



Composition Analysis of Municipal Solid Waste A Case Study in Benghazi, Libya

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ABSTRACT

Benghazi, like other cities in Libya, faces problems associated with poorly managed solid waste operation. The uncertainty of the types of municipal solid waste (MSW) it is the challenge that, hinders chosen the best method for solid waste management. This study deals composition analysis of the city's MSW as, sustainable waste management options. To specify types of MSW the samples collection in wet seasons and dry seasons. Number of samples collected as 40 samples per season. And to get a representative sampling, in this case employed a range of sampling techniques including stratified sampling, systematic random sampling, and purposive sampling. The samples was collected, mixed and then weighed as, kilogram (Kg). The samples were characterized. as, paper, glass, metals, plastics, textiles, non-food, food and putrescibles, misc-combustibles, misc. non-combustibles, household hazardous waste. And then the samples weighed again to determine the proportion of each type. Finally, this study forwarded some important conclusion and recommendations towards improving the current situation.

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Belediye Katı Atıklarının Bileşimi Analizi (Libya-Bingazi Örneği)

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ÖZET

Bingazi, Libya'daki diğer şehirler gibi, kötü yönetilen katı atık işleme ile ilgili sorunlarla karşı karşıyadır. Belediye katı atık (BKA) türlerinin belirsizliği, katı atık yönetiminde en iyi metodun seçilmesinde karşılaşılan zorluktur. Bu çalışma sürdürülebilir atık yönetimi seçeneklerinde şehrin BKA kompozisyonunu ele almaktadır. BKA türlerini belirlemek için örnekler yağışlı ve kuru mevsimlerde toplanmıştır. Örnek sayısı her mevsim 40 örnek olarak toplanmıştır. Örnekleme temsilini sağlamak için, amaçlı örnekleme, sistematik rastgele örnekleme ve tabakalı örnekleme tekniklerini içeren bir dizi örnekleme teknikleri kullanıldı. Örnekler toplanmış, karıştırılmış ve kilogram (Kg) olarak ölçülmüştür. Örnekler, kağıt, cam, metal, plastik, tekstil, gıda dışı, gıda ve biyolojik olarak ayrışabilen malzeme, çeşitli yanıcı ve yanıcı olmayan maddeler ile evsel tehlikeli atıklar olarak karakterize edildi. Sonra örnekler her bir türün oranını belirlemek için tartıldı. Sonuç olarak, yapılan çalışma mevcut durumun geliştirilmesine yönelik sonuç ve önerileri ortaya koymuştur.

Introduction

Municipal Solid Waste

Every unwanted or non-useful solid substance generated in any human population is referred to as solid waste (Kaseva and Mbuligwe, 2003). Over time, consumption practices and activities of economic nature have resulted in generation of MSW (Cointreau, 2006) which is basically waste that is generated from different sectors of a society such as households, educational, health and commercial institutions, public places, etc., and which is taken care of either directly or indirectly by the municipal or local authorities (Williams, 2005). (EEA, 2009) defines MSW as: "...waste from households and other waste which because of its nature or composition is similar to waste from households (cf. the Land Directive). Some of this waste is biodegradable, e.g. paper and cardboard, food waste and garden waste. Biodegradable waste means any waste that is capable of undergoing anaerobic or aerobic decomposition, such as food and garden waste, and paper and paperboard (cf. Landfill directive)" (EEA, 2009). The components of such waste, often an assorted mix, are seldom the same for different areas due to factors ranging from standard of living and habits of residents to resources and climatic conditions found in each geographical location. MSW is often generated in urban areas and has contents that are organic and inorganic nature; the former being often found more in developing countries than the latter. The reverse is mostly the case in the developed part of the world and this is regarded as a significantly distinctive feature from the waste generated in their developing counterpart (Oteng-Ababio, 2011; UNEP, 2005 a,b). Nowadays, solid waste disposal in landfills is still a widespread occurrence throughout the world, even if municipal prefer reduction, recycling and reuse (Xiaoli et al., 2011; Vaverkova and Adamcova, 2014).

Recycled plastic composes no hurtful emissions while it is being manufactured or while it is being used by the consumer. Plastic spills no toxic chemicals into the water or soil and recycling diminishes pollution. While recycling plastic, it helps to create eco-friendly products and prevents from putting tons of waste into our landfills (Brooks and Cetin 2012; Cetin 2013 a,b,c; Cetin 2015 a,b).

