

Municipal solid waste characterization and it is assessment for potential compost production: A case study in Zanjan city, Iran

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Abstract: The increasing amount of municipal solid waste (MSW) generations and their improper disposal have great social costs, and is an issue of increasing concern. There are strict mandatory targets in many nations to reduce the amount of MSW entering the landfill. At present, the source reducing, recycling, reusing, waste combusting, and also composting the MSW are the major strategies which are being advised spread across the world. Municipal solid waste management (MSWM) practices in Zanjan, a city with population of about 350,000 persons, are generating about 300 tons of MSW daily those are consisting of the collection, transportation and land filling of the wastes. The wastes are not recycled and composted but just mainly land filled. Therefore, this research is conducted to study the generation, characterization and management strategies of solid wastes in Zanjan city. The samplings of MSW were performed in all four seasons during 2010 and the contents of its main components are determined. The qualitative and quantitative results indicated that the composting of MSW is feasible and can be adopted as a proper MSWM approach in the studied area. Recycling of paper, plastic and glass along with composting of MSW are highly recommended.

Keywords: Municipal Solid Waste Management, Composting, Recycling, Zanjan, Solid Waste

1. Introduction

Solid waste is a serious environmental problem in both developing and developed nations. Most developing countries have recently started to improve their municipal solid waste management practices. Inadequate management of solid waste leads to problems that impair human and animal health and ultimately result in economic, environmental and biological losses (Sharholly et al., 2008). In these countries MSW is generally disposed of in low-lying areas without taking any precautions or operational controls. Therefore, MSWM is one of the major environmental problems confronting many developing countries. MSWM involves activities associated with waste generation, its storage, collection, transfer and transport, processing and disposal. In most Iranian cities, the MSWM system comprises only for four activities, i.e., waste

generation, collection, transportation, and disposal (Ziaee et al., 2012). The management of MSW requires proper infrastructure, maintenance and upgrade for all activities. This is very expensive and complex due to the continuous and unplanned growth of urban centers. Providing the desired level of public service in the urban centers is often attributed to the poor financial status of the managing municipal corporations (Ahsan., 1999, Mor., 2006, Raje et al., 2001, Siddiqui et al., 2006, Kumar Kaushal et al., 2012). Per capita generation and characteristics of household waste depends on household income levels and area characteristics. MSW generation in Asia in 1998 was 0.76 million ton/day (Jin et al., 2006) with a growth rate of 2-3 percent annually in developing countries as compared to 3.2 - 4.5 percent in developed countries. The per capita MSW generation rate is varied in different parts of Asia ranging from 0.88 kg/day in Iran (Damghani et al., 2008) to 0.95 kg/day in Turkey (Metin et al., 2003) and 1.21 kg/day

in China (El-Salam, M. M. A. 2013).

The MSW disposal problems can be reduced by waste minimization, reuse and recycling of its components and converting the organic components of the waste into a valuable product and reused without adversely affecting the environment. This can be achieved by converting the waste into biogas through anaerobic digestion and into plant nutrients by way of composting (Mbuligwe and Kassenga 2004, Jha *et al.*, 2013). Compost characteristics are essentially dependent upon the raw materials and the factors that affect the progress of the process. The factors affecting the composting process can be divided into two groups: those depending on the formulation of the composting mix, such as nutrient balance, pH, particle size, porosity and moisture; and those dependent on the process management, such as O₂ concentration, temperature and water content. Nutritional balance is mainly defined by the Carbon/Nitrogen ratio. Microorganisms require an energy source (degradable organic Carbon) and Nitrogen for their development and activity (Hubbe *et al.*, 2010).

This study was conducted in Zanjan Province which occupies about 1.3% of Iranian territory and has an area of 22,164 square kilometers. The province is located in the northwestern part of Iran between latitudes 36° 27' and 37° 15' N and longitudes 47° 17' and 48° 54' E. Zanjan Province has a population of nearly 1,077,254 people which is about 1.5% of Iran's population. Zanjan city is the capital of the province with a population of about 350,000 people. The municipality of Zanjan is responsible for all aspects of solid waste management. Zanjan has a main municipality and is composed of 3 sub municipalities. MSWM practices in Zanjan, generating about 300 tons of MSW daily, consist of collection of waste, waste transportation and land filling. The waste is mainly land filled and recycling and composting are not yet introduced. This paper presents an overview of current MSWM system in Zanjan city, and provides several recommendations for its improvements.

