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Municipal solid waste generation rate and chemical analysis in Hadero Town, Southern Ethiopia

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Abstract

Solid waste is generated hastily and created lots of complications in developing countries like Ethiopia. If solid waste is not managed properly, it will certainly have a negative impact on sustainable living style, local environment, and human health. Therefore, the objective of this study was to assess the solid waste generation rate, physico-chemical characterization, and heavy metal concentration of municipal solid waste in the study area. To achieve the objective, a cross-sectional descriptive survey design was used, and multi-stage sampling methods were employed. Primary data were gathered from 141 respondents through questionnaires and interviews, and observations were also used for waste characterization. The study showed that the Hadero town generated 0.09, 0.14, and 0.16kg/capita/day based on the low, middle and higher income respectively. The average solid waste generation rate of the present study area was 0.13kg/capita/day. The study revealed that in the town the daily total solid waste generation was 5825.43kg and the annual total generation of solid waste was 2126281.95kg. The pH and EC values were 5.82, and 2.42ds/m respectively in the study area. Moreover, the nitrogen, phosphorus, and potassium content of the solid waste sample were 1.35%, 0.223%, and 0.923%, respectively. The results revealed that the highest proportion of heavy metals such as Fe (1812.7mg/kg) followed by Mn (1072.7mg/kg) and Zn (448.92mg/kg) was recorded in the study area. The least heavy metal in municipal solid waste is Cd (2.92mg/kg).

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Introduction

The population expansion and the rate of urbanization are frighteningly increasing throughout the African continent. But the technology, financial capacity, culture, and understanding of the community required to properly manage municipal solid waste and generation rate are not adequately available related to this all noted that with the increase of population. Solid waste management and the chemical nature of the solid waste would be the main challenges for the responsible body (UNESC, 2009). Particularly, waste volumes have increased in urban areas due to the growing urban population, the concentration of industries, the consumption of residents, and inadequate finance and facilities to manage waste collection and disposal. The imperfect community contribution is the main factor that contributed to the poor waste collection in solid waste management. The limited participation has budded from co-ordination and collaboration problems that exist among the stakeholders such as private sectors, the public (government), and solid waste management (NEMA, 2007).

The quantity and composition of solid waste were varying from country to country making it difficult to adopt solid waste management systems. The efforts made by the town municipality administration were not efficient to solve the problem in relation to waste management activities of the town. Moreover, there was no waste reduction at its source, recycling of waste, collection, transportation, and disposal. In addition, there was a limitation on the public solid waste storage containers and adequate roadside dust bins. The shortage of the above mention facilities led the inhabitants to dump solid waste on open areas, near rivers, drainage channels, on roadside, and gullies. Consequently, illegal left of solid waste is everywhere which causes the closing up of sewerage channels, Sewerage channels are blocked by illegally disposed solid waste creating bad odor, damaging the physical aspects of the town, and cause for various diseases. In general, the health situation of residents or inhabitants, the quality of the environment, and the aesthetical value of the town are highly affected.

Waste generation refers to all activities of identification of materials as no longer being of value and thus are either thrown away or collected for disposal. The economic status of the household, geographic location of cities, and the attitude of residents about waste are some of the factors that directly affect the waste generation rate of cities. Correct information on Solid waste generation rate and quantity of waste helps to determine the required human, financial and equipment resources for the management of the waste. The generation of Solid Waste is a critical phase that determines the activities of all the subsequent functional elements. In other words, there is a strong interdependence between waste generation and the other functional elements and this is known as systems continuity (Tchobanoglous, 1977). For effective and efficient management of solid waste generated in a particular city, adequate knowledge and data about the characteristics of solid waste are essential. In order to decide or determine the types of facilities required for solid waste management, best disposal options, and projecting future needs requires precise information about the quantities, compositions, densities, moisture content, and chemical nature of solid waste produced in a city (Rushbrook, 1999). Therefore, the purpose of this study was to assess the generation rate and chemical characterization of municipal solid waste in Hadero town. So, this study was intended to fill the current research gap related to the inefficient, generation rate and improper municipal solid waste management practices.

Materials and methods

Study area description

The study was conducted in the Hadero town Southern Nation Nationalities and Peoples Region of Ethiopia. It is far away from Addis Ababa and approximately 295 km southwest from Addis Ababa and 175km from Hawassa city in the North West. The area geographically lies between 7025'30" to 7035'39"N and 37040'10"E to 37048'52"E with an average altitude of 1547 meters above sea level. The town had four *Kebeles*, namely 01, 02, 03, and 04, and each *kebele* population was 10919, 10820, 11007, and 12065 respectively.