Since the use of plastics is increasing, the new method is considering a solution like recycling. One of methods is that some of the plastics get mixed in the other materials for recycling; the recycled plastic then becomes valuable. Whole plastic material can be used as a binder in the recycling of permeable pavements, which has also been an improvement (Brooks and Cetin 2012; Cetin 2013 a,b,c; Cetin 2015 a,b).

Waste and Waste Management

Waste can be generally described as any item or material that is generated and disposed of or intended to be disposed of by a person that has custody of it. However, in addition to considerations of legal nature and geographical location of generation, different definitions of waste exist based on conditions under which they occur (Williams, 2005). A process whereby strategic combination of methods is employed to efficiently

regulate waste from source of generation up to the final disposal point is referred to as waste management, and the aim is to maintain a perpetually safe and healthy environment at minimal cost (Igbinomwanhia, 2011). Waste management has been identified as a challenge in many countries all over the world, much more so in developing countries, and a correlation has been identified between accelerated urbanization, population explosion, industrial development and rate of waste generation in cities found in such countries (Narayana, 2009; UNEP, 2005 a,b).

Sustainable Municipal Solid Waste Management

Sustainable development is an intergenerational concept. It has been defined as development that fulfills today's generation needs without blighting the opportunity for successive generations to fulfill their own (Idowu et al., 2011). The whole process of collecting, transferring, treating, recycling, recovering resources and disposing solid waste in metropolitan areas defines municipal solid waste management MSWM (Ogwueleka, 2009). Sustainable MSWM should entail handling of waste (from collection, treatment to disposal) in a manner that ensures continued safety of public and environment (Adewole, 2009).

Environmental Protection

Poorly collected or improperly disposed of waste can have a detrimental impact on the environment. In low- and middle-income countries, Municipal Solid Waste (MSW) is often dumped in low-lying areas and land adjacent to slums. Lack of enforced regulations enables potentially infectious medical and hazardous waste to be mixed with MSW, which is harmful to waste pickers and the environment. Environmental threats include contamination of groundwater and surface water by leachate, as well as air pollution from burning of waste that is not properly collected and disposed (World Bank, 2012). Some Studies on water quality have shown that environmental threats affect surface waters and reservoirs (Gu, Q. et al., 2016; Mutlu et al., 2016; Mutlu et al., 2014; Kara and Gömlekçioğlu, 2004; Mutlu and Uncumusaoğlu, 2017).

Resource Management

MSW can represent a considerable potential resource. In recent years, the global market for recyclables has increased significantly. The world market for post-consumer scrap metal is estimated at 400 million tones annually and around 175 million tones annually for paper and cardboard (Un-Habitat, 2009). This represents a global value of at least \$30 billion per year. Recycling, particularly in low- and middle-income countries, occurs through an active, although usually informal, sector. Producing new products with secondary materials can save significant energy. For example, producing aluminum from recycled aluminum requires 95% less energy than producing it from virgin materials. As the cost of virgin materials and their environmental impact increases, the relative value of secondary materials is expected to increase.

Waste Disposal Options

The waste management sector follows a generally accepted hierarchy. The earliest known usage of the 'waste management hierarchy' appears to be Ontario's Pollution Probe in the early 1970s. The hierarchy started as the 'three Rs' — reduce, reuse, recycle — but now a fourth R is frequently added — recovery. The hierarchy responds to financial, environmental, social and management considerations. The hierarchy also encourages minimization of GHG emissions. See Figure 1 for the waste hierarchy.

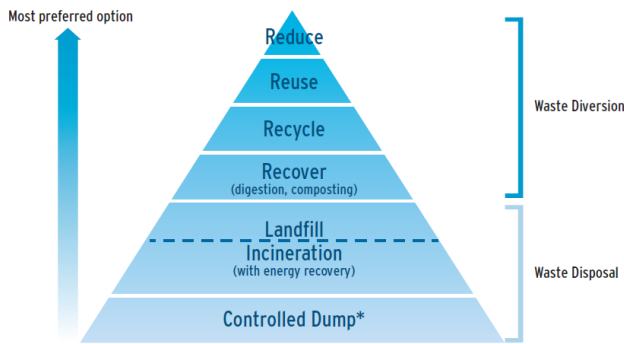


Figure 1 The waste hierarchy

Waste Reduction

Waste or source reduction initiatives (including prevention, minimization, and reuse) seek to reduce the quantity of waste at generation points by redesigning products or changing patterns of production and consumption. A reduction in waste generation has a two-fold benefit in terms of greenhouse gas emission reductions. First, the emissions associated with material and product manufacture are avoided. The second benefit is eliminating the emissions associated with the avoided waste management activities.