2. Materials and Methods

To perform household wastes management studies in any city, it is necessary to know the constituents of wastes; that is physical and chemical analysis, measurement of weight, volume, quality and quantity of wastes produced in different seasons. Hence in this method, based on the most recent instructions available, the wastes from different localities of Zanjan city were collected during seven continuous days in the mid of each seasons during 2010. After analysis and evaluation of MSW, the results were used in studying the quality of wastes from Zanjan City.

2.1. Sample Collection and Segregation

MSW samples were collected through seven working days in each season and from each of four different communities (i.e. High class districts, Middle economic class, Low class and commercial districts). This means a total number of 20 samples were collected and segregated

per day from four different socioeconomic localities. The samples were then segregated manually into different physical components such as; organic material, paper, plastics, rubber, wood, glass, metals, textiles and PET. Each of these recyclable materials was weighted to determine its fraction in the total solid waste sample collected. The remaining material was a uniform mixture of soil, mud, sand and other inert materials that were not manually separable, and is termed mixed organic materials. 1.5 kg of this mix from each sample was collected in polyethylene bags, brought to the laboratory, and analyzed for moisture content immediately. The remaining samples were stored and analyzed for other important parameters.

2.2. Laboratory Sample Analyses

Representative samples (organic components) were first grounded to homogenous powder in a miller apparatus and then the following analyses were carried out.

Moisture content: Samples of 100 g were taken in triplicate, dried to a constant weight in an oven at 105°C for 24 h, cooled in a desiccators and the difference in weight was recorded (Vesilind *et al.*, 2003). Moisture content was calculated using Eq. (1)

$$M_n = ((W_w - W_d) / W_w) \times 100 \quad (1)$$

M_n = moisture content (%) of material

W_w = wet weight of the sample, and W_d = weight of the sample after drying

Carbon/Nitrogen Ratio: Total Kjeldahl nitrogen and volatile solids (VS) were analyzed by standard methods (APHA, 1998). C/N ratio was calculated using Eq. (2)

$$\frac{C}{N} = \frac{(vs \times 0.58) \% \text{ dry matter}}{(Kjeldahl - N) \% \text{ dry matter}} \quad (2)$$

pH: pH of the water extract (1:5) was measured using a pH meter (Metrohm model 780).

Statistical sample analyses: In this paper, SPSS software (version 11.5) was used for the statistical analysis of the data.

3. Results and Discussion

Waste production and composition depend on many factors, such as the stage of development; socio-economic, climatic and geographical conditions; and collection frequency (Collivignarelli *et al.*, 2004). Data on quantity variation and generation are useful in planning for a collection and disposal system (Sharholly *et al.*, 2008). The current state of Zanjan MSW management, its challenges and our recommendations for improvement of the system are discussed in this section.

3.1. Solid Waste Generation and Characteristics

A comparison of the average amounts of MSW components of Zanjan city in different seasons are reported

in Table 1 & 2. The amount of waste produced in Zanjan is 300 tons per day. Qualitative study of the MSW sampled in different seasons, different social areas of the city (According to the culture of consumption and waste production that is associated with life) and different economic classes shows that maximum percent of organic materials in MSW are found in low economy class in

spring and minimum organic contents belongs to samples from commercial areas in autumn. On the other hand, the maximum total dry recyclable waste in MSW is from commercial regions in summer, and minimum such contents are related to the lower economic classes and in autumn. The highest dispersal is related to organic materials.

Table 1. Composition of municipal solid waste in different socioeconomic localities (high, middle, low and commercial localities).

Socio-economic Localities	organic material (Percent %)	paper (Percent %)	Card board (Percent %)	rubber (Percent %)	plastic (Percent %)	PET (Percent %)	textiles (Percent %)	glass (Percent %)	iron (Percent %)	other metal (Percent %)	sand (Percent %)	wood (Percent %)	D(kg/m ³)
High Class	64.1	5.3	4.9	0.1	9.3	2.7	3.0	4.0	0.7	2.5	1.9	1.2	189
Middle Class	66.1	3.9	5.3	0.2	9.1	2.3	3.5	5.1	0.6	1.9	0.8	1.1	194
Low Class	67.5	3.7	4.5	0.9	7.7	1.9	2.9	3.1	0.9	1.8	2.6	2.2	275
Commercial	46.7	6.6	5.8	1.4	12.6	2.2	5.8	3.1	3.3	3.2	4.4	4.4	187
Mean	61.4	4.8	5.1	0.7	9.7	2.2	3.8	3.0	1.4	2.3	2.4	2.2	210

