Physico-chemical, heavy metal analysis and physical composition of household solid waste, Shone Town, Ethiopia

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Abstract. *Balilo G, Aschalew A, Manikandan R, Feyisa A. 2023. Physico-chemical, heavy metal analysis and physical composition of household solid waste, Shone Town, Ethiopia. Nusantara Bioscience 15: 32-37.* In Ethiopia, Shone is one of the country's fast-developing towns; inadequate solid waste management was observed. Therefore, the objective of the study was to determine the generation rate and selected physico-chemical characterization and heavy metal analysis of household solid waste. The study was conducted on randomly selected 120 households from two Kebele of the town. The physico-chemical analysis results revealed that moisture content, pH, electrical conductivity (dS/cm), nitrogen, organic carbon, (%), phosphorus and potassium content of household solid waste were 54.6, 8.25, 2.52 (dS/cm), 2.47, 10.25, 0.54, and 0.82%, respectively. In addition, in the decomposed household solid waste samples, heavy metals such as iron, manganese, copper, zinc, nickel, cobalt, chromium, lead, and cadmium were analyzed using atomic absorption spectrophotometer. Results showed the concentration of these heavy metals in the decomposed solid waste samples was in the order of iron>manganese>zinc>copper>nickel>chromium>cobalt>lead>cadmium. Daily solid waste from those households was separated into its components, and each component was measured. That was conducted for 7 consecutive days to quantify and characterize household solid waste. The result revealed that the household solid waste generation rate in the study area was 0.206 kilogram/capita/day. The physical composition of the solid waste in Shone Town is mainly organic, constituting 92.8%. The organic waste of the town has a high content of biodegradable waste such as food waste (49.56%), ash and dust (29.74%), yard waste (4.95%), textile (4.006%), old shoes and bone (2.5%), paper and cardboard (2.04%) and recyclable material such as plastic (3.28%), glass and metal (3.88%) all account for 92.8% (biodegradable) and 7.17% (non-biodegradable), respectively.

Keywords: Generation rate, heavy metals, household, physico-chemical, Shone, solid waste

INTRODUCTION

Household solid waste management is one of the critical concerns facing developing countries because of the social, economic, and environmental implications once not properly managed. Household solid waste, normally termed garbage or trash, is an inevitable byproduct of human activity. Municipal solid waste is usually generated from human settlements, small industries, and commercial activities. Solid waste disposals (open dumps, landfills, sanitary landfills, or incinerators) represent a significant source of metals released into the environment. Household solid waste management is one of the critical concerns facing developing countries because of the social, economic, and environmental implications once not properly managed. Studies showed that household solid waste, directly and indirectly, affects the environment and human welfare. Improper household solid waste management causes serious health effects in daily life. Poor waste management, inadequate collection, and improper disposal of the waste facility could lead to various diseases, infections, and infestation. These include Malaria, Typhoid, Diarrhea, Cholera, Helminthiasis, and Dysentery (Yasmin and Rahman 2017; Ochieng et al. 2019). Moreover, 30-50% of the waste generated in developing countries is collected and managed properly. Still, the remaining is either burned or left to decompose in open space or dumped in unregulated landfills (Abebe et al. 2021).

Solid waste is a global environmental problem in today's world in both developed and developing countries due to rapid population growth, economic activities, and the rise of community demand, accelerated solid waste generation in the world. Activities in society generate large quantities of waste, posing a problem for their disposal. Therefore, improper disposal leads to unhygienic conditions besides spoiling the aesthetics (Gezahegn et al. 2018). Solid waste management practices differ between developed and developing countries, urban and rural areas, and residential and industrial producers. Solid waste management in most African countries has two problems: a lack of accurate data on waste generation and characterization and a lack of information about waste collection, processing, and disposal. The changing economic trends and rapid urbanization complicate solid waste management in developing countries.

