

Composition, Generation and Management Method of Municipal Solid Waste in the case of Addis Ababa city, Central Ethiopia: A review

Abstract

Municipal Solid Waste management is one of the most fundamental issues in the contemporary urban environments particularly in developing countries like Ethiopia. Huge generation of waste coupled with unbalanced waste management services is the major challenges facing the City of Addis Ababa. A continuous increasing of production of more wastes and change in composition of waste into complex, the waste management practice is challenged by low prioritization of waste management, limited revenues for financing waste management with the ever increasing population of this city. This paper reviewed composition, generation and current waste management system in the case of Addis Ababa. The mechanism of Addis Ababa city Sanitation, Beautification and Park Development Authority to coordinate stakeholders has played a vital role in waste management. However, the daily monitoring of waste management by the community development section has not been sufficient because of poor governance where accountability, participation and transparency are lacking. It is also unauthorized solid waste dumping practice problem in different locations and has an effect on water sources and its resources. Effective involvement of both private and public sectors should improve waste management and provide door-to-door collection, street sweeping and facilitate drainage disposable canals. Therefore, an integrated solid waste management practice should be implemented for the City and also for the surrounding environment. As a result, strong political will, multi-sectorial approach, public awareness and participation, strategic planning, adequate funding and the adoption of Integrated Solid Waste Management is recommended SWM system required in Addis Ababa city.

Keywords: urbanization, waste management, municipality, open landfill, collection

1. Introduction

Solid waste management (SWM) is one of the development environmental challenges facing city authorities in the world and that is a major concern to every nation of the world (Craig *et al.*, 2002; Hoornweg & Bhada-Tata, 2012; Miezah *et al.*, 2015). Waste management issues are coming to the forefront of the global environmental agenda at an increasing frequency and it is an issue mostly witnessed in urban areas (Al-Khatib *et al.*, 2010; Javaheri *et al.*, 2006; Zerbock, 2003). As a consequence of population expansion, urbanization, economic growth, intensive use of packaging goods, informal

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32 settlement, urban agriculture, improvement of living standard and food habit has been taking place during
33 the 20th century virtually transformed world in to communities of cities facing resulted in the substantial
34 increase in the amount of solid waste being generated and variation in solid waste composition (Ezeah &
35 Roberts, 2012; Zarate *et al.*, 2008), and which making SWM more challenging in urban areas continues
36 increasing (Hoornweg *et al.*, 2013; Shen *et al.*, 2011).

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37 The burden of increased waste generation poses on the municipality budget as a result of the high costs
38 associated to its management, lack of understanding over a diversity of factors that affect the different
39 stages of waste management and linkages necessary to enable the entire handling system functioning
40 (Desta *et al.*, 2014; MALENYA, 2015). Municipal solid waste management (MSWM) problems have
41 become more pronounced in recent years coupled with inadequate financial resources, has led to
42 indiscriminate dumping of solid waste into roadsides, open spaces, football fields, river banks, drainage
43 channels and even grave yards as dumping sites and causing flooding, environment pollution and public
44 health issues because as long as humans have been living in settled communities, solid waste generation
45 has been an unavoidable and critical issue (S. Abdulwahid, 2006; Marshall & Farahbakhsh, 2013; Perera,
46 2003; Vickers *et al.*, 2006). Due to lack of means the collecting of waste is not always done on a regular
47 basis and dumping on sites is still the most common way to dispose the wastes (Babybonela, 2013;
48 Schübeler *et al.*, 1996; Werner *et al.*, 2011).

Comment [D5]: Abdulwahid, S., 2006;

49 The production of worldwide solid waste is projected to increase with world's population growth and
50 urbanization (Kasa *et al.*, 2011; Zerbock, 2003). Global MSW generation levels are approximately in
51 1900, 110 million tonnes and 1.1 billion tonnes in 2000, which is tenfold. The worldwide municipal solid
52 waste production is projected at almost 1.3 billion tonnes annually, and anticipated to grow to about 2.2
53 billion tonnes annually in 2025. Global urban population likewise grew to 1.5 billion by 2010 from 1
54 billion in 1960 and is estimated to be 4.5 billion in 2025. A substantial rise of waste production
55 proportions per person is likewise estimated from the present 1.2 kg per person daily to 1.42 kg per
56 person daily by 2025 (Hoornweg *et al.*, 2013). A substantial rise of waste production proportions per
57 person is likewise estimated from the present 1.2 kg per person daily to 1.42 kg per person daily by 2025
58 (Benti, 2007; Scarlat *et al.*, 2015).

