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Analysis of Generation Rate, Physicochemical and Physical Composition of Household Solid Waste in Jigjiga Town, Somali Regional State, Ethiopia

Amdiya Kedir, Abebe Aschalew, Rejila Manikandan*

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ABSTRACT

The disposal of solid waste in water bodies, dumping roadside aggravates the problems of low sanitation levels across the African countries including Ethiopia. This is mainly due to the lack of available information about the types and quantity of solid waste generation rates in most of the towns and cities in Africa. Therefore, the objective of this study was to determine the rate of household solid waste generation rate and its physical and physicochemical composition in Jigjiga town. In this study, a cross-sectional descriptive research design was used and the study was conducted on randomly selected 136 households selected from 3 *Kebeles* of the town Jijiga. Every day the solid waste from the selected household was collected and was separated into its components and the weight of each component was recorded on daily basis. This has been conducted for 7 consecutive days to have a better average per day household solid waste generation rate. The physical composition of the solid wastes was analyzed based on the standard methods. The mean value of moisture content, pH, electrical conductivity, organic carbon and total nitrogen% were 56.1%, 6.0, 2.43 ds/m, 11.3% and 1.3% respectively in the study area household solid waste. The findings of this study showed that the rate of the weekly, monthly and annual generation rate of solid waste were 281,962.kg (282 ton), 1208409.6kg (1,208 ton) and 14,702,316.8kg (14,702 ton) respectively. Based on the physical composition of solid wastes of a sample of household food waste comprised the highest percentage (35%) while metal comprised the least percentage (0.11%). As per the results, the house hold solid waste may be it is suitable for compositing process due to the presence of more biodegradable waste. The negligible amounts of glass and metals were noticed in the study area because they considered as recyclable materials.

Keywords Household soil waste, Generation rate, Physicochemical, Jigjiga.

INTRODUCTION

Many cities in Africa, dealing with the environmental costs of rapid growth and urbanization represents a phenomenal change, this is predominantly accurate in the field of solid waste management. However, solid waste generation is increasing in the urban areas but the efficiency of their solid waste collection and disposal systems is on the way out. In urban centers throughout the African region, less than half of the solid waste produced is collected and 95% of that amount is either indiscriminately thrown away at different dumping sites (Mohammed and Elsa 2003).

Urbanization with inadequate waste management practices, specifically, widespread disposal of waste

Amdiya Kedir, Abebe Aschalew, Rejila Manikandan*
College of Agriculture, School of Natural Resources Management and Environmental Science and Management, Haramaya University, Haramaya, Dire Dawa, Ethiopia
Email : rejularaja@gmail.com
*Corresponding author

in water bodies, dumping along the side of the roads and uncontrolled dumpsites aggravates the problem of generally low hygiene levels across underdeveloped countries like Ethiopia (UNESC 2009). Urbanization is one of the serious issues in underdeveloped countries like Ethiopia. Moreover, the poor waste management practices due to quick urbanization and leading to the excess population to the source of slums and informal settlements. A large quantity of solid waste and sewage was generated by urban households than rural households, this is mainly due to the consumption capacity (Tewodros 2009). Solid waste management is one of the basic services that are currently receiving wide attention in many towns of Ethiopia. This is mainly because solid waste that is generated in most towns of Ethiopia is not appropriately handled and managed (Afewerk 2015). Municipalities and other stakeholders in Ethiopia have overall responsibility for solid waste management (SWM) in their towns and cities. However, most of them are failed to fulfill their responsibilities especially, sound ways of dealing with waste generation, collection, transport, treatment and disposal (Mohammed 2015). Poor environmental quality of cities can deprive citizens of a good quality of life as it affects their health and consequently, affect productivity and economic development adversely however large volume of waste is generated from households. For example, in Addis Ababa household waste constitutes 76% of total solid waste generated (Taddesse 2004).