Table 2. Composition of municipal solid waste in different seasons (by percent)

Seasons	organic material	paper	Card board	rubber	plastic	PET	textiles	glass	iron	other metal	sand	wood	D(kg/m ³)
Autumn(October)	57.5	4.4	4.0	0.0	9.5	1.5	6.1	5.3	2.4	1.7	3.0	3.5	160
Winter(January)	62.9	4.9	5.7	0.7	11.4	2.1	2.5	3.1	0.4	2.6	2.4	1.2	206
Spring(April)	63.5	5.3	5.3	0.8	9.4	2.4	3.3	3.2	1.0	2.5	2.2	1.9	201
Summer(July)	61.5	4.7	5.3	1.4	8.5	3.0	3.2	3.7	1.9	2.5	2.0	2.2	276
Mean	61.4	4.9	5.1	0.7	9.7	2.2	3.8	3.8	1.4	2.3	2.4	2.2	210

3.2. Waste Handling and Separation/Processing at Source

The method of handling, storage and processing of solid wastes at the source plays an important role in public health, aesthetics and the efficiency of the MSW system (Abdoli, 1995). Source separation of wastes will not only bring economic benefits, but also make the recycling of other components more efficient (Aydin, 2004). Unfortunately, separation of household wastes is not yet considered in MSWM program in Zanjan city.

3.3. Collection of Solid Wastes

Collection, transportation and disposal of MSW are the critical problems of the MSWM in any city today (Kinman, 1987). The organic parts of MSW can be easily degraded, which causes problems in storage containers. In Zanjan, municipalities are fully responsible for waste collection and transportation directly, using their own infrastructure, and indirectly through private sector contracts. At present, both mechanical and manual methods are used to collect residential waste. Although mechanical methods of collection have been implemented in some parts of the city, direct lifting and carrying of waste to the collection vehicles is the most commonly used method for waste collection in most parts of Zanjan city. Almost all of the MSW generated is collected daily (including holidays) and are transported to Temporary Transfer Station (TTS) or disposal site.

3.4. Transport and Transfer

In recent years, the use of small TTS in different cities of Iran has become popular (Moghadam 2009). At present, there is only one TTS in Zanjan city. The main reason for using a transfer stations is to decrease transport costs. The type of the transfer station in Zanjan is direct load. The waste that is collected by small vehicles is discharged into an open top trailer.

3.5. Final Disposal

Safe and reliable long-term disposal of waste is an important component of integrated solid waste management. Land filling, incineration and composting are three main methods of MSW disposal in the world. In Iran, land filling, open dumping and composting are the main methods of waste disposal (Moghadam 2009). In Zanjan, only open dumping method for waste disposal is adopted.

3.6. Evaluation of Composting by Municipal Solid Waste in Zanjan

Composting is generally defined as the biological oxidative decomposition of organic constituents in wastes of almost any nature under controlled conditions. Since composting is a biological process of decomposing organic materials, it requires special conditions, particularly of

temperature, moisture, aeration, pH, particle size and C/N ratio, related to optimum biological activity in the various stages of the process. The main products of aerobic composting are carbon dioxide, water, mineral ions and stabilized organic matter, often called humus. The process is accomplished through different phases (Sharma *et al.*, 1997).

Amount of biodegradable materials in MSW of Zanjan is 75.2 percent, which comes to 225.6 tons per day and composting can be produced by utilizing almost 60 percent of MSW transferred to landfill.

The chemical composition of the bulk material affects some parameters, especially the C/N ratio. Very high C/N ratios delay the microbial metabolism, whereas low values cause the loss of nitrogen through ammonia volatilization (Sharma *et al.*, 1997). Residual carbon to nitrogen ratio of Zanjan ranges between 14.22 to 19.53 and the average is 17.6. That is, its value is much lower than standards (Table 3). To obtain a high quality compost, the C / N ratio of the waste can be adjusted to an optimum level by adding cow manure, poultry manure, garden waste etc (Jilani 2007). Another parameter of significant importance is the percentage of water content in the feed material. It is to be noted that the higher water content may cause problems for the complete oxygenation of the material, whereas the lower values, on the other hand, may interrupt the process prematurely (Sharma *et al.*, 1997). Relative Humidity interval in MSW of Zanjan city is 67.94 to 70.3 with a mean of 69.2. The standard rates of more than 50 were identified by Zucconin&deBestoldi (1987) as shown in table 3. As the mean relative humidity of MSW in Zanjan is high, it has to be reduced by aeration during the process of composting.