Consequently, solid waste is increasing in quantity and changing in composition from less organic to more paper, packing waste, and plastics, glass, and metal waste, among other types, a fact leading to rates. But most household solid waste compositions generated in most parts of Africa are biodegradable organic wastes (Gezahegn et al. 2018). Therefore, solid waste management is a major public health and environmental concern in cities of many African

countries. The expansion of the urban population is one of the reasons many African countries continuously increase the amount of solid waste. However, because of the development of cities and the increase in the population, the country is doing the opposite boost in waste disposal (Emmanuel and Jiquan 2019).

Typically, components of most household solid waste are food waste, paper, cardboard, plastics, textiles, leather, yard waste, wood, glass, tin cans, aluminum, other metal, ashes, street leaves, special waste (including bulky items, consumer electronics, white goods, yard waste collected separately, batteries, oil, and tires), and household hazardous wastes (Tesfahun et al. 2022). The percentage of household components varies with location, season, economic condition, and many other factors. The composition of Solid Wastes plays a major role in determining the compaction, decomposition, and incineration process. Furthermore, the waste generated in low and middle-income countries has high moisture content and density (Syeda 2014).

Shone Town Administration is characterized by rapid population growth and urbanization. This rapid increase in population, coupled with the town development, has produced an increasing solid waste generation rate. The household solid waste generated in the study area is dumped in open areas. Roadsides and gully communities are unaware of recycling, reducing, and using the massive amount of waste generated in the town. As a result, household solid waste management in Shone Town Administration has not been carried out sufficiently and well. As a result, the aesthetic and sanitary conditions of the town have become more serious from time to time, and people are suffering health problems in such conditions. In addition, the generation rate, composition, and characteristics of household solid waste in the Shone Town Administration are unknown. Therefore, this study was designed to determine the generation rate and selected Physico-chemical characteristics of household solid waste in Shone Town Administration, Hadiya Zone, Southern Ethiopia.

MATERIALS AND METHODS

Description of the study area

The Shone Town is the administrative center of Shone Town Administration (Figure 1). It is located at a distance of 338 km from Addis Ababa, 121 km from Hawasa Town, and 98 km from Hosanna Town. Shone is a town located in the southern part of Ethiopia at 37° 56'30" to 37° 58'0" East and 7° 7'0" to 7° 10'0" North. According to the total population of Shone, the town administration was 47,420. Among them, 23,236 are male, and 24,184 are female. The district's mean annual maximum and minimum temperatures are 28°C and 8°C, respectively, with an altitude range between 1,000 to 2,300 masl and annual rainfall estimated at 531.1 mm to 1261 mm (STAMRMAO 2020).

Sample size determination and sampling technique

Shone Town Administration has seven administrative *kebele*. For this study, the two *kebele* named Arancha and Licha were selected purposively based on the households' settlement and the number. A total of 120 households were selected from two *kebele* (Arancha 50 and Licha 70 household) by using the following formula (Cochran 1977).
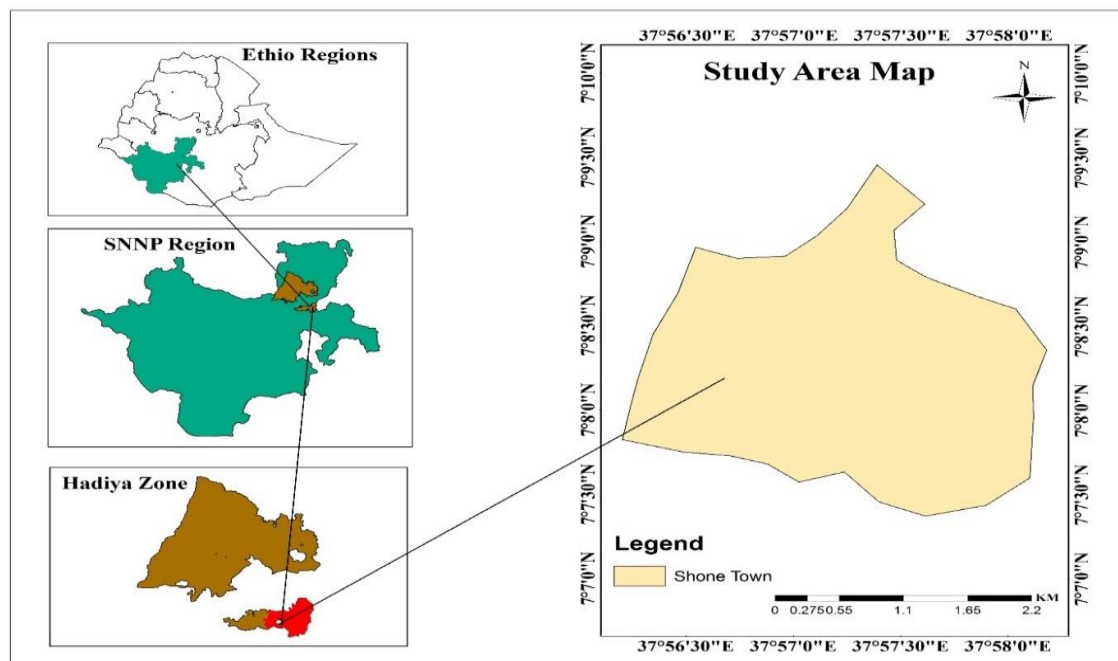
Figure 1. Map of the study area in Shone Town, Ethiopia