59 Municipal solid waste, that is any material discarded by primary users in urban areas, contributes to about
60 70 percent of total waste generated in Ethiopia (Kneeland & Knutson; Otu, 2011). Both biodegradable
61 and non-biodegradable waste products can produce negative environmental, social and economic effects.
62 Biodegradable pollutants are waste materials that can decompose naturally, but these pollutants can still
63 become a problem when added to the environment faster than they can decompose (Filaba, 2008;

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64 Kneeland & Knutson). Although the Ethiopian government has begun taking steps to address the
65 environmental and social challenges associated with municipal waste management, there remains a great
66 deal of inefficiency in, and environmental degradation as a result of current waste management systems
67 (Asmamaw, 2015; Thabrew *et al.*, 2009). However, this has not been the case, as many towns in Ethiopia
68 lack of financial resources and institutional capacity to provide the most basic infrastructures and services
69 including solid waste management. Therefore, solid waste management is a complex task that requires
70 appropriate organizational capacity and cooperation between numerous stakeholders (Desta *et al.*, 2014;
71 Lohri *et al.*, 2014); otherwise poor environmental quality in a city can deprive people of good quality of
72 life (Abas & Wee, 2014; Habitat, 2013).

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73 According to Environmental Protection Authority (EPA) and World Bank study conducted in 2004, per
74 capita amount of waste generated in Ethiopia ranged from 0.17 to 0.48 kg/person/day for urban areas to
75 about 0.11 to 0.35kg/capita/day for rural areas. The range depends on several factors such as income and
76 season(Getahun *et al.*, 2012). The total generation of municipal solid waste in Ethiopia in 2003 is
77 estimated to be 2.8 to 8.8 million tones. This can be split to approximately 0.6 to 1.8 million tons from
78 rural areas and 2.2 to 7 million tons from urban areas(Birke, 1999; Kuma, 2004; SBPDA, 2003).The
79 population of Ethiopia is growing at a rapid pace. In 2000, the population was 63.5 million; the current
80 population is more than 100 million, second largest in African countries next to Nigeria and by 2025
81 projected to be more than 125 million (Asgedom, 2017; Holden *et al.*, 2004). Addis Ababa City, being the
82 largest city in the country, Population increasing from time to time and showing impressive economic
83 growth trend and one of the swiftly urbanizing centers in Africa, has been grappled with an increasingly
84 growing urban waste management problem(Yntiso, 2008).

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85 Waste management in Ethiopia is important because only a small percentage of the country's inhabitants
86 have access to safe drinking water: 21% in rural areas, 84% in urban areas, and 30%country-wide.
87 Additionally, only 7% of populations in rural areas, 68% in urban areas, and 15% of people country-wide
88 have adequate access to latrines or other improved human waste disposal options (Kumie & Ali, 2005).
89 In this regard, a review survey was carried out on the solid waste generation source, assessment of SWM
90 systems, waste disposal and problems of SWM. Thus, this review revised documents from books, thesis
91 works, annual waste management conference reports, journals on waste management, newsletters,
92 abstracts and proceedings which can properly address the main factors that strongly hinder proper waste
93 management and the extent to which community is aware of appropriate waste disposal systems in Addis
94 Ababa city.

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96 2 Literature Review

97 2.1 Description of the Study Area

98 Addis Ababa is the capital city of Ethiopia at the horn of Africa, was founded in 1887 by emperor
99 Menelik II (and his wife) located in its own region (of the same name).Despite its early establishment, the
100 city of Addis Ababa started its SWM 71 years later after its establishment with the aim of ensuring the
101 health of its residents. Yet, the city is still faced with a number of waste management problems(Abiye *et*
102 *al.*, 2009). It is located at the heart of the country as shown on the figure (1), and is one of fastest
103 growing cities on the continent and the largest as well as the dominant political, economic, cultural and
104 historical city of the country (Bustos *et al.*, 2004; Mossu, 2015).

