wastes, and more than 90% of MSW is landfilled with no precautionary measures.[1, 4] In Turkey, recyclable materials are separated, washed, and dried by the vendors and are finally sold to brokers in order to be further separated in special factories.[3] In Pakistan, there are no specific programs for the collection of recyclable materials (separation at the source), and commercial and household wastes are dumped in the streets without organization and separation (open-dumping waste sites).[5]

In the present study, none of the cities in the studied regions had laws, regulations or specific patterns regarding the type and size of special and proper containers for the storage and preservation of wastes at the generation source. On the other hand, depending on the welfare and income status of the families in these cities, 10-40-liter plastic buckets or 17-liter tin containers were used for the collection, preservation, and temporary storage of waste. However, a major problem with the use of stationary waste containers is the need for being carried by workers, which may lead to their damage. Furthermore, corrosion of containers and leachate leakage are among the other problems of these containers.[6]

According to the current research, many households used plastic bags to store wastes in the garbage can, and the waste was laid out with a plastic bag in the street. Consequently, animals may have access to the waste bags, and the ripping the waste bags may lead to the spread of waste and leachate at the generation site, thereby causing the spread of contaminants.[7]

Municipal waste collection

With the exception of Shadegan city, the main methods used for waste collection in the cities of the studied region were the curb approach and house-to-house collection systems. In addition, 60% of the waste collection in Shadegan city was performed through the setout-setback process, and the remaining waste (40%) was collected using the curb approach on a daily basis. In Abadan, Khoramshahr, and Darkhoveyn, waste collection was performed mechanically in 35%, 20%, and 50% of the cases, respectively. As for the other cities, waste collection was carried out completely manually. In order to mechanize waste collection systems and reduce the associated costs, the municipalities have recently installed open-top containers (volume: 700-1,100 liters) in main and side streets in order to collect combined wastes, so that several households or waste generators could dispose their wastes into these containers. Due to the lack of general training and aesthetic problems, these containers are not considered to be proper options in urban environments.

Waste transfer and transport

In recent years, use of transfer stations in Iran has become commonplace. However, waste transport to the final disposal site is directly carried out by waste collection vehicles, and no transfer station is used due to the close proximity of the disposal sites to the studied cities (often at the distance of 10 kilometers).

Processing and recycling of municipal wastes

No processing and recycling centers were observed to be active in the studied region. According to the findings, recyclable materials in the cities were collected by vendors and sold to occasional buyers in an informal cycle. These cycles are often carried out by vendors and sweepers in a primitive manner with no precaution, which could increase the risk of infections and disease transmission in the community.[6, 7]

The final disposal of municipal wastes

The main methods used for the final disposal of wastes in Iran include landfilling, dumping, and composting. The current waste disposal sites in the cities located in Shadegan wetland are depicted in Fig. 1. In this region, dumping is considered to be the only approach for waste collection, which is considered to be the most deleterious option in this regard.

Waste generation rate

Several factors affect the amount and type of the compounds in waste, such as economic, social, and local factors.[7] Determining the generation rate of wastes and its changes could contribute to the proper planning for the collection and disposal of waste.[18] According to the results of the present study, the total daily generated waste was approximately 321.5 tons per day in the studied region, and the waste generation rate (average per capita) was estimated at 0.55-0.85 kg/capita/day with the total average of 0.64 in the entire region.

Typically, the waste generation rat in developing countries is within the range of

0.3-1.44 kg/capita/day, while in developed countries, this rate has been reported to be 1.33-2.8 kg/capita/day.[7] These findings are consistent with the global limits of waste generation rate in developing countries. In 2005, the average per capita generation rate in Iran and Khuzestan province was 0.64 and 0.44, respectively.[19] This generation rate in some cities of the world has reported as follows: 0.63 kg/capita.d in Morelia (Mexico),[20] 0.75 kg/capita.d in Kumasi (Ghana),[21] 0.82 kg/capita.d in Nablus (Palestine) and 0.98 kg/capita.d in Kartal District of Istanbul (Turkey).[22]

The results of this study showed that the maximum amount of per capita waste generation was related to Abadan city (0.88 kg/capita.d) and the minimum amount of waste generation is observed in Minushahr cities (0.55 kg/capita.d.) and Chavibdeh (0.55 kg/capita.d). Meanwhile, it can be argued that, among the studied cities, Abadan is commercially and industrially prominent. Most of the waste components in Abadan are more than other cities, however the generation of corrupt waste in this city is lower than other cities studied. Generally, in this study, the waste generation rate was significantly associated with increasing population of cities.