$$n = \frac{NZ^2PQ}{d^2(N-1)+Z^2(PQ)}$$

Where: n = total sample size, N = Total number of households housing units of the selected kebele, Z = standard normal deviation at the required confidence level that corresponds to a 95% confidence interval equal to 1.96, d = the level of statistical significance (0.05), P = housing unit variable (the proportion in the targeted population estimated to have characteristics being measured), i.e91% p=0.91, Q = 1-p i.e., 1-0.91= 0.09. According to data from Shone Town Administration Municipality Office (STAMO), the socio-economic profile is about 2,486 housing units N in the two selected kebele, Arancha, and Licha, in the Shone Town.

$$\text{Hence } n= \frac{NZ^2PQ}{d^2(N-1)+Z^2(PQ)}$$
$$n = \frac{2486(1.96)^2 \times 0.91 \times 0.09}{(0.05)^2(2486-1)+(1.96)^2(0.91 \times 0.09)} \quad n = 120$$

Sample collection

Determination of the generation rate and composition of solid waste generated from selected 120 households should be done carefully. Accordingly, the collection and sorting of wastes from the areas of the household were conducted for 8 consecutive days. The first-day training was given to the enumerators, who distributed the plastic bags for each selected household one day before collection. Two plastic bags labeled with their house number was given as one for dry (red plastic) and another for wet waste (black plastic) for the selected household. Another bag with the same label was given for the next day's collection, and these processes were continued for one week. Every morning, the solid wastes were collected from selected households using donkey carts, and after that, the solid waste was transported to a temporary sorting site. Sorting was the next step after collecting waste in the long process of determining the generation rate and composition of waste from household solid waste. Finally, sorted wastes from households were measured, and the value of each sample was recorded.

Determination of household solid waste generation rate

The household solid waste generation rate was determined by Fobil et al. (2008). Accordingly, the Per Capita Per Day Solid Waste Generation Rate (PCPDSWGR) was calculated using the following formula.

$$PCPDSWGR = \frac{\text{Total Solid Waste Generation within 7 Days}}{7 \text{ Days} \times (\text{Total family size of 120 households})}$$

Based on the above equation, the daily, weekly, monthly, and annual generation rate of household solid waste was calculated for the town as the town's total population (47,420) times per capita per day of household solid waste generation rate.

Sample preparation for physico-chemical analysis

From selected *kebeles*, two samples of household solid waste were collected in two days, and subsequently, for one week, four samples from two *kebele*. After that, the collected samples were mixed to get a composite. The composite household solid waste was well mixed (homogenized) by minimizing the size of each sample component, chopped and grounded material like a knife, mortar, and pestle into powder forms. A sample of 500 gm was obtained for Physico-chemical analysis.