Recycling and Materials Recovery

The key advantages of recycling and recovery are reduced quantities of disposed waste and the return of materials to the economy. In many developing countries, informal waste pickers at collection points and disposal sites recover a significant portion of discards. In China, for example, about 20% of discards are recovered for recycling, largely attributable to informal waste picking (Hoorweg et al., 2005). Related GHG emissions come from the carbon dioxide associated with electricity consumption for the operation of material recovery facilities. Informal recycling by waste pickers will have little GHG emissions, except for processing the materials for sale or reuse, which can be relatively high if improperly burned, e.g. metal recovery from e-waste.

Aerobic Composting and Anaerobic Digestion

Composting with windrows or enclosed vessels is intended to be an aerobic (with oxygen) operation that avoids the formation of methane associated with anaerobic conditions (without oxygen). When using an anaerobic digestion process, organic waste is treated in an enclosed vessel. Often associated with wastewater

treatment facilities, anaerobic digestion will generate methane that can either be flared or used to generate heat and/or electricity. Generally speaking, composting is less complex, more forgiving, and less costly than anaerobic digestion. Methane is an intended by-product of anaerobic digestion and can be collected and combusted. Experience from many jurisdictions shows that composting source separated organics significantly reduces contamination of the finished compost, rather than processing mixed MSW with front-end or back-end separation.

Incineration

It is an important technique used around the world, including explosive materials such as health waste incineration, biodegradable waste, polyvinyl chloride plastics, papers and scrapped pieces of equipment (Lee et al., 2003; Lee et al., 2003; Jang et al., 2006). It is also a process designed to treat health wastes that use thermal degradation by thermal oxidation at elevated temperatures between 900 and 1200 °C to burn down the organic fraction of the waste (Ghasemi and Yusuff, 2016; Singh and Prakash, 2007).

Incineration of waste (with energy recovery) can reduce the volume of disposed waste by up to 90%. These high volume reductions are seen only in waste streams with very high amounts of packaging materials, paper, cardboard, plastics and horticultural waste. Recovering the energy value embedded in waste prior to final disposal is considered preferable to direct landfilling - assuming pollution control requirements and costs are adequately addressed. Typically, incineration without energy recovery (or non-autogenic combustion, the need to regularly add fuel) is not a preferred option due to costs and pollution. Open-burning of waste is particularly discouraged due to severe air pollution associated with low temperature combustion.

Landfill

The method of landfill method is one of the popular methods because after disposal or treatment all waste requires landfill for final wastes in order to remove the health waste that has the least environmental impact. The treated waste can be disposed of in a regular municipal waste landfill with most non-incineration technologies (Özkan, 2013). Although the landfill method is an easy and cost-effective waste disposal method, it can increase human health risk and environmental pollution if not carefully and properly (Ghasemi and Yusuff, 2016; But et al., 2008; Narayana, 2009).

The waste or residue from other processes should be sent to a disposal site. Landfills are a common final disposal site for waste and should be engineered and operated to protect the environment and public health. Landfill gas (LFG), produced from the anaerobic decomposition of organic matter, can be recovered and the methane (about 50% of LFG) burned with or without energy recovery to reduce GHG emissions. Proper landfilling is often lacking, especially in developing countries. Landfilling usually progresses from open-dumping, controlled dumping, controlled landfilling, to sanitary landfilling (World Bank, 2012).

Material and Method

This section outlines the approach and overall methodology used in the study. It defines the types of waste material as waste management options.

Geographically

Benghazi is located 32° 7' 0" N, 20° 4' 0" E, it is the second largest city in Libya after Tripoli (Fig. 2). And spread over an area of about 11372 km² with population 674591 in 2006 (Table 1). Kuwayfiah and Bodezera area is located East of Benghazi, as the zones sampled.