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105 Currently, Addis Ababa city is a seat for both Federal Democratic Republic of Ethiopia and Oromiya
106 National Regional State Government. It is bordered with Oromiya National Regional State in all
107 directions and also it is the largest urban center in the country (already fourteen times larger than the
108 second largest city Dire Dawa). It is also where headquarters of some continental and international
109 organizations like the Organization of Africa Unity (AU) and the United Nation Economic Commission
110 for Africa (UNECA) and regional headquarters for UNDP, UNICEF, UNHCR, FAO and ILO. The city is
111 sub-divided into three layers for administrative purposes namely City government, sub-cities
112 administrations and Woreda (local name for District) are found. Moreover, due to its natural beauty, its
113 location along the northern historic route as well as the availability of standardized tourist facilities, it has
114 become one of the major tourist and gate way for diplomats of the country due to variety of attractions.
115 The city has expanded rapidly throughout the 20th century. At the same time, as the city modernizes, it is
116 converting more and more land into streets, parking lots, hotels, etc., increasing the amount of surfaces
117 that cannot absorb the seasonal rains in the area. This storm runoff overflows sewage systems and creates
118 an influx of contaminated rivers (D Fikreyesus *et al.*, 2011).

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119 Addis Ababa city accommodates about 30% of the total urban population in Ethiopia. Its population
120 amounted to 2.1 million in the 1994 census, and estimated 2.3 million in 1997. The population census of
121 1984 gave a population at that time of 1.4 million, revealing an increase of 60% over a decade, at an
122 annual growth rate of 3.79%. Most of this growth is due to in-migration from all direction of the country
123 in search of employment opportunities and services (SBPDA, 2003; Un-Habitat, 2012).The city has
124 currently a population of about 3.5 million with density of 5936.2 km². Average household size was 5.1%
125 in 2007 (CSA, 2007), and projected to be 12 million in 2025(Potter, 2012).Demographic pressure has led
126 to a high rate of unemployment, high concentration of slum dwellers, and very poor quality housing
127 infrastructure and sanitary development (Bihon, 2007).Today it is facing ever increasing environmental

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problems, which include changing temperature patterns, eradication of green areas, unsolved problems of solid and liquid wastes, etc. However, Addis Ababa's main environmental problems are not the "green" issues (natural resource degradation) but it is the "brown" issues (pollution and other environmental problems) that are damaging the health and life of the residents (Basha, 2007).

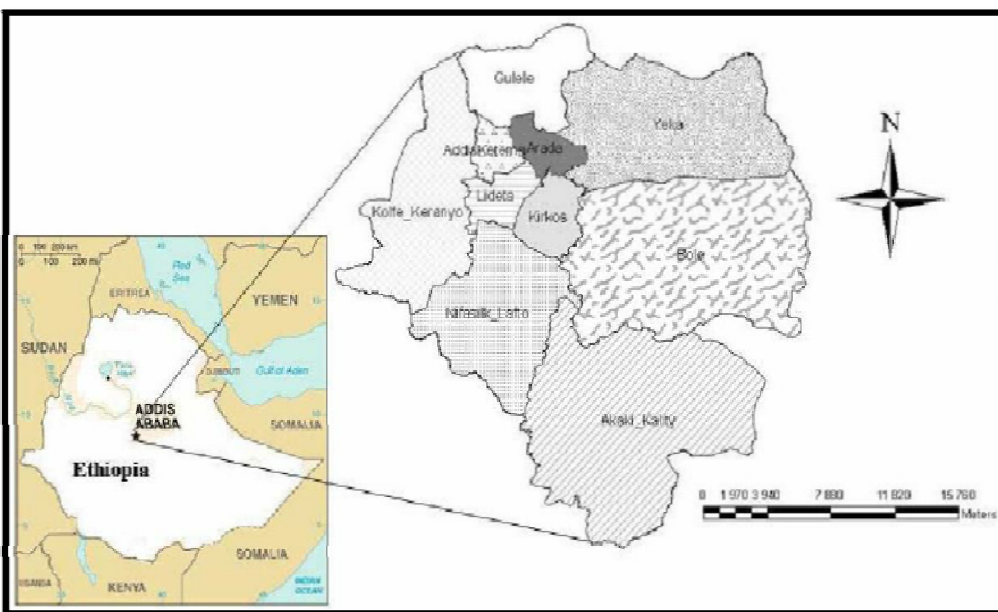


Figure 1: Location of Addis Ababa city Administration. Source: Adopted from (Desta *et al.*, 2014)

A Global position of the city is between located between 8°55' and 9° 05' N Latitude and 38° 40' and 38°50' E Longitude. The city enjoys tropical type of climate with an average annual temperature of 19.6°C, the lowest (usually occurs from November to February) and the highest (usually occurs from March to May) annual temperatures are 10°C and 20 °C respectively. Average annual rainfall of the city is 1200 mm from this about 80% of the rainfall occur in July and August months, only 3% fall during the dry months, the rest fall in the remaining months (SBPDA, 2003) while the small rain occurs between March and May. The average elevation of the city is estimated 2500m meters above sea level ranging from 2000-2800 meter above sea level. It is the highest capital of Africa. The size of the city covers around 540 square kilometer (54000 hectare) of which 18.174 square kilometer is rural (Benti, 2007).