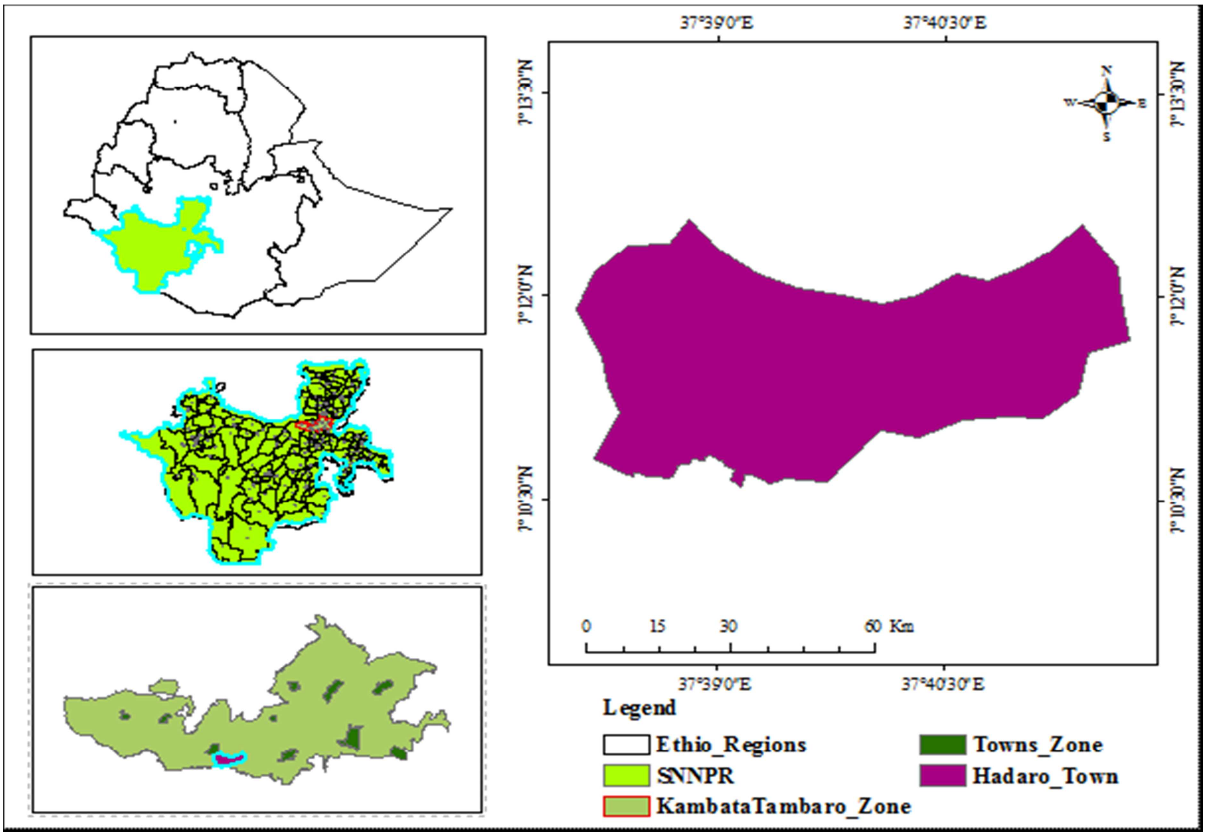

Fig. 1. Study area map.

Sampling, sample preparation and analysis

In the present study, to analyze the socio-economic characteristics of the household, the descriptive method was adapted. The town was consisting of four *kebele* administrations, namely, *kebele* 01, *kebele* 02, *kebele* 03 and *kebel*e 04. In the first step four Kebeles are classified into two separate strata, *Kebeles* near the center of the town (*kebele* 01 and 02) and *kebeles* periphery to the center of town (*kebele* 03 and 04). In the second step, only two *kebeles* were selected from all *kebeles* of the town, by using a simple random sampling technique depending on the business center, availability of different infrastructures, and population density. In the third step, the total sample sizes of 133 households were selected (Cochran, 1977). In addition to this, purposively and randomly selected three institutions (Urban development and housing office, Municipalities and Forest and environment protection office) and five commercial centers (Duna cafe and restaurant, Lemelem hotel, Hidase cafe and restaurant, Degu stationery and Abe tesfa cafe and restaurant) from the two selected *kebeles* (01 and 04). The structured questionnaire and interview were used for the selected residential housing units in the two selected *kebeles*.