Sampling Technique and Data Analysis

The timing of sample collection could be a vital factor, with respect to types of solid waste materials, as occasionally as different from season to season in the year, as dry seasons and wet seasons. In this case, the timing of sample collection as wet seasons in February, 2016 and number of samples for analysis select as 40 samples in season. And the timing of sample collection as dry seasons in June, 2016 and number of samples for analysis select 40 samples in season, these values is more than adopted values by California Integrated Waste Management Board (CIWB) as, values are 40 samples per year for residential waste. To get a representative sampling, in this case employed a range of sampling techniques including stratified sampling, systematic random sampling, and purposive sampling. The Samples collected weighed as kilogram (Kg). The samples was characterized. as, paper, glass, metals, plastics, textiles, non-food, food and putrescibles, misc-combustibles, misc. non-combustibles, household hazardous waste. And then the samples weighed again to determine the proportion of each type. A statistical analysis was conducted using a Microsoft Excel 2007 for Windows. See (Table 2, 3, 4. and Figures 1, 2, 3). The remaining material was a mass of mainly biodegradable material termed putrescibles in this study.

Results

Solid waste generation in Benghazi the quantity and rate of solid waste generation in different cities of Libya depends on the population, level of industrialization, socio-economic status of the citizens and the kinds of commercial activities being predominant. Benghazi, having a population of 674591 (Ministry of Planning in Libya, 2006), the result of the survey in the Benghazi city showed that, quantities of solid waste generated were estimated to be 750 tones per day. As an average 1.11 kg/capita/day. And types of seasonal materials in the municipal solid waste (MSW) as follows:

Dry Season Composition of MSW Samples

The main components of the MSW in dry season from Benghazi are represented in Figure 1 and Table 2. The Food and putrescibles materials represented the single largest component of the MSW from Benghazi accounting for 30.827% by weight - followed by non-food at 21.920%; misc. non-combustibles 15.384%; misc-combustibles 14.980%; plastics 7.000%; paper 3.470%; metals 2.429%; textiles 2.313%; glass 0.868%; and

household hazardous waste 0.809%. From the statistics, it could be seen that, more than 30% of the dry season waste sample from Benghazi is biodegradable, as 82125 tones per year. Mostly comprising of kitchen wastes.



Figure 2 Case study area (Benghazi)

Table 1 Overview of socio demographic characteristics of case study area.

Geographic description	Benghazi
Area /km ²	11372
Population	674591
Population density	59.35
Average size of household	5.7

Source: National Census in Libya in 2006

Table 2 Solid waste composition analysis in dry seasons.

Material classification	Calculated Amount (kg)	%*
Paper	6.00	3.470
Glass	1.50	0.868
Metals	4.20	2.429
Plastics	12.10	7.000
Textiles	4.00	2.313
Non-food Total	37.90	21.920
Food and Putrescibles	53.30	30.827
Misc-combustibles	25.90	14.980
Misc. Non-combustibles	26.60	15.384
Household hazardous waste	1.40	0.809
Total	172.90	100

Putrescibles = biodegradable material, *Percentage (by weight in kg)

Table 3 Solid waste composition analysis in wet seasons.

Material classification	Calculated Amount (kg)	%*
Paper	7.53	3.001
Glass	2.76	1.100
Metals	7.00	2.790
Plastics	14.55	5.798
Textiles	5.01	1.997
Non-food Total	56.45	22.499
Food and Putrescibles	71.00	28.296
Misc-combustibles	40.15	16.002
Misc. Non-combustibles	44.41	17.700
Household hazardous waste	2.05	0.817
Total	250.91	100

Putrescibles = biodegradable material, *Percentage (by weight in kg)

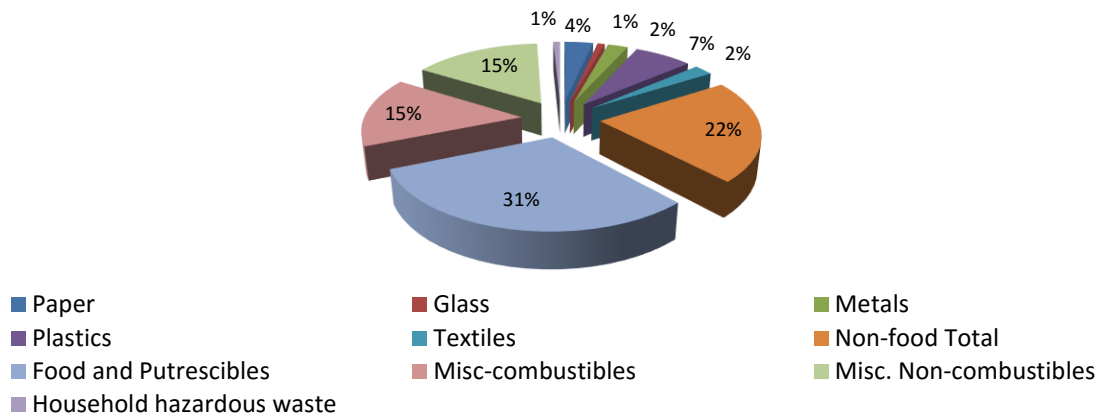


Figure 3 Solid waste composition analysis in dry seasons.