2.1.1 Solid Waste Collection

Waste collection service is one of the chief components of municipal SWM practices. Huge generation of MSW coupled with unbalanced waste management services is the major challenges facing the City of

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146 Addis Ababa(Amiga, 2002).Waste collection and disposal in Addis Ababa follows formal and informal
147 approaches. The formal approach is the sole responsibility of the city government. This is handled in two
148 ways: door-to-door collection for households along accessible streets done by micro and small
149 enterprises(Amiga, 2002; Regassa *et al.*, 2011). The number of enterprises organized to work on solid
150 waste collection is 750 with a total number of 5815 operators(Ababa, 2010; Basha, 2007).These pre-
151 collectors have a formal agreement with the municipality to do the activity and get payment for that. Most
152 of the areas in the city are inaccessible for motorized collection. Therefore, the human powered collection
153 system is mostly used. With regard to the transportation of wastes to the containers is possible using
154 hands and hand pushed carts (see **Figure 2**). In each Kebele, strategic locations are assigned where
155 collectors make ready for the motorized collection. The container system under which residents are
156 expected to carry and dump their waste in containers located at accessible sites (see **figure 3**).Once these
157 are full, municipal trucks dispose of this waste in the landfill site of Addis Ababa, called Repi or Koshe
158 (Mahiteme, 2005).

159 Door-to-door primary collection is carried out by pre-collectors' associations and street sweepers (see
160 **figure 2**), and this too is put in containers for final disposal by the waste management agency, SBPDA.
161 So in practice, the majority of waste is collected via the containers system, but the efficiency of this
162 method is limited because of a lack of capacity of the city government to deploy adequate numbers of
163 vehicles and waste containers (see **Figure 3**). Besides, containers are not protected from rain and sun,
164 which makes the rubbish rot and smell, creates unsightly urban spots, and leads to the deterioration of
165 neighborhoods and a disturbance of human activities. The site is also exposed to stray animals that scatter
166 the waste while scavenging. So, these are created bad smell, unsightly urban picture, and deterioration of
167 the neighborhood(I. Abdulwahid, 2003).



168
169 **Figure 2:** waste pre-collectors in Addis Ababa.

source:(Mohammed & Elias, 2017)

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Comment [D21]: space; Abdulwahid, I. 2003

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Figure 3: Primary solid waste collection in Addis Ababa city. Source: (Ababa, 2010; Amiga, 2002; Cheru, 2016)

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Addis Ababa city residents pay for cooperatives per month based on volume of solid waste generation rate into consideration in the area in which cooperatives provide solid waste collection services for dwellers (30 birr per m^3 = USD1.70/ m^3) (Bjerkli, 2013). Most residents (91.02%) are willing to pay for service improvement while 8.98% of residents are not willing to participate in cost share for better solid waste management services supply in the city. The amount of money respondents were willing to pay towards improved collection service ranges from 2 to 100 Ethiopian birr with mean of 18.46 Birr. Moreover there is clear difference among different economic groups concerning the willingness to pay for improved service; the willingness to pay more is 72%, 51% and 28% for high, middle and low income households respectively (Tilaye & Van Dijk, 2014). The government in financing SWM Service charges is collected with water consumption bill. Services charges are fixed according to the amount of water consumed in terms of the ability and willingness to pay residential houses 20%, Commercial houses 42.5% of the total water consumed. Collection is regular and full coverage (Amiga, 2002). The second approach is the informal recovery and recycling system. Qoralés¹ buy waste materials door-to-door from households and institutions. Waste pickers collect waste materials from municipal containers and from Repi dumpsites. Once the materials have been collected by Qoralés and waste pickers, they are taken to the market at Minalesh Tera, the central market of Addis Ababa, and sold to middlemen or wholesalers. These then sell the materials to recyclers (Amiga, 2002; Bjerkli, 2005; Cheru, 2016). Due to shortage of containers collected wastes are improperly stored on open spaces and roadsides (see figure 4).