Physical composition of municipal solid waste

The solid waste collected for seven consecutive days from different sources such as households, institutions, and commercial centers were kept separately in the different plastic bags given. Then the solid waste from the sources were opened onto the plastic sheet and segregated into different types as plastics/rubber, food waste, glass/ceramics paper/cardboard, metals, and ash and dust. The separated waste was weighed by using hand balance and recorded.

Physical and chemical characterization of municipal solid waste

After weighing and separating each sample, the collected biodegradable municipal solid waste was taken to the laboratory. The analysis of moisture content of SW was carried out by ASTM Standard D 5231-5292. The chemical analysis such as pH , electrical conductivity (EC), organic carbon (OC), nitrogen (N), phosphorus (P), and potassium (K) was done by Tondon (2005) and Trivedi & Goel (1984). Heavy metals such as Fe, Mn, Cu, Zn, Ni, Co, Cr, pb, and Cd were determined using atomic absorption spectrophotometer (Buck Scientific, Model 210 VGP Atomic absorption spectrophotometer, USA) using wet and dry digestion methods.

Generation rate of solid waste

Municipal solid waste generation is essential due to discarding unwanted materials away for disposal. Per-capital per day solid waste generation rate (PCPDSWGR) can be calculated as the total solid waste generation rate within seven days divided by seven times the family size of 133 households (Fobil, 2000).

$$\text{PCPDSWGR} = \frac{\text{Total Solid Waste Generation with in 7 days}}{\text{7 days time total family size of 133 HHs}}$$

In this method, the solid waste generation rate of institutions and the commercial areas was calculated

Results and discussion

Generation rate of municipal solid waste by day, week and month

The generation rate of municipal solid was calculated in the study area and the results were indicated in fig.-2. It revealed that the major sources of municipal solid waste in the town were residential, commercial, and institutional areas. In addition to this, a high proportion (69.07%) of solid waste was generated from residential areas. Next to these, the commercial areas (22.11%) were other large sources of solid waste, and institutional areas (8.82%) were the least quantity of the solid waste. Moreover, this finding was supported by the UN (2003) and a huge amount of municipal solid waste is produced at the rate of urbanization (Hoornweg & Bhada-Tata, 2012).

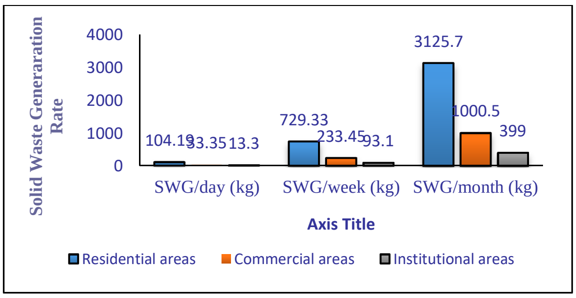

Fig. 2. Generation rate of municipal solid waste by day, week and month.

Generation rate of households depend on income level

According to the town finance and socio-economic point of view, households were categorized into the higher, middle, and lower-income groups in the study area (fig.-3). The daily solid waste generation rate of Hadero town for low, middle, and high-income households was 0.09, 0.14 and 0.16 kilograms per capita per day respectively. This indicated that the waste generation rate of higher-income household was 0.07 kilograms per capita per day greater than lower-income households. Consistence with the findings of Ngoc and Schnitzer (2009), solid waste generation in Hadero town has a direct relationship with income level. This may be a result of some households earning more and having better living standards. The average per capita per day household generation rate of Hadero town was 0.13 kilograms per capita per day. The finding of average per capita per day household generation rate of Hadero town was lower, when compared with other Ethiopian towns like Mekelle 0.277 kilograms per day, Adama 0.265 kilograms per day, Debramarkos 0.227 kilograms per day, and Bahirdar 0.22 kilograms per day (Gebrie, 2009).