Physical and chemical characteristics of the waste

According to Table 1, the average density of municipal solid waste is 243 kg/m^3 (225-262 kg/m^3) and the moisture content was 72.7% (60-74.5%). The density of waste in Nigeria, Indonesia, Tanzania and Thailand was 250 kg/m^3, 500 kg/m^3, 390 kg/m^3 and 300 kg/m^3 respectively.[21,23] Moreover, the review of previous studies shows that the moisture content in Ghana and Malaysia was 25-76% and 55% respectively.[21,24] Table.1 shows that the average pH and C/N ratio of the corruptible part of municipal wastes in the studied region were 5.6 and 23.4, respectively. The C/N ratio was observed 21.1 to 30.9 in different cities of India.[6] In a study in Ghana, this value was identified to be in range of 37 to 100.[21]

Table 1. Generation rate and physical and chemical properties of MSW in Shadegan wetland district

Location	Density (kg/m^3)	Moisture (%)	C/N	pH	Generation (g/capita.d)
Abadan	250	74.5	24.5	5.6	800
Khorramshahr	256	65	22.1	5.1	700
Shadegan	251	69	26	5.5	600
Arvandkenar	244	60	21.5	4.9	700
Minushahr	229	62.5	23.8	5.1	550
Darkhoveyn	240	70	20.2	6.9	600
Choubadeh	221	67	25.6	6	550
Average	242	72.7	23.4	5.6	642

The composition of the waste

The composition of wastes is an important topic in waste management, which affects the density of waste and, ultimately, affects the selection of the method of disposal, reuse, and recycling of the waste.[23] Figures 2 and 3 show fraction and generation rate of MSW in the studied region. The results showed that the average percentage of food waste in MSW was 70.5%. The results of this study are consistent with the results of studies in Erbil (Iraq) and Palestine in terms of putrescible waste content,[6,7] in which the weight percentage of food waste in the city of Erbil was 79.7% and in Palestine has measured to be 74%. In developing and underdeveloped countries, the putrescible wastes contain the highest percentage of municipal solid waste; so that, the amount of this kind of waste was estimated to be 42-80% in Turkey,[9] 40-60% in India[8] and 66% in Sri Lanka.[10]

However, in industrialized countries, the waste is generally less recyclable and degradable.[25] The next step included the plastics, e.g., PET, PE, PS, etc. (mean percentage of 12.6 with the variation of 10.7% -

14.3%). The logical reasons for the higher percentage of plastic in the municipal solid waste of this region are as follows: increasing the throwaway plastic containers compared to the past, increasing the supply and consumption of products and food packed with plastic materials and water bottles.

In different regions, e.g., Ghana, the plastics accounted for 2 to 20% of the waste.[21] In many cities of China, plastics contain 3 to 19.9% of wastes.[25] In the cities of Nigeria, 8 to 18.1% of the waste was the plastics.[26] The percentage of plastics in the household wastes of Tehran was 10.9% to 12.6%. Paper and cardboard were 8.8% which it was higher than the average weight of the whole of Iran (6.6%) according to Hassanvand *et al.*[19]

The average weight of glass, textiles, metals, and other wastes were 8.2%, 2.4%, 1.3% and 1.6% respectively. On the other hand, the results indicated that the percentage of construction and demolition waste is low that its reason can be related to separate collection and disposal of construction and demolition waste. Unlike this, the construction and demolition waste in America constitute was 29% of solid waste. In addition, almost 35% of the landfill capacity is occupied by construction and demolition waste in Canada.[27]

Finally, it can be said that the average amount of biodegradable materials (food or garbage) in municipal wastes of the Shadegan was about 70% that can be used for composting and biofuels. Moreover, more than 25% of the waste in this region can be used in recycle programs, which means that the waste has a significant potential for recovery of the wastes.