Physico-chemical analysis

The determination of moisture content, a sample from which were selected components of the solid waste immediately after measuring the weight, was taken to Laboratory for 5 consecutive days. Fifty (50) grams of fresh compost samples of food and yard waste were weighed before being dried at 105°C and weighed moisture. Then, the samples were put into an oven for 24 h at 105°C. Afterward, the sample was removed from the oven, cooled in a desiccator for 30 minutes, and weighed. The percentage of moisture was calculated as follows (Hogarh 2012).

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

Where,
MC = moisture content
W = initial weight of sample in grams,
 D = weight of the sample after drying at 105°C in grams

The pH value of the sample was determined by a pH meter with a glass electrode. Next, 10 grams of the sample was placed in a flask; 500 ml of distilled water was added and stirred for 3 to 5 minutes. The mixtures were allowed to settle for 5 minutes, and pH was measured using a pH meter with a glass electrode (Philippe and Culot 2009). Finally, the Electrical conductivity of a 1:1 aqueous extract was measured, and the reading was corrected to conductivity at 25°C sample saturation with the chemical method (Rhoades 1996).

Total nitrogen content was analyzed using the Kjeldahl digestion described by Hogarh (2012). The total organic carbon content in the samples was measured by Walkley and Black (1934). Total phosphorus analysis in compost samples requires a conversion of insoluble phosphates to soluble forms by digestion with a mixture of nitric acid and sulphuric acid. Phosphorus was measured using a spectrophotometer. Total potassium analysis in compost samples requires a conversion of insoluble potassium to soluble forms by digestion with a mixture of nitric acid and sulphuric acid. The potassium content in the solution was estimated with a flame photometer (Hogarh 2012).

Analysis of heavy metals from household biodegradable solid waste

The solid waste composite samples were digested with concentrated nitric (HNO_3) and perchloric ($HClO_4$) acids. First, 3 mL of concentrated HNO_3 were added to 0.5-1.0 g samples. Next, the acid sample mixture was heated to about 145°C for 1 hour. After 1 hour of heating, 4 mL concentrated $HClO_4$ was added, and the mixture was heated to 240°C for a further 1 hour. After complete digestion of all samples, the digests were allowed to cool to room

temperature. The content of the digests was filtered through Whatman No. 42 filter paper and diluted to 50 mL volume with deionized water. The diluted digests were taken for subsequent analysis of heavy metals, as described by Saudi et al. (2021). The selected heavy metal concentrations (Fe, Mn, Cu, Zn, Cd, Ni, Pb, Co, and Cr) were measured by Atomic Absorption Spectrophotometer model number 210VGP. The level of each heavy metal was measured at a specific wavelength; Chromium (357.9nm), Lead (217nm), Zinc (324.8nm), Iron (248.3nm), and Cadmium (228.8nm).

RESULTS AND DISCUSSION

Physical compositions and household solid waste generation rate

This study showed that (Table 1) almost half (49%) of total solid waste generated by households of Shone Town was food waste compared to other waste categories. The fraction of food waste obtained in this study is in the same order of magnitude as those obtained in previous studies for cities in other parts of Africa. For example, in developing and even most developed countries, food waste represented a large fraction of household solid waste in Nsukka town, and almost half (47%) of total solid waste generated by households was food waste in Nigeria (Endrias and Solomon 2017). The quantity of food waste in household solid waste is commonly taken as a hint of living standards, but it also represents the lifestyle pattern. In line with this, the study conducted in Fonko Town of Analemo District, Southern Ethiopia, also revealed that the composition of food waste takes a larger quantity than other households' solid waste composition (Abebe et al. 2021).

In this study, ash and dust waste was 29.74%, possibly due to the main energy source being firewood in the study area. Moreover, this study cooperates with the study conducted in Sawulatown in Ethiopia revealed the cooking energy source for most of the households were wood, charcoal, cow dung, and yard trimmings (Haile et al. 2019). In addition, yard waste is 4.95%, textile is 4.006%, old shoes and bones 2.5%, and paper and cardboard 2.04%.