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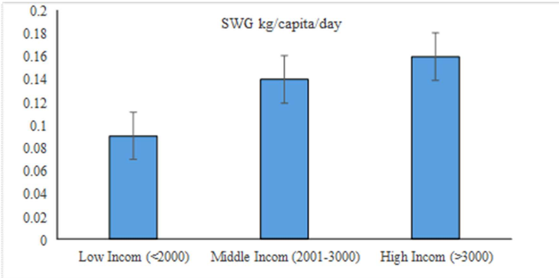

Fig. 3. Generation rate of municipal solid waste by income level.

Physical Composition of Municipal Solid Waste

In the study area, the major component of the biodegradable residential waste was food waste (53.99%). This indicated that municipal waste was an aggregate of all substances disposed of in the study area. Similarly, World Bank (2012) reported that low and middle-income countries have a high percentage of organic waste in the urban waste stream, ranging between 40 to 85% of the total solid waste. Moreover, the food waste in Hadero town was much higher than that reported in Debreberhan 33.0% (Tyagi *et al.*, 2014). Cointreau & Coad (2000) stated that waste from urban areas in developing countries have a much higher percentage of food waste reported by Perez *et al.* (2008). These were lower than Hadero town. Whereas, the lowest residential biodegradable waste were paper and cardboard waste (11.64%). However, the highest (2.63%) and lowest (0.44%) residential non-biodegradable waste were plastics and E-waste respectively.

The physical composition analysis of biodegradable solid waste revealed that 28.49% of institutional waste were paper and cardboard and wood waste accounted for small fractions, i.e. 6.83%. The result indicated that fractions of paper and cardboard waste were higher in institutional solid waste followed by commercial waste (18.23%). Plastic waste were also higher in commercial waste (15.02%) followed by institutional solid waste (8.35%). The percentage of plastic waste in the study area (8.67%) was higher than the 4.8% in Hosaina (Endalu & Habtom, 2014).

The biodegradable solid waste were the main component of the municipal solid waste quantity which accounted for 76.98% of the total waste generated in the town. However, non-biodegradable solid waste accounted for only 23.02% of waste.

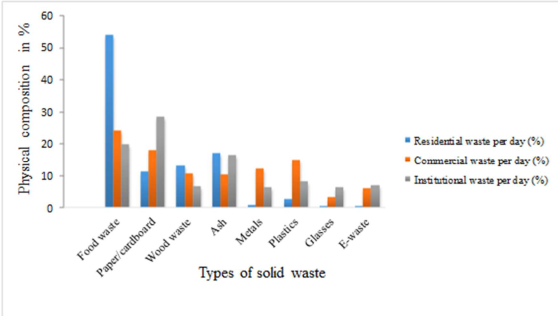

Fig. 4. Physical composition of solid waste from different sources.

Physico-chemical analysis of municipal solid waste

The selected physico-chemical parameters were analysed in the municipal solid waste sample at the study area. The pH value was found to be 5.82 pH is one of the factors for indicating of acidic or alkaline nature of the waste samples.

In comparison with recommended standards (6.9-8.3), solid waste samples of pH value were found to be lower than the recommended range in the study area. The electrical conductivity of waste samples was 2.42ds/m., the electrical conductivity was found to be medium in the normal range (2-6ds/m) in the study area compared with recommended standard.

The nitrogen content of all the waste samples was 1.35%. Which were found higher in the solid waste compared with recommended standards (0.05%) (Bordna Mona, 2003). The increase of nitrogen content in the household solid waste may be due to the strong degradation of organic carbon compounds which reduces the weight of composting materials (Bermal *et al.,* 1998). In relation to this solid waste showed the presence of vegetables, leaves, food waste, etc. which is the main source of nitrogen content in the solid waste. The organic carbon of the solid waste sample was 6.34% which might be contributed by different carbon-containing materials.

Table 1. Physico-chemical parameters of municipal solid waste.

No	Parameter	Unit	Value
1	pH	-	5.82
2	EC	ds/m	2.42
3	Nitrogen (N)	%	1.35
4	Phosphorus (P)	%	0.223
5	Potassium (K)	%	0.923
6	Organic carbons	%	6.34
7	Bulk density	kg/m3	277.34
8	Moisture content	%	47.08

The phosphorous content of the sample waste was 0.223%, phosphorous is also an important nutrient for plant growth. In comparison with recommended standards (0.4-1.1%), it was medium and the potassium concentration of the sample waste was 0.923%, the recommended values for potassium in the range between 0.6 - 1.7% (Bordna Mona, 2003). Potassium is one of the nutrient elements and it can soluble in the waste and leaches out easily. Potassium is not known to have harmful or toxic effects on human beings and it helps in plant growth as an essential nutritional element. These values indicated that the organic content from town waste may stand as a potential source for plant growth and development through composting process (Sharholy *et al.*, 2007).