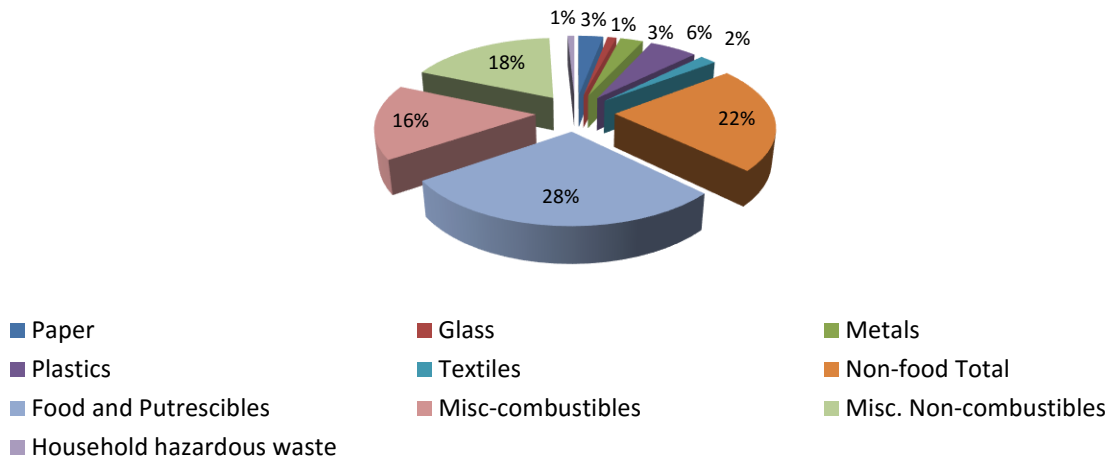


Figure 4 Solid waste composition analysis in wet seasons

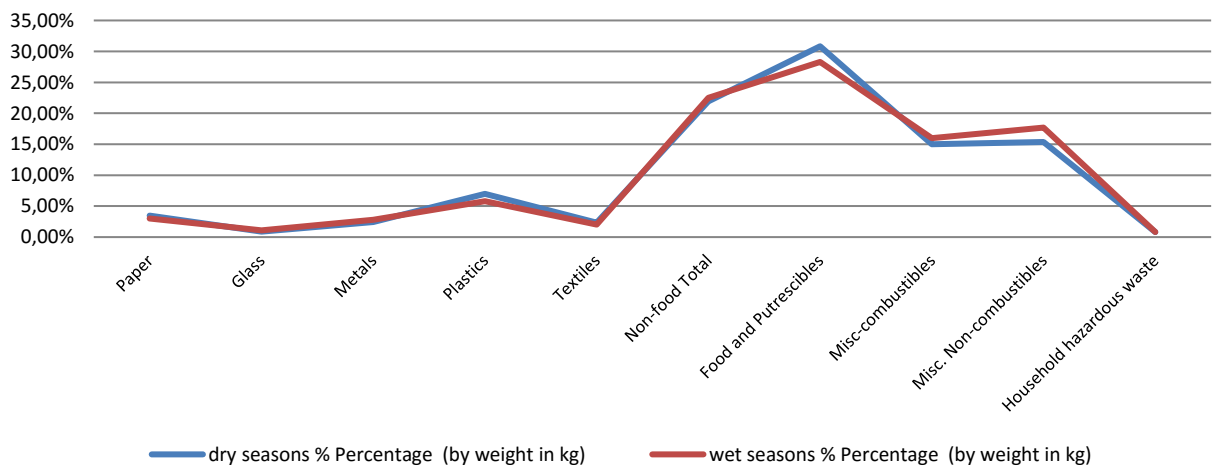


Figure 5 Seasonal comparison of solid waste

On the other hand, the outstanding 70% of the dry season sample comprises non-degradable but recyclable materials such as glass, plastics, paper, textiles and metals, which represents more than 16% from samples, as 43800 tones per year. And more than 14% misc-combustibles materials, as 38325 tones per year. Almost as 40% the remaining materials as, non-food, misc. non-combustibles, and household hazardous waste, as 109500 tones per year.

