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Municipal Solid Waste Characterization and it's Assessment for Potential Compost Production: A Case Study

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Abstract: The increasing amount of solid waste generation and its improper disposal has huge social costs and is an issue of increasing concern. There are strict mandatory targets in many nations to reduce the amount of Municipal Solid Waste (MSW) entering the landfill. At present, the source reducing, recycling and reusing, waste combustion and composting of MSW are the major strategies which are carried out. Municipal Solid Waste Management (MSWM) practices in Zanjan a city with population of about 350000 persons are generating about 300 ton of MSW daily those are consisting of the collection, transportation and land filling of the wastes. The wastes are neither recycled nor composted but just mainly land filled. The generation, characteristics determination and management of solid wastes in Zanjan were studied. The samplings of MSW were performed in all 4 seasons during 2010 and the percentages of its main components were determined. The qualitative and quantitative results showed that the composting of MSW is feasible and can be adopted, as a proper MSWM method in the studied area. Recycling of paper, plastic and glass along with composting of MSW are also advised.

Key words: Municipal solid waste management, composting, recycling, solid waste, Zanjan

INTRODUCTION

Solid waste is a serious environmental problem in both developing and developed countries. Most developing countries have recently started improving their municipal solid waste management practices. Inadequate management of solid waste leads to problems those impair human and animal health and ultimately result in economic, environmental and biological losses (Sharholy *et al*., 2008). In these countries MSW is generally disposed of in low-lying areas without neither taking any precautions nor 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 4 activities, i.e., waste generation, collection, transportation and disposal (Omrani, 2005). 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 regions. Providing the desired level of public service in the urban areas is often attributed to the poor financial status of the managing municipal corporations (Ahsan, 1999; Mor *et al*., 2006; Raje *et al*., 2001; Siddiqui *et al*., 2006). Per capita generations and characteristics of household waste depend on household income levels and area characteristics. MSW generation in Asia in 1998 was 0.76 million ton day^{-1} (Jin *et al*., 2006) with a growth rate of 2-3% annually in developing countries as compared to 3.2-4.5% in developed countries. The per capita MSW generation rate is varied in different parts of Asia ranging from 0.88 kg day^{-1} in Iran (Damghani *et al*., 2008) to 0.95 kg day^{-1} in Turkey (Metin *et al*., 2003) and 1.21 kg day^{-1} in China (Suocheng *et al*., 2001).

The MSW disposal problems can be reduced by waste minimizing, reusing and recycling of its components, converting the organic components of the waste into valuable products and reusing without adversely effects on the environment. This can be achieved by converting the waste into biogas through anaerobic digestion and into plant nutrients by way of

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composting (Mbuligwe and Kassenga, 2004). 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 2 groups: Those depend on the formulation of the composting mix, such as nutrient balance, pH, particle size, porosity and moisture and those depend on the process management, such as O_2 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 growth and activity (De Bertoldi *et al*., 1983).

This study was conducted in Zanjan Province which occupies about 1.3% of Iranian territory with an area of 22,164 km^2. 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 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 three sub municipalities. MSWM practices in Zanjan with generating about 300 ton of MSW daily, consist of collection, transportation and land filling of the waste. The wastes are neither recycled nor composted but just mainly land filled. This study presents an overview of current MSWM system in Zanjan City and provides several recommendations for its improvement.

MATERIALS AND METHODS

To study household wastes management in each city, it is necessary to know the constituents of the waste including physical and chemical analysis, measurement of the weight, volume, quality and quantity of the waste which are generated in different seasons. Hence in this method, based on the most recent available instructions, the waste from different localities of Zanjan City were collected during 7 consecutive days in the mid of each seasons in 2010. After analyzing and evaluating of MSW, the results were used in the quality assessment of the waste of Zanjan City.

Sample collection and segregation: MSW samples were collected through 7 working days in each season and from each of 4 different communities (i.e., high class districts, middle economic class, low class and commercial districts). A total number of 20 samples were collected and segregated per day from 4 different socioeconomic localities. The samples were then segregated manually into different physical components, such as organic materials, paper, plastics, rubber, wood, glass, metals, textiles and PET. Each of these recyclable materials was weighted to determine its fraction in the total collected solid waste sample. The remaining materials include uniform mixture of soil, mud, sand and other inert materials those were not manually separable and are termed mixed organic materials. The 1.5 kg of this mix from each sample was collected in polyethylene bags, brought to the laboratory to determine the moisture content, immediately. The remaining samples were stored and analyzed for the other important parameters.

Laboratory sample analysis: Representative samples (organic components) were first grounded to homogenous powder in a Miller apparatus followed by below analysis.

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*., 2002). Moisture content was calculated using Eq. 1.

$$M_n = \frac{(W_w - W_d)}{W_w} \times 100 \quad (1)$$

$$(\text{Moisture content of material } (\%))$$

Where:
W_W = Wet weight of the sample
W_d = Weight of the sample after drying

Carbon/nitrogen ratio: Total Kjeldahl nitrogen and Volatile Solids (VS) were analyzed by standard methods (APHA/AWWA/WEF, 1998). The C/N ratio was calculated using Eq. 2.