The moisture content of food waste and yard waste were found to be 55.93% and 38.22% respectively. The average moisture content of the waste was 47.08%. The moisture content of food waste was high because of the high proportion of green vegetables found in food waste. These large amounts of moisture in the organic waste were mainly contributed by food waste. In line with this, in a similar study conducted by Sharma & Gupta (2006), large amounts of moisture in the waste are mainly contributed by cooked waste material from hotels, restaurants, and kitchen waste. The results were somewhat similar to those reported by Sivapalan *et al.* (2002), from the study of Kuala Lumpur city waste. In order to increase the composting potential of raw waste, components that have lower moisture content like plastic, and other non-degradable materials should be removed for recycling and other activity. The water content is the most important factor in the degradation of organic waste. If the moisture content goes below 25% it will directly affect the rate of composition.

The bulk density of the solid waste of Hadero town was calculated and revealed that, be 277.34kg/m3. The bulk density was also directly related to the nature of waste materials. For instance, if the waste contains a high proposition of food waste increases the bulk density. Comparing this value with world bank (2012) studies for lower-income countries (250kg/m3-500kg/m3), middle (170kg/m3-330kg/m3) and high income countries (120kg/m3-200kg/m3) respectively. In this study, the value of bulk density falls within the range of bulk density in low-income countries (250kg/m3-500kg/m3).

Heavy metals concentrations of municipal solid waste

The selected heavy metal such as Fe, Mn, Cu, Zn, Ni, Co, Cr, Pb, and Cd was identified from solid waste and the results were indicated in table.3. The results revealed that the highest proportion of heavy metals such as Fe (1812.7mg/kg) followed by Mn (1072.7mg/kg) and Zn (448.92mg/kg) was recorded in the study area. The least heavy metal in municipal solid waste is Cd (2.92mg/kg).

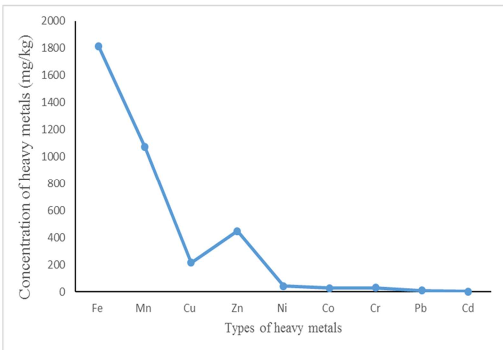

Fig. 5. Heavy metals concentrations in municipal solid waste.

In the present study the concentrations of heavy metals such as Fe, Mn, Zn, and Cu in municipal solid waste at the study site (Table 3) were comparatively higher than the results reported by Alemayehu *et al.*, 2016. This might be due to the presence of higher propotion of metallic waste in the study site. The presence of Cd (4.91mg/kg) and Pb (12.22mg/kg) of municipal solid waste were relatively lower compared to other heavy metals. Similar findings were reported by Alemayehu *et al.* (2016) from Harari city waste dumping sites. In addition to this, variation in heavy metals concentration also depends on seasonal variations.

Conclusion

The study showed that the municipal solid waste generation rate was 0.09, 0.14 and 0.16kg/capita/day for low, middle and high income respectively in the study area. Similarly, the generation rate was determined for different sources such as residential area (69.07%), commercial area (22.11%) and institution (8.82%). The physical composition of household solid waste revealed the presence of food, yard waste, ash, dust, textile, old shoes, bones, paper, cardboard, plastic, glass, and metals waste. Among these waste, biodegradable waste was found to be large quantity (76.98%) in the study area. Regarding the Physico-chemical analysis, such moisture content pH values were within the standard limited ranges. Moreover, a sufficient quantity of organic carbon, nitrogen, phosphorus, and potassium content was identified in the municipal biodegradable solid waste. Finally, results showed the concentration of heavy metals in the solid waste samples was in the order of Fe>Mn>Zn>Cu>Ni>Co>Cr>Pb>Cd. Therefore, in the study area solid waste is suitable for composting and can be used as organic manure.

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