Jigjiga is one of the highly expanding and rapidly growing towns in Ethiopia. It is very common to see piles of waste on the streets, riverbanks, besides individual houses, available open places and market areas. In this study area, it was observed that waste generators throw household solid wastes illegitimately; it is also noticed that flies, rodents, dogs, goats and sheep were accountable for scattering the wastes. In addition to this 'Chat' (*Catha edulis*), chewing is widely practiced in the town, which produces a large amount of solid waste which emanates from the household. The dispersal of household solid wastes like plastics, papers is a visible problem around the resident's site of the town. This may be, unsafe solid waste practices in the town leads to serious problem upon the health of the residents and deteriorate the socio-economic life of the society in the town. It also decreases the aesthetic value of the Jijiga town.

MATERIALS AND METHODS

Description of the study area

Jigjiga is the capital city of Somali Regional State of Eastern Ethiopia, which is about 630 km East from Addis Ababa City and 105km from Harar city of East Hararge Zone of Oromia and Harari Region. The city is located between 9° 16' 30" to 9° 24' 30" N Latitude and 42°44' 0" to 42° 51' 0" E Longitude. Based on the recent census the city has a population of 125,876 of which 67,128 were males and 58,745 were female. The climate of the city is subtropical with a mean annual temperature of 19.50C and annual average rainfall ranging from150mm to1000mm. The highest temperature is experienced between November and March and the lowest between July and September.

Sampling techniques and sample size

The study was conducted in Somali Regional State, in Jigjiga town (Fig. 1). Jigijiga town has a total of twenty *kebeles* out of this 15 *kebeles* were located in urban areas and the remaining 5 *kebeles* in the rural areas. Out of twenty *kebeles* three *kebeles* were purposively selected hence *kebele* 05, *kebele* 06 and *kebele* 07 with their households number of 2470, 2330 and 3100 respectively.The study participant's household were randomly picked from sampling frame.In order to make representative samples, all three *kebeles* were considered in the study area. The total households of the three *kebeles* are 7900, sample sizes was selected by using a sample technique formula (Cochran 1977). Sample size (n) with the desired degree of precision for general population, was used. In this case population variable (P) is house unit's variable and is given as:

$$n = \frac{NZ2PQ}{d2\ (N-1) + Z2PQ}$$

n= Sample size of housing units
P= Housing unit variable (residential houses)
Q= Non-residential houses (offices, schools) = 1-P
N= Total number of housing units
Z= Standardized normal variable and its value that corresponds to 95 % confidence interval equals 1.96

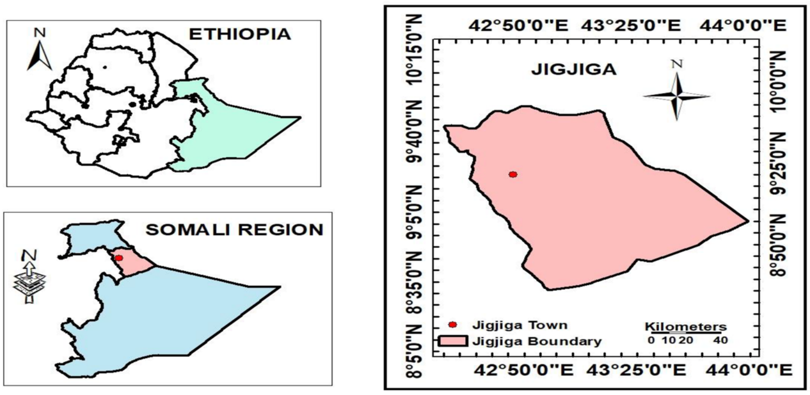

Figure 1. Map of Jigjiga town

d = Allowable error (0.05)

According to data obtained from Housing Development Section of the town (2007), there are about 6248 housing units (N): Out of these more than 90 % (P) are residential and the rest 10 % (Q) is for commercial activities and offices.

$$\text{Hencen} = \frac{7900\ (1.96)2 \times (0.9)(0.1)}{(0.05)2\ (7900\text{-}1) + (1.96)2\ (0.9)(0.1)} = 136$$

Therefore, n = 136 was the minimum sample size of households for reliable results. Finally representative sample households were drawn for data collection using simple random sampling method's in *kebele* 05 out of 2470 household 42 households samples were taken Similarly, from *Kebele* 06 from the total of 2330 households, 41 households samples was taken and finally from *kebele* 07 out of 3100 household 53 households were selected. The study participant's household was randomly picked from sampling frame using systematic random sampling method.