Generally, the present study also revealed a large quantity (92.8%) of biodegradable household solid waste in Shone Town. That was comparable with other studies conducted in Ethiopia, especially the physical composition of the household solid waste in Sodo town was 93.7% (Max and Timothy 2014). In line with this, Meseret et al. (2019) reported that the large quantity of organic content (compostable organic matter) in the solid waste indicates the necessity of recycling the organic waste into valuable resources like compost (organic fertilizer).

In the study area, non-biodegradable solid waste was identified, such as plastic at 3.28%, and glass and metal accounting for 3.88%. The non-biodegradable solid waste found in the study areas compared to biodegradable solid waste is very small, i.e., plastic, glass, and metals constitute 7.17% of the total solid waste generated from households. A study conducted in Jigjiga Town Ethiopia revealed that glass and metal appear negligible because they are not discarded for disposal but are sold to recyclable material buyers (Amdiya et al. 2022).

Physico-chemical properties of household solid waste

The moisture content in the study area was 54.6% (Table 2). The moisture content in the study area was high compared to other findings due to the large portion of household solid waste being organic, and the season was not too cool and not too dry it was medium. That is in line with this study conducted in Fonko Town of Analemo District, Ethiopia, which accounts for moisture content at 46.44% (Abebe et al. 2021). The variation in the amount of moisture content depended on the source, composition, and season fluctuation.

The pH value of this study was 8.25 for composite samples, which were collected from household solid wastes, indicating that the composite sample's pH values were slightly alkaline. However, it showed within the standard limits of 5.5-8.5 and is suitable for composting. In addition, Hiranmai and Anteneh (2016) observed that pH tended to a neutral value towards the end of the composting process, indicating that the matured compost will have neutral pH. The above finding revealed that the pH of a household's solid waste at the beginning step might be acidic or basic until it reaches the neutral pH at the end of matured compost, which means that when pH is acidic, composting is very slow because microorganisms are destroyed. Therefore, the pH of this study was 8.25, and the basic then rate of decomposition is fast at the beginning step of the process to reach the neutral value to form compost.

Table 1. The physical composition of household solid waste in Shone Town Administration, Ethiopia

Categories of solid waste	Types of solid waste	Weight in kg/week	Kg/capita/day	%
Biodegradable	Food waste	501.942	0.102	49.56
	Ash and Dust	301.1652	0.0612	29.74
	Yard waste	50.16	0.0144	4.95
	Textile	40.575	0.00824	4.006
	Old shoes and bones	25.58	0.0052	2.5
	Paper and cardboard	20.7	0.004	2.04
Non-biodegradable	Plastic	33.24	0.00675	3.28
	Glass and metals	39.368	0.008	3.88

Table 2. Physico-chemical characteristics of organic solid waste from households in Shone Town, Ethiopia

Parameters	Units	Values	Recommend standards
Moisture contents	%	54.6	45-65
pH	-	8.25	6.9-8.3
EC	dS/m	2.52	2-6
Nitrogen	%	2.47	0.5 to 2.5
Organic carbon	%	10.25	<30
Phosphorus	%	0.54	0.4-1.1
Potassium	%	0.82	0.6-1.7

Table 3. Heavy metals concentrations in decomposed household solid waste

Types of heavy metals	Concentration (mg/kg)
Fe	912.7
Mn	172.6
Cu	34.42
Zn	68.92
Ni	6.5
Cu	0.75
Cr	7.74
Pb	2.22
Cd	0.4

In the present study, the electrical conductivity (EC) value was 2.52 dS/m, which determines the amount of salt in solid waste. The EC values also found in solid waste were within the recommended range. Moreover, Saudi et al. (2021) reported that EC is an important parameter in determining the quality of solid waste concerning the composting process. The results of this study revealed that the organic carbon of dry solid waste is 10.25%. The carbon-rich waste, such as dried leaves, tree bark, cardboard, etc., whereas the fruits and vegetable waste contains a high percentage of nitrogen such as banana, cabbage, carrot, potato, etc. (Cristina and Ana 2020). Similarly, the Nitrogen content of the organic matter in the study area was 2.47% which shows that food waste contains the vegetable and fruit (cabbage, potatoes, tomato, banana, mango, etc.), which was the main source of nitrogen (green waste)

The phosphorus value for biodegradable composite samples of household solid waste in the study area was 0.54%. This finding was comparable to the other study of the phosphorus contents of the compost in Ethiopia in Fonko Town of Analemo District, Ethiopia (Abebe et al. 2021). The value of the total potassium for composite biodegradable household solid waste in the study area was 0.82%. This finding was supported by a study conducted on chat waste in Aweday, that the average value of potassium (0.68-0.12%) and the result for the organic waste composite sample lie reasonably within the acceptable range for use in the preparation of compost.