Wet Season Composition of MSW Samples

The main components of the MSW in wet season from Benghazi are represented in Figure 2 and table 3. The Food and putrescibles materials represented the single largest component of the MSW from Benghazi accounting for 28.296% by weight - followed by non-food 22.499%; misc. non-combustibles 17.700%; misc-combustibles 16.002%; plastics 5.798%; paper 3.001%; metals 2.790%; textiles 1.997%; glass 1.100%; and household hazardous waste 0.817%. From the above statistics it could be seen that, more than 28% of the wet season waste sample from Benghazi is biodegradable, as 76650 tones per year mostly comprising of kitchen wastes.

Table 4 Seasonal comparison of solid waste in case study area (% Percentage, by weight in kg)

Material classification	Dry Seasons (%)	Wet Seasons (%)
Paper	3.470	3.001
Glass	0.868	1.100
Metals	2.429	2.790
Plastics	7.000	5.798
Textiles	2.313	1.997
Non-food Total	21.920	22.499
Food and Putrescibles	30.827	28.296
Misc-combustibles	14.980	16.002
Misc. Non-combustibles	15.384	17.700
Household hazardous waste	0.809	0.817
Total	100	100

Putrescibles = biodegradable material

On the other hand, about 72% from the dry season sample comprises mostly of non-degradable but recyclable materials such as glass, plastics, paper, textiles and metals, which represents more than 14% from samples, as 38325 tones per year. And more than 16% misc-combustibles materials, as 43800 tones per year. Almost as 42% the remaining materials as, non-food, misc. non-combustibles, and household hazardous waste, as 114975 tones per year.

Seasonal Comparison of MSW Composition

This section is a comparison of overall the municipal solid waste (MSW) composition during the dry and wet seasons. The Figure 3 and Table 4 showed that, there was a slight difference in types of MSW over the two seasons. As result there was a slight drop in the quantity of glass in the dry season 0.868 % as compared to wet season 1.100 %. Similarly, metals, non-food, misc-combustibles, misc. non-combustibles.

Household hazardous waste and fine elements dropped from 2.429 %, 21.920 %, 14.980 %, 15.384 % and 0.809 % in the dry season to 2.790 %, 22.499 %, 16.002 %, 17.700 %, 0.817 % respectively, in the wet season. On the other hand, paper, plastics, textiles and food and putrescibles increased from 3.470 %, 7.000 %, 2.313 % and 30.827 %, in the dry season to 3.001 %, 5.798 %, 1.997 % and 28.296 %, respectively, in the wet season.

Discussion

In Benghazi city used manual waste collection method is generally practiced to collect household waste to transfer it to the containers. Waste collection vehicles collect the waste from open containers, transfer stations; and transport them to official landfilling. Each day, approximately, 750 tones per day of MSW is dumped at the site. as an average of (1.11 kg/capita/day) . The results of per capital production obtained in the present study also agrees with that reported else-where in other parts of the world, as the solid waste generation in high income countries from (1.1 to 5.0 kg/cap/day) as compared to (0.46, 0.49 and 0.79 kg/cap/day) in low income countries (Chandrappa and Das, 2012). (Alias et. al., 2014) Alias found solid waste generation 1519.3 kg, and the average of solid waste generation per household was 0.29 kg/person/day in Sabah, Malaysia. In the solid waste composition study, food waste formed the largest fraction of the MSW at 37%, followed by plastic 31%, paper 14.7%, glass 7.2%, and metal 6.3%. In other study, Özbay obtained annual waste generation increased from 451,873 tons to 547,543 tons between 2006 and 2012 (Özbay, 2015).