Physical characterization of solid waste

The sampled households (HHs) were thought to put solid waste (SW) separately in the different plastic bags given. The mixed SWs in some sampled HHs were opened onto the plastic sheet and separated into different types as food waste, paper/cardboard, plastics/rubber, glass/ceramics, metals and ash/dust. Each category was weighed by using movable hand balance and recorded in the datasheet by the researcher and research assistant before the house to house SW collectors come to take the SW physical composition calculation. The daily solid waste generation rate (DSWGR) of the town as well as per capita per day solid waste generation rate (PCPDSWGR) at household level were calculated according to equation (Fobil 2000).

$$\text{PCPDWGR} = \frac{(\text{Total solidwaste Genrtionrate withn 7 days})}{(7\ \text{day} \times \text{Total family size of 136 surveyhouse})}$$

Physicochemical analysis household solid waste

To determine the percentage of moisture content (MC) in the samples, 10 g of fresh substrate was dried in an oven at 105 °C for 24 hours and reweighed. The moisture content was then calculated as follows (APHA 2540 E 1999).

$$\%\text{MC} = \frac{(\text{W-D})}{\text{W} \times 100}$$

Where,

MC = moisture content

W = initial weight of sample in grams

D = weight of sample after drying at 105°C in grams

pH of households solid waste was determined by using pH meter with a glass electrode. 10 grams of the sample will be placed in a flask; to this 500 ml distilled water will be added and stirred for 3 to 5minutes.The mixture will be allowed to settle for 5 minutes and PH will be measured by using PH meter with a glass electrode (Philippe and Culot 2009). The electrical conductivity (EC) and pH of the mixed solid waste compost samples was measure in suspension ratio of 1:2 (decomposed compost to water) by used electrode method. The organic carbon (OC) was analyzed using the Black and Walkley methods, in which the mixed solid waste samples were oxidized at a temperature of about 120^0C with the mixture of potassium dichromate ($K_2 Cr_2 O_7$) and concentrated sulfuric acid H_2SO_4 (Walkley and Black 1934). Nitrogen (N) was determined by Kjeldahl method after digestion with concentrated (H_2SO_4) in the presence of selenium catalyst (Kjeldahl 1982).

The bulk density will be determined by putting the waste into the 20 liter capacity plastic bucket to measure the volume and weight for each category of solid waste sources. After measuring the weight and the volume the waste will be placed on plastic sheet. Bulk density will be calculated by the following formula (UNEP 2005).

$$\text{Bulk density in kg/m}^3 = \frac{\text{(Wet weight of sample)}}{\text{(volume of sample)}}$$

RESULTS AND DISCUSSION

Determination of household solid waste generation rate of the study area

Determination of solid waste generation rate were analyzed and the results were showed in Table 1. Based on the field measurement result the daily total solid waste generation rate of residential areas of the town was calculated. This indicated that, solid waste generation rate of the city per capita per day at household level was 0.32 kg/capital/day. Daily total solid waste generation rate of residential areas of the town was calculated as total population of the town (125,876) times per capital household solid waste generation rate. Based on the updated per capita household generation rate of 0.32 kg, daily total solid waste generation were 40,280.32 kg (40 ton). The weekly, monthly and annual generation rate of solid waste were 281,962 kg (282 ton), 1208409.6kg (1,208 ton) and 14,702,316.8kg (14,702 ton) respectively. The studies which were conducted in the same town by Yohannis and Genemo (2015) result showed that the average waste generation rate of the city was estimated 26.6 ton/day. The present finding (40 ton) was greater than that of the previous study due to increased population density, consumption pattern and economic development.

Table 1. Generation rate of household solid waste in the study area.

Time	Generation rate (kg)	Generation rate (ton)
Daily	40,280.32	40
Weekly	281,962.3	282
Monthly	1208409.6	1,208
Annually	14,702,316.8	14,702

Comparing the household solid waste (HHSW) generation rate of Jigjiga town (14,702 ton) with other town that have similar socio-economic condition, Hawasssa town 14,490.5 tons of HHSW being generated per year (Derege 2009). Likewise similar study was conducted in Adama town, generated 12,856 tons of HHSW per year (Lema 2007). The amounts and characteristics of HSW differ from country to country. These differences depend on socio-economic structure, income level, consumption and usage habits of people (Kale and Anathappan 2012).