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

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

Statistical sample analyses: The data were analyzed statistically using SPSS software (version 11.5).

RESULTS AND DISCUSSION

Many factors are involved in waste generation and composition 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 (Sharholy *et al*.,

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

Socio-economic localities	Organic material (%)	Paper (%)	Card board (%)	Rubber (%)	Plastic (%)	PET (%)	Textiles (%)	Glass (%)	Iron (%)	Other metal (%)	Sand (%)	Wood (%)	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	Textile	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

2008). The current state of Zanjan MSW management, its challenges and the recommendations for improving the system are discussed here.

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 and 2. The amount of the waste generation in Zanjan is 300 ton day^{-1}. Qualitative assessment 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 showed that maximum and minimum percent of organic materials in MSW were found in low economic class in Spring and in commercial areas in Autumn, respectively. On the other hand, the maximum and minimum total dry recyclable waste in MSW was collected from commercial regions in Summer and from lower economic classes in Autumn, respectively. The highest dispersal was related to organic materials.

Waste handling and separating/processing at source: The methods of handling, storage and processing of solid waste at the source play an important role in public health, aesthetics and the efficiency of the MSW system (Abduli, 1995). The source separation of the waste not only has some economic benefits but also make the recycling of the other components more efficiently (Aydin and Kocasoy, 2004). Unfortunately, the separation of household waste has not been yet considered in MSWM program in Zanjan City.

Collection of solid wastes: Now-a-days collection, transportation and disposal of MSW are the critical problems of the MSWM in all cities (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 using their own infrastructure directly and through private sector contracts indirectly. At present, both mechanical and manual methods are used to collect residential waste. Although, the mechanical collecting methods have been implemented in some parts of the city, direct lifting and carrying of the waste to the collection vehicles was the most commonly used method for waste collection in most parts of Zanjan City. Almost all of the generated MSW was collected daily including holidays and were transported to Temporary Transfer Station (TTS) or disposal site.

Transport and transfer: In recent years, the use of small TTS in different cities of Iran has become popular (Moghadam *et al*., 2009) Currently, there is only 1 TTS in Zanjan City. The main reason for using a transfer stations was to reduce transportation costs. The type of the transfer station in Zanjan was direct load. The waste that was collected by small vehicles was discharged into an open top trailer.

Final disposal: Safe and reliable long-term disposal of the waste is an important component of integrated solid waste management. Land filling, incineration and composting are 3 main methods of MSW disposal in the world. In Iran, land filling, open dumping and composting are the main methods of waste disposal (Moghadam *et al*., 2009). In Zanjan, only open dumping method for waste disposal is adopted.

Evaluation of composting by municipal solid waste in Zanjan: Composting is generally defined as the biological oxidative decomposition of organic constituents in waste 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

Table 3: Average chemical composition of MSW in Zanjan and the standard values suitable for composting

MSW components	Autumn	Winter	Spring	Summer	Mean	*Standard values suitable for composting
Organic matter (% wet basis)	57.53	62.95	63.540	61.53	61.38	>20
C	44.50	38.46	37.900	55.35	44.05	No specs
N	3.20	2.30	2.010	2.94	2.61	>0.6
C/N	14.23	17.96	19.530	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	69.280	69.33	69.21	>50

*Standard (Zucconi, 1987)

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 was 75.2% which comes to 225.6 ton day^{-1} and composting can be produced by utilizing almost 60% 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 was ranged from 14.22-19.53 and the average was 17.6 indicating that its value was 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 and etc. (Jilani, 2007). Another parameter of significant importance is the percentage of water content in the feed material. It should be noted that the higher water content may cause some 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 was 67.94-70.3 with a mean of 69.2. The standard rates of >50 were identified by Zucconi (1987) as shown in Table 3. The mean relative humidity of MSW in Zanjan was high therefore, it must 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 (De Bertoldi *et al*., 1983; Miller, 1993). 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 4 different seasons was 5.45 which is almost close to the standards (Table 3).

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

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 mm 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 were in range of 8-40 mm (Table 4). Therefore in the compost production process, it is necessary to mill the organic components to be more homogenously.

Seasonal change in MSW characteristics: ANOVAs test was used to differentiate organic material contents and C/N ratio in samples collected in 4 different seasons with 3 degrees of freedom. The mean squares of organic material and C/N ratio were 51.3 and 39.5, respectively in which were significant at the 5% significance level (0.014 and 0.04), also with the mean squares of relative humidity was 6.6 which was not significant at the level of 5%.

CONCLUSION

The waste analysis of Zanjan showed that the percentage of organic waste in the MSW was

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% 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. About 61.38% of the total MSW produced in Zanjan (184.2 ton day^{-1}) was 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 were 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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