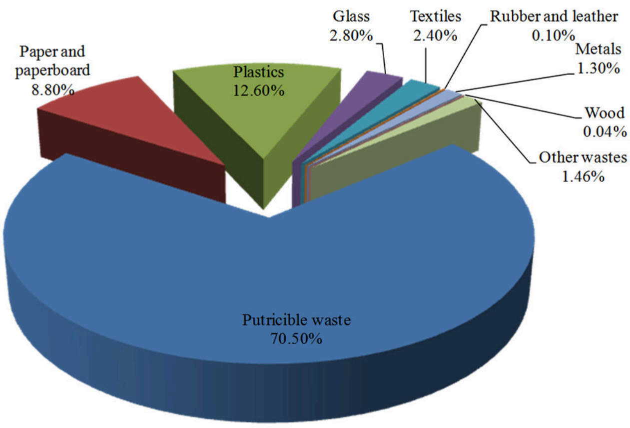

Fig. 2. Fraction of MSW (percent) in the studied region

Table 2. Components of MSW in Shadegan wetland region

Fraction	Weight percentage (Average)								
	Abadan	Khorramshahr	Shadegan	Arvandkenar	Minushahr	Darkhoveyn	Chavibdeh	Average	Standard deviation
Putrescible waste	66.9	75.85	73.29	70.91	68.11	68.95	69.5	70.5	2.9
Paper & paperboard	11.2	8.44	7.97	8.97	10.41	8.18	6.5	8.8	1.5
Plastics	12.6	9.51	10.75	11.85	10.02	12.5	11.5	11.2	1.1
PET	1.7	1.23	0.76	1.61	1.41	1.85	1.5	1.4	0.3
Rubber	0.13	-	-	-	0.15	0.2	0.2	0.1	0.09
Leather	-	-	-	-	-	-	-	0.0	0.0
Wood	0.25	-	-	-	0.04	-	-	0.04	0.09
Textiles	1.1	0.8	3.86	2.26	3.41	2.54	2.9	2.4	1.1
Glass	2.8	2.84	1.91	2.47	3.89	2.25	3.2	2.8	0.6
Ferrous metals	-	-	-	-	-	-	-	0.0	0.0
Non-ferrous metals	1.35	1	1.14	1.02	1.49	1.25	1.6	1.3	0.2
Construction waste	0.57	-	-	-	-	-	-	0.1	0.2
Household hazardous wastes	0.23	0.22	0.17	0.42	0.37	0.25	0.45	0.3	0.1
Others	1.22	0.1	0.14	0.48	0.7	2.03	2.65	1.06	0.9

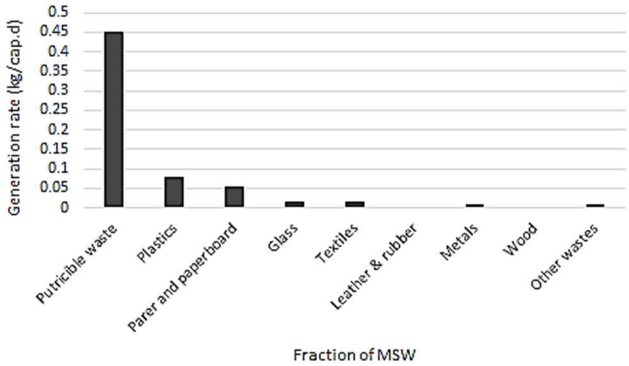

Fig. 3. Average generation rate of MSW (capita/day)