The average solid waste generated in Jigjiga town was estimated 0.32 kg/capita/day. This generation rate is higher, when compared with findings of other major Ethiopian towns, such as Gambella town 0.229 kg/capita/day (Afewerk 2015), 0.231 kg/person/day in Hawassa town (Yeballework 2014) and 0.21 kg of Gondar (Mohammed 2015).The higher solid waste generation rate in Jigjiga town (0.32 kg/per/day) as compared to the other Ethiopian city may be due to the comparably higher income levels, high businesses activity and socio-economic, seasonal difference , physical conditions of the town.

Physical composition of household solid waste

The physical composition of household solid waste (HSW) was analyzed and the results were indicated in (Fig. 2). The major components of the household solid waste were food waste,with average weight of 45kg (35%).The present finding is inline with some previous studies. According to Tchobanoglous and

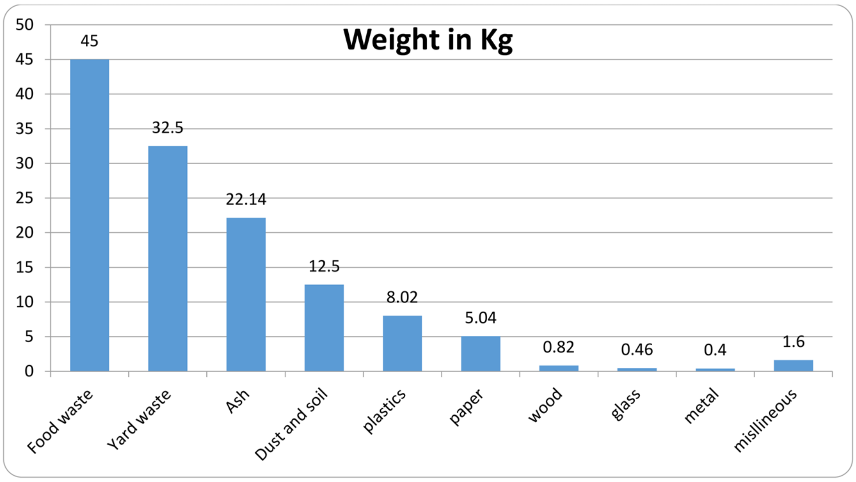

Figure 2. Physical composition of household solid waste in the study area.

Theisen Samuel (2009) large portion of solid wastes of developing countries is food waste. Similarly, wastes from urban areas in developing countries have a much higher percentage of food waste in their overall garbage mix (Cointreau 1982). Such a high proportion has been reported by studies conducted in many different cities of most of the developing and developed countries and in many different cities and town of Ethiopia (Tyagi *et al.* 2014).Yard waste ranked second place with 32.5 kg (25.2%) .This solid waste contain high quantity of chat (*Chata edulis*) waste.This results was compared with study conducted within the country, it indicated that,Addis Ababa,Arada sub city yard waste accounted for12.2% (Yitayal 2005).Whereas Adama town had yard waste 12.1% by weight (Lema 2007).

The preveous study was less than the present study may be due to life style of the people. However compositions of solid waste depends upon a number of factors such as food habits, cultural traditions, socio-economic status and climatic condition (Enayetullah *et al.* 2005). The result indicated that, ash waste rated third rank with 22.14 kg (17.2%). This may be due to the life style of the population who used fire wood and charcoal as source of energy. Inline with this, studies in Jimma town showed the ash accounted for 21.5% second among solid waste components (Melaku 2008). Moreover, the study conducted in Dire Dawa city showed dust and ash accounts for 38.1% (Zerihun 2018), 21%in Laga Tafo Laga Dadi town (Mesfin and Muktar 2017).