The parameters, such as pH, alkalinity and volatile acids,

are closely inter-related in the composting process. In the beginning of the process, the formation of carbon dioxide and organic acids causes values of approximately 5-6, whereas, as the process progresses, the pH value reach even up to 8-8.5. This is mainly due to the decomposition of proteins, as well as elimination of the carbon dioxide (Sharma *et al.*, 1997).

A pH of 6.7–9.0 supports good microbial activity during composting. Optimum values are between 5.5 and 8.0 (Bertoldi *et al.*, 1983 and Miller., 1992). Usually pH is not a key factor for composting since most materials are within this pH range. However, this factor is very relevant for controlling N-losses by ammonia volatilization, which can be particularly high at pH >7.5. Elemental sulphur (S) has been used as an amendment for avoiding excessively high pH values during composting (Mari *et al.*, 2005). Average pH in four different seasons was 5.45, which is almost close to the standards (Table 3).

Concerning biological aspects, it is necessary that the starting material is qualified physically, chemically and biologically. For example, the size and consistency of particles should be such that they confer suitable porosity to the bulking material, avoiding exaggerated packing and, thus, allowing free air passage, even in a wasting pile of nearly 2 m height. In order to avoid any eventual slowing of the microbiological degradation, the particle size must be in the cm range because the microbial transformation of a substance is directly proportional to the surface area available (Sharma *et al.*, 1997). Most organic materials in MSW of Zanjan are in range of 8-40 mm (Table 4). Therefore in production of compost it is necessary to mill the organic components to have a more homogenous mater.

Table 3. Average chemical composition of MSW in Zanjan and the standard values Suitable for composting

MSWComponents	Autumn	Winter	Spring	Summer	Mean	*Standard values suitable forcomposting
Organic matter (% wet basis)	57.53	62.95	63.54	61.53	61.38	>20
C	44.50	38.46	37.90	55.35	44.05	No specs
N	3.20	2.30	2.01	2.94	2.61	>0.6
C/N	14.23	17.96	19.53	18.91	17.66	25-50:1
pH	5.25	5.49	5.515	5.55	5.45	5.5-8
Moisture	67.94	70.30	69.28	69.33	69.21	>50

* Standard (Zucconin&deBertoldi, 1987)

Table 4. Composition of particle size in MSW

Particle size(mm)	Autumn	Winter	Spring	Summer	Mean
8>	10.42	10.84	10.26	10.85	10.592
8-120	51.22	50.67	49.47	49.22	50.147
40-120	33.70	32.14	33.80	34.27	33.477
120<	4.62	6.32	4.48	5.53	5.237

3.7. Seasonal Change in MSW Characteristics

ANOVAs test was used to differentiate organic material contents and C / N ratio in samples collected in four different seasons with three degrees of freedom, mean squares of respectively 51.3 and 39.5 in the 5% significance level test (0.014 and 0.04) are significant.

Relative humidity also with three degrees of freedom, mean squares of 6.6, and significant level of 5% is not significant.

4. Conclusion

The waste analysis of Zanjan showed that the percentage of organic waste in the MSW is substantially high, mainly

due to the use of unprocessed food in the daily diet of inhabitants. At present, both mechanical and manual methods are used for the collection of residential wastes. Due to high organic components and its high moisture content, the MSW must be collected daily and transferred to disposal site, substantially increasing the cost of solid waste management.

Composting of MSW are feasible in the studied area and compost production can be chosen as a proper management method utilizing about 60 percent of MSW generated, and substantially reducing the amount of waste land filled. Since composting is a biological process of decomposing organic materials, it requires special conditions, particularly of temperature, moisture, aeration, pH, particle size and C/N ratio. 61.38 percent of the total MSW produced in Zanjan (184.2 tons per day) is biodegradable and can be used for compost production. Average C/N ratio of the MSW was low (17.6) and must be adjusted to an optimum level by adding cow or poultry manure. Average pH values of MSW were 5.4 which are almost close to optimum values for composting. Mean relative humidity was high (69.2%) and may be reduced by aeration during the process of composting. In order to avoid any eventual slowing of the microbiological degradation during the process of composting, it is necessary to mill the organic components to have a more homogenous mater. Recycling of paper, plastic and glass along with composting of MSW are also advised.

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