Waste Management 34 (2014) 952–960

Contents lists available at ScienceDirect

Waste Management

journal homepage: www.elsevier.com/locate/wasman

A baseline study characterizing the municipal solid waste in the State of Kuwait

Rawa Al-Jarallah [a,*], Esra Aleisa [b,1]

[a] Civil Engineering Department, College of Engineering and Petroleum, Kuwait University, Khaldia Bldg. # 14KH, 2nd Floor, P.O. Box 5969, Safat 13060, Kuwait, Kuwait
[b] Industrial and Management Systems Engineering Department, College of Engineering and Petroleum, Kuwait University, Khaldia Bldg. # 8KH, 3rd Floor, P.O. Box 5969, Safat 13060, Kuwait, Kuwait

ARTICLE INFO

Article history:
Received 10 October 2013
Accepted 20 February 2014
Available online 20 March 2014

Keywords:
Municipal solid waste
Waste composition
Waste characterization
Statistical analysis
Regression
Kuwait

ABSTRACT

This paper provides a new reference line for municipal solid waste characterization in Kuwait. The baseline data were collected in accordance with the Standard Test Method for the Determination of the Composition of Unprocessed Municipal Solid Waste (ASTM). The results indicated that the average daily municipal waste generation level is 1.01 kg/person. Detailed waste stream surveys were conducted for more than 600 samples of municipal solid waste (MSW). The waste categories included paper, corrugated fibers, PET bottles, film, organic matter, wood, metal, glass, and others. The results indicated that organic waste dominated the characterization (44.4%), followed by film (11.2%) and then corrugated fibers (8.6%). Analysis of variance (ANOVA) was used to investigate the influence of season and governorate on waste composition. A significant seasonal variation was observed in almost all waste categories. In addition, significant differences in proportions between the current level and 1995 baseline were observed in most waste categories at the 95% confidence level.

1. Introduction

Municipal solid waste (MSW) characterization is the first step toward achieving an integrated solid waste management system (ISWMS) that efficiently reduces and treats the ever-increasing amount of MSW (Metin et al., 2003). A waste characterization study quantifies waste components with respect to weight and composition fractions. Reliable data on MSW composition are key in determining and customizing suitable technologies for an overall ISWMS (Magrinho et al., 2006).

This study has three objectives: conduct an up-to-date characterization of the MSW generated in Kuwait, investigate whether any significant changes have occurred since the previously established national waste characterization baseline study, and conduct a statistical analysis to detect sources of variations resulting from seasons and governorates. The objectives were achieved while adhering to the Standard Test Method for the Determination of the Composition of Unprocessed Municipal Solid Waste (ASTM) (ASTM, 2008). In addition, factorial analysis, regression, and residual analysis at the 95% confidence level were performed.

The MSW generation rate and composition are typically believed to be influenced by several factors, such as geographical and climatic conditions, population, and socio-cultural properties (Akinci et al., 2012; Al-Jarallah and Aleisa, 2013; Chandrappa and Das, 2012; Magrinho et al., 2006; Tinmaz and Demir, 2006). The economic status of a country is particularly related to its waste generation rate and composition (Khatib, 2011). Chandrappa and Das (2012) state that low-income countries with an annual GDP below US $5000 per capita have the lowest MSW generation rates of 0.3–0.9 kg/capita/day. In contrast, the MSW generation rates of countries with a higher GDP reach 1.4–2.0 kg/capita/day. The complexity of waste is also associated with country development (Khatib, 2011). Studies have reported that MSW in developing countries is rich with degradable material (Chandrappa and Das, 2012) and has an annual growth rate of 2–3%, whereas the MSW in developed countries is rich in recyclable materials and has an annual growth rate of 3.2–4.5% (Liao et al., 2009; Shekdar, 2009). Recent research suggests that despite the challenges that it may bring to MSW management, urbanization may still facilitate opportunities for lowering or at least stabilizing the rate of MSW generation (Rode and Burdett, 2011). According to Mazzanti (2008), although waste generation is still increasing proportionally with income, this correlation is lessened when waste policies are effectively implemented. The work of Sjöström and Östblom (2010) supports the assertion that waste management policies

* Corresponding author. Tel.: +965 2498 5738/9; fax: +965 2481 7524.
E-mail addresses: rawa@civil.kuniv.edu.kw, rawa1@yahoo.com (R. Al-Jarallah), e.aleisa@ku.edu.kw, aleisaE@gmail.com (E. Aleisa).
[1] Tel.: +965 2498 7527; fax: +965 2481 6137.

http://dx.doi.org/10.1016/j.wasman.2014.02.015
0956-053X/

directed toward increased recycling activities have decoupled the classical association of MSW generation with GDP for some European countries. For instance, the Waste Prevention Programme for England (Defra, 2011) has led to a reduction in MSW generation in general and a 12% reduction in household MSW in 2012 compared to 2006 (Defra, 2013). Another example is the positive results of the New Zealand Waste Minimisation Act of 2008, which reduced MSW when curbside recycling was made available to 95% of the population (ISWA, 2010). This argument may also be applicable to some Asian countries, such as Japan, South Korea, and Taiwan, where urbanization and development appear less destructive to waste generation compared to developing countries within the same region (Othman et al., 2013).