Solutions and suggestions

A large amount of putrescible waste is generated daily which its management and conversion into useful materials according to the conditions of the studied region is mandatory, considering the massive amount of organic matter generated per day. Therefore, in order to convert these materials, the establishment of a concentrated composting plant in Abadan is recommended for the cities of Abadan, Khorramshahr, Shadegan, Darkhoveyn and Minushahr based on domestic and international standards.[6,7] In the cities of Arvandkenar and Chavibdeh, according to the distance, more simple methods of anaerobic composting (controlled burning) can be used. This will reduce the cost of land-filling, collection and transportation. It should be noted that the proper and accurate implementation of public education and separation at the source is essential for the success of this system. Determining the C/N ratio and moisture content is very important for the feasibility of producing a suitable compost product. As shown in Table 1, the C/N ratio and the moisture content of the waste were somewhat appropriate and there is a need for a brief change and adjustment for the process of composting. The highest value of C/N ratio was related to Shadegan and the lowest was observed at the Darkhoveyn. In order to better result, it is suggested that, in the bio-compost production program, some of the yard (plant or garden) wastes such as dry agricultural waste, should be added to the waste mass to reduce the moisture content and to increase the percentage of carbon.[9]

The results of thi s study showed that the pH of municipal waste in the south west of Khuzestan province is 5.6 ± 0.4 and is somewhat acidic. Therefore, the leachate can be corrosive and this should be considered in the design of recycling systems. On the other hand, the pH of the waste should be considered in order to select the appropriate equipment for the recycling process, especially in the production of compost. Acidic pH waste will result in more cost to build and to maintain the equipment and also it needs for great changes. Due to the fact that the standard pH for compost is about 7, hence the acidic pH of the s tudied region for the production of compost should be neutralized.[6]

The PE, PS plastics constitute totally 11.2% of the solid waste and PET content accounted for 1.4% of the total waste. Considering the rapid expansion of petrochemical industries in Iran and increasing the use of various types of plastic containers, especially throwaway containers, it is anticipated that the amount of plastic in the waste will continue to increase in the future years.[6] Considering the economic value of plastic materials and the possibility of its recycling with the development of science and technology and reducing the pollution of the environment and its preservation, the most principled way is the separation, collection and recycling of these materials. Due to the various capacity of plastic conversion and recycling devices, the creating the plastic recycling centers in small, medium and large regions is easily possible.[6,7,9] The contents of paper and cardboard and, in general, the cellulosic components of this region are 8.8% and there is a potential for it.[8,10]

The results of this study showed that, in addition to the putrescible component, more than 25% of solid waste generated in this region is recyclable material. The recycling of these materials, in addition to economical profits, is led to reducing the volume and area of the site required for disposal. The source reduction and the separate collection preserve the quality of recycled materials and reduce the costs associated with the separation. Except for limited recycling operations at disposal site, there is no significant activity in the field of recycling in this area. More than 70% of solid wastes in this region are the putrescible organic materials; therefore it is suitable for compost. Recycling and composting will reduce the volume of required disposal site by 65 percent and will decrease it from 10402500 m^3 to 365,000 m^3 at a period of 25 years. According to estimates, the net profit of recycling and compost operations in a 25-year period from 2010 to 2035 is equivalent to 3280 billion Rials. Therefore, it can be said that it is economical.

Shadegan wetland region is considered as the tourism hub of Khuzestan province and has the high potential for development of tourism and ecotourism industry, which it comprises 37% of wetlands in Iran and is known as the 12th largest wetland in the world.[28,29] Therefore, non-systematic and non-sanitary disposal large volumes of municipal waste into the wetland can be appear through the scattering the light components of the waste in the region by wind, soil contamination, emission of contaminants by surface runoff, greenhouse gas emissions due to decomposition of putrescible waste, the emission of air pollutants including the toxic gases such as dioxins and furans due to the open combustion of wastes containing plastics, paper, etc.

Conclusion

Considering the composition of the waste in this region, it can be said that the municipal waste of the Shadegan wetland has approximately 95% compostable and recyclable materials. Regarding this issue and also due to the many problems in waste management in this region, the great percentage of the waste in this region can be reduced and an economic and environmental stability can be achieved through integrated implementation of comprehensive waste management including the improvement of the regulations, environmental education, development of source reduction programs, organizing the recycling, mechanization of collection and presentation of specific programs for it, as well as the establishment of a central composting plant. In addition, the situating of the waste disposal site in the ecosystem of Shadegan wetland can have a high potential for creating the environmental disaster in the southwest of Iran. Therefore, the emergency teams are needed in this regard that, in addition to making the proper and expert decisions, can select and design a landfill site for the residues resulted from the waste recycling.

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