Dust and soil also ranked fourth 12.5 kg (9.7%) due to most houses are poorly constructed using mud and wattle or mud bricks for walls, rammed earth and cemented for floors. Plastic waste ranked fifth with 8.1 kg (6.3%) by weight. The plastic wastes, mainly of thin polythene type, locally called and plastic bottles (mainly of packed-water). Due to its non-decomposability and easy mobility due to wind, plastic wastes were found everywhere.The proportion of plastic reported in present study (6.3% by weight) was higher than the 4.8% of Hossana (Endalu and Habtom 2014) and the 2.9% of Adama (Lema 2007). Paper found six position with 5.1 kg (4.1%). The solid wastes from low and middle-income countries contain less paper and non-food items. However, glass (0.4%), metals (0.1%) and wood (0.6 %) were low in terms of percentage. Among this soild waste compoistion metal waste was avery small percentage. This is because metals are reused at household level and sold to other informal recycling sources. Glass and metals appear in negligible amounts because they are not discarded for disposal but are sold to recyclable material buyers (Nicolas 2011). Finally mislineous solid waste contain baby diaper and other hazardous waste which is in account for 1.25%.

hysico-chemical composition of household solid waste

Physico-chemical composition of household solid waste were analyzed in the study area and the results were indicated in (Table 2). The results indicated that, the mean value of moisture content of food and yard waste 60% and 52.1% respectively. The moisture content of the food waste is high due high proportion of green vegetables in the food waste. This may be advantages for aerobic composting process. In line with this, Tchobanoglous and Theisen Samuel (2009) moisture content range between 50 and 60% is suitable for composting process. Compost with low moisture content (<35%) may be too dry and dusty and irritating when handled. Compost with too high moisture content (>65%) can become too clumpy and difficult to transport, which will limit its chances of being advertised. According to Christian *et al.* (1997) the acceptable moisture content throughout the composting process is 45-65%, with optimum range of 50-60%. If the moisture level drops below about 40 to 45%, the nutrients are no longer in an aqueous medium and are not easily available to the micro-organisms. Under the circumstances, the microbial activity decreases and the composting process slow down. Below 20% moisture, very little microbial activity occurs. The pH value for composite samples were analyzed, the mean value of food waste and yard waste are 6.8 and 5.7 respectively. This indicates that the pH values of composite sample are within the standard limits of compost 5.5-8.5 as reported by Rawat *et al.* (2013).

The mean values of electrical conductivity for food and yard waste were 2.72 and 2.14. This value is within the recommended range (1.5 to 3ds/m) for composting (US composting Council 2003). In addition to this, high salinity levels (when suspended solids Concentrations are greater than 10-15) can be toxic to plants (Bizatu and Negga 2010).

Moreover, the mean organic matter of food and yard waste were 24.1 and 15 respectively, this result shows that food waste high amount of organic matter as compared to yard waste. According to US Composting Council (2003).organic matter under the EPA waste-licensing system of USA compost should contain at least 30% organic matter on a dry weight basis while the European countries quality set standards on compost containing greater than 20% OM on dry weight basis. However the result shows only food waste fulfill the recommended amount for preparation of compost.

Table 2. Physico-chemical composition of household solid waste in the study area.

Type	Moister content %	PH	Electrical conductivity ds/m	Organic carbon %	Total nitrogen content
Food waste	60	6.8	2.72	14.0	1.08
Yard waste	52.1	5.2	2.14	8.6	1.51
Mean	56.1	6.0	2.43	11.3	1.3

The mean nitrogen values of food and yard waste were 1.08 and 1.51 respectively. Solid waste compost contains large amounts of organic matter and nitrogen content in both organic and inorganic forms. The inorganic nitrogen pool of municipal solid waste (MSW) compost represents a small fraction of the bio available nitrogen, while most of the nitrogen is tied up in the organic fraction. In line with this our findings were corroborate with Abiyot (2014) reported that the average municipal solid waste compost may contain 0.7 to 1.8 % nitrogen on a dry weight basis. Finally, the average value of the bulk density of the town was determined to be 370 kgm-3. Similar study was done 342.36 kg/m3 reported from Hawassa town by (Derege 2009) and also this value falls within the range for low- medium income countries generally(250-500 kg m-^{3}) (Contrieau 1982).

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