Finally, the results of these studies revealed that the physico-chemical composition of selected biodegradable solid waste from household solid waste in the Shone Town Administration was suitable for composting. Due to the high percentage of biodegradable organic matter in the study area, composting the solid waste and using the compost as an organic fertilizer would be the best option for sustainable household solid waste management. That could be a good source of organic manure or fertilizer for farmers to reduce inorganic (chemical fertilizers) use. Composting system is technically simple, economically viable easily adaptable to anywhere at the farmers' level for composting locally available feedstock (Hiranmai and Anteneh 2016).

Heavy metals concentrations in decomposed household solid waste

The selected heavy metal, such as Fe, Mn, Cu, Zn, Ni, Co, Cr, Pb, and Cd, was identified from solid waste. The results indicated in Table 3 revealed that the highest proportion of heavy metals such as Fe (912.7 mg/kg) followed by Mn (172.7 mg/kg) and Zn (68.92mg/kg) was recorded in the study area (Table 3). On the other hand, the least heavy metal in solid waste is Cd (0.4 mg/kg).

The concentrations of heavy metals such as Fe, Mn, Zn, and Cu in decomposed solid waste (Table 3) were relatively higher than the results reported by Alemayehu et al. (2016), which might be due to more metallic waste in the study area. On the other hand, the presence of Cd (0.4 mg/kg) and Pb (2.22 mg/kg) in decomposed wastes was relatively lower than in other heavy metals. Similar findings were reported by Alemayehu et al. (2016) for Harari city waste dumping sites. In addition, heavy metal concentration variation also depends on summer and monsoon seasons. In line with this, Saudi et al. (2021) reported that a high concentration of heavy metals was observed during the summer season in their study. However, the concentrations of heavy metals such as Cu, Zn, Ni, Cr, Pb, and cadmium in decomposed solid waste did not exceed the limits compared with Indian and USEPA standards (Anjanapriya and Lalitha 2016).

Saudi et al. (2021) pointed out that Pb, Cd, Cu, and Ni are potentially toxic to plants and animals and have been shown to accumulate in the food chain. Zinc (Zn) is a necessary micronutrient for plants, but at a high level is phytotoxic and might reduce the fertility of the land. Therefore, continuous dumping of wastes can disturb natural soil's physical, chemical, and biological characteristics, pollute groundwater and causes a hazardous impact on human health. In addition, the food crops grown on soils contaminated with heavy metals absorb the metal ions depending on their metal uptake and storage capabilities.

In conclusion, the household solid waste generation rate of Shone Town Administration was 0.206 kg/capita/day, and based on the per capita/per/day solid waste generation rate, the daily, weekly, monthly, and yearly generation rate of Shone Town Administration was 9,768.52, 68,379.64, 293,055.6 and 3,565,509.8 Kg respectively. The physical

composition of household solid waste reveals the presence of food, yard waste, ash, dust, textile, old shoes, bones, paper, cardboard, plastic, glass, and metal waste. Among these wastes, biodegradable waste was found to be in a large quantity in the study area. Regarding the physico-chemical analysis, such moisture content pH values were within the standard limited range. Moreover, the household biodegradable solid waste identified a sufficient quantity of organic carbon, nitrogen, phosphorus, and potassium contents. Finally, results showed the concentration of heavy metals in the decomposed solid waste samples was in the order of Fe>Mn>Zn>Cu>Ni>Cr>Co>Pb>Cd. Therefore, in the study area households, solid waste is suitable for composting and can be used as organic manure.

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