Table 1 compares the waste compositions of developing countries, such as the United Arab Emirates (UAE), Jordan, Egypt, and the Gaza Strip, as well those of developed countries, such as the USA, UK, and Japan. Developing countries have a high percentage of organic waste in the solid waste stream (Abd-Alqader and Hamad, 2012; Salah Abu-Salah, 2013; SCAD, 2013; Tinmaz and Demir, 2006; Zayani, 2010), followed by recyclable materials (Khatib, 2011), particularly plastics and paper. Developed countries tend to produce waste with a higher fraction of non-degradable waste due to the increased spending on packaging material, absence of rag picking, and lower number of scrap dealers (Chandrappa and Das, 2012).

2. The MSW of the State of Kuwait

Kuwait occupies a land area of 17,818 km^2 located on the Arabian (Persian) Gulf Peninsula of the Middle East. The population of Kuwait was approximately 3.250 million in 2012, with an average annual income of $47,926 per capita per year and an average family size of 5.6 persons (WBI, 2012). Kuwait has a hyper-arid desert climate. In the summer months, the average daily high temperatures range from 42 °C to 46 °C. From mid-August through September, humidity can exceed 95%. Dust storms are particularly frequent in the summer and can reach speeds up to 50 km/h. Winter seasons are short and relatively warm, with temperatures ranging from 7 °C to 21 °C. Rain events occur occasionally, with average annual rainfall amounts varying from 75 to 150 mm. Annual rainfall amounts as low as 25 mm and as high as 325 mm have been recorded (UNFCCC, 2012).

Along with Kuwait's acute increase in resource consumption, which has almost doubled over the last 10 years, statistics indicate that waste generation has also increased (WHO, 2012). The average waste generation rate is reported to be 1.4 kg/capita (Al-Meshan and Mahrous, 2002), which is one of the highest waste generation rates in the world (Al-Fares et al., 2009; Al Yaqout and Hamoda, 2002, 2005).

MSW management, including control, collection, processing, utilization, and disposal, is the responsibility of Kuwait Municipality. Dumping sites, which are commonly labeled landfills, are not properly cited or designed (Al-Muzaini, 2006; Al-Yaqout et al., 2002; Al Yaqout and Hamoda, 2002). Although the municipality waste management service continues to be provided free of charge, it has rapidly improved through the use of modern equipment and vehicles to transport the waste to the landfills. The daily collection service is provided to all residential areas using curbside collection for mixed municipal waste. Due to the absence of legislation that would either enforce recycling or compensate users for it, most of the recyclable materials are instead landfilled. A small amount of recyclables are either collected by scavengers from residential garbage containers or sent by advocates to recycling containers at community centers (Koushki et al., 2004a). Recently, the municipality has engaged in an effort to increase public awareness about waste minimization and waste segregation and has provided convenient community drop-off centers for recyclable materials. In addition, it has facilitated private recycling companies' efforts to reclaim any recyclable material before being discarded at the landfills. However, these efforts are carried-out on a small scale. Collected residential waste is sent directly to the landfills. Kuwait Municipality has contracts with 16 private companies for the collection and transportation of household waste to landfill sites. The overall cost of this service is 266.8 million KD ($940 million) for 5 years. The MSW is deposited into three active MSW dumpsites (the Jahra, Mina Abdulla, and Seventh Ring Road dumpsites), in which waste is "dumped" in sand quarries rather than buried within engineered landfills.

3. Methodology

Three approaches are commonly applied to characterize waste: waste product analysis, market product analysis, and direct sampling (Moore et al., 1994). Waste product analysis and market product analysis are suitable for large geographical areas, whereas direct sampling is suitable when site-specific data are not available (Kreith and Tchobanoglous, 2002). This study adheres to the international ASTM D5231-92 (ASTM, 2008) standard method, which a well-established method for waste characterization that has been widely used in the literature (Burnley et al., 2007; Dahlén et al., 2007; Koushki, 1995; Nas and Bayram, 2008; Tinmaz and Demir, 2006). This study adheres to the ASTM standards.

An official agreement was established between Kuwait University and Kuwait Municipality for the purpose of this project; this agreement allowed the research team access to the daily and monthly waste generation reports and landfill sites to conduct the survey needed for waste composition analysis. The three operating landfill sites were visited and studied, and the Seventh Ring

Table 1
Comparing MSW composition of Kuwait to those of some developed and developing countries within close proximity and with similar cultures.

Region	Type					
	Paper & cardboard	Organic	Metal	Plastics	Glass	Others
Kuwait (Koushki, 1995)	14.2	50.7	2.8	17.7	5.6	6
UAE (SCAD, 2013)	25	39	3	19	4	10
Jordan (Salah Abu-Salah, 2013)	14.7	49.7	1.4	15.7	2.6	15.9
Egypt (Zayani, 2010)	10	60	2	12	3	13
Gaza Strip (Abd-Alqader and Hamad, 2012)	11	52	3	13	3	18
Turkey (Tinmaz and Demir, 2006)	12.3	54.2	3	13.2	6.3	11
Japan (Shekdar, 2009)	46	26	8	9	7	12
Malaysia (Shekdar, 2009)	15	40	3	15	4	23
UK (Wales) (Burnley et al., 2007)	33.2	20.2	7.3	10.2	9.3	19.8
USA (EPA, 2010)	28.2	27.8	8.6	12.3	4.8	18.3