The result of the study area showed that MSW in Benghazi is composed of paper, glass, metals, plastics, textiles, non-food, food and putrescibles, misc-combustibles, misc. non-combustibles, household hazardous waste. Compositional analysis of samples indicates that, there is a marked increase in the quantity of food and putrescible, as in the wet seasons (28.296%) to (30.827%) in the dry season. And non-food, as in the dry seasons (21.920%) to (22.499%). Underlining the influence of seasonal dynamics on waste composition (Trankler et. al., 2006; Ezeah, 2010). Generally, the composition analysis of Benghazi MSW samples seems to indicate that sample characteristics are typical of MSW samples from urban environment, high in biodegradable/organic waste and low in industrial waste (Smith, 1997; Rushbrook and Pugh, 1999; John et al., 2006; Sha'ato et al., 2007; Igoni et al., 2007; Ezeah, 2010). Hamid et. al. (2015) found daily waste organics (55%), plastics (30%), papaer (11%), glass (1%)and metal (2%), plus rubber, leather, and wood (1%). And his study determined organic waste has the highest percentages than others (Hamid et al., 2015).

During the same period however, the quantities of the plastic it is increase from (5.798%) in the wet season to (7.000%) in the dry season, the reason is drink more water in the hot season, (Parrot et al., 2009). There is a little difference of percentage in the paper and other industrial products from the case study area. For instance, Paper in the wet seasons (3.001%) and in the dry season (3.470%);

Metals in the dry season (2.429%) and in the wet seasons (2.790%). There is slightly rise in the Glass, as (0.868 %) in the dry season to (1.100%) in the dry season. And the Textiles in the wet seasons from (1.997%) to (2.313%) in the dry season. The interpretation of these results is believed to reflect the consumption pattern of the standard of living convergent in the case study area (Afroz et al., 2009; Ezeah, 2010). The quantity of the Seasonal Household hazardous waste with little change from (0.809%) in the dry seasons to (0.817%) in the wet seasons. This quantity represents just a small percentage of overall MSW. In EU and the USA it is generally reported that the quantities of Household hazardous waste arising represent (1%) of municipal waste (Adamcová et al., 2016; Gendebien et al., 2002; NHHWF, 2008; USEPA, 1997). The quantity of the Seasonal Misc. Non-combustibles, there is slightly difference as (15.384%) in the dry seasons to (17.700%) in the wet seasons. About quantity of the Seasonal Misc -combustibles, there is little difference as (14.980%) in the dry seasons compared (16.002%) in the wet seasons. MSW contains organic components which are combustible. Thus, energy could be gained from incineration of waste or landfill gas combustion, which may be used to generate electric power or produce heat for buildings (through boilers) (Williams, 2005). As such, the process of converting solid waste of organic nature into other useful forms such as gas, heat, steam and ash residues via combustion (Magutu and Onsongo, 2011).

Conclusion

This study finds the quantity of solid waste generated in Benghazi was estimated to be 750 tones per day. as an average of (1.11 kg/capita/day). Approximately 28 to 30% of municipal solid waste MSW samples were found to be bio-degradable materials, were estimated to be 76650 to 82125 tones per year of MSW. This is ideal for compost production. Apart from the bio-degradable, there are about 14 to 16% recyclable materials, as paper, glass, metals, plastics, and textiles, were estimated to be 38325 to 43800 tones per year of MSW. This is important for providing gainful employment to many. On the other hand, there are about 14 to 16% of MSW samples is misc-combustibles, which about 38325 to 43800 tones per year. This is ideal for energy recovery. And approximately 40 to 42% of MSW samples is materials, it can be disposed of in sanitary landfill as, non-food, misc. non-combustibles, and household hazardous waste. Which about 109500 to 114975 tones per year. As conclude that, There is a noticeable difference in the character of the waste seasonal quantity of bio-degradable materials and other key components of the municipal solid waste. (Macias and Piniarski, 2016) pointed out the key problem for the Pobiedziska and Pobiedziska rural area waste management system is illegal dumping sites, which result from incorrect system solutions applied by the municipality (Macias and Piniarski, 2016). Finally, we conclude that, municipal solid waste management options in Benghazi city It should be based on 'waste management hierarchy' as the whole process of collecting, transferring, treating, recycling, recovering resources and disposing solid waste, in a manner that ensures continued safety of public and environment.

Recommendations

- On the central government to provide the enabling environment for all stakeholders in waste/resource management to take responsibility and show leadership through appropriate actions for sustainable waste management.
- Invest in new technologies that emphasize recycling of resources, energy recovery and sanitary landfill. As, usage of the 'waste management hierarchy'.
- On consumers – Businesses as well as households to seek all avenues to generate less waste, separate their waste at source for easy recycling thereby lessening adverse environmental impacts.
- On the retailers, prefer to market products from eco-friendly producers.
- On the local authorities to provide residents with adequate education on how to reduce waste and provide convenient and sustainable waste management options.

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