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¹Qorales-refers individuals who purchase recyclable solid waste door to door and resell for factories and whole sellers

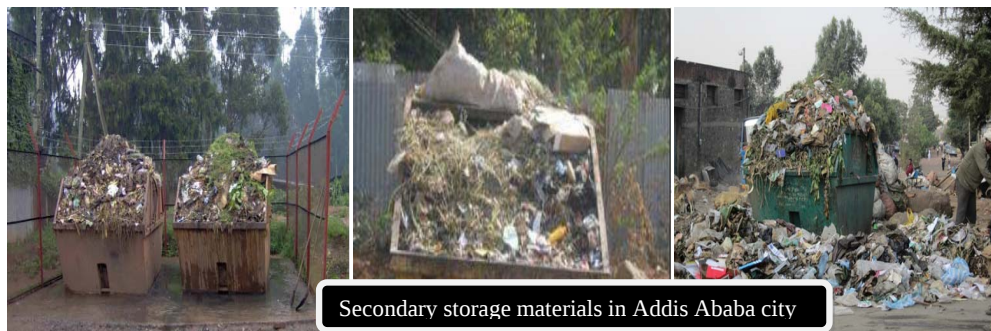


Figure 4: Typical solid wastes collection containers in Addis Ababa city. Source:(Cheru, 2016; Desta *et al.*, 2014)

The storage bins used in the city of Addis Ababa are not standardized bins, and dust bins are located only on main roads with the assumption that those roads are the popular ones. For temporary storage, households prepare different types of receptacles such as baskets, card boxes, bamboo made containers, cans, plastic bags, barrels, etc. Majority of households (70%) stock up solid wastes in sack (Figure 5), 14% used plastic container, 10% used basket, 3% used private pit, 2% used metallic container and 1% of households used other materials to store wastes temporary (Amiga, 2002; Tilaye & Van Dijk, 2014).

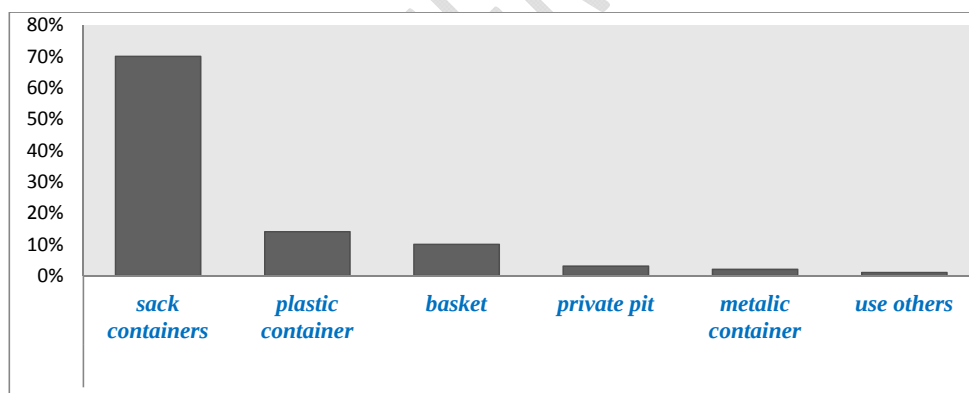


Figure 5: Types of primary solid waste storage materials of households. Source: (Amiga, 2002)

2.1.2 Sorting of waste

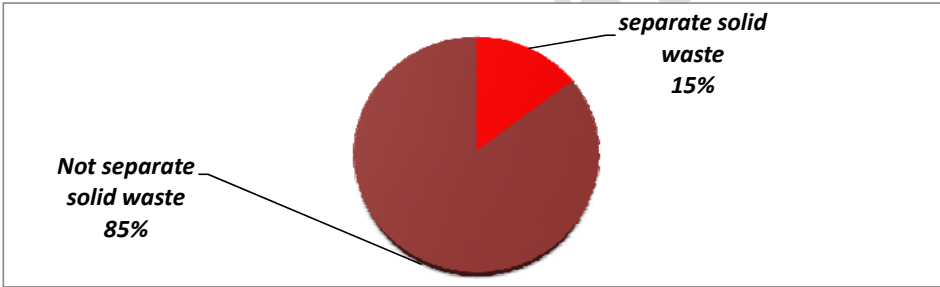
Sorting is an essential component of solid waste management. It is a kind of activity which is separating different types of wastes in their respective nature. It makes waste management easy and simple(Poon *et al.*, 2001). Sorting of waste takes place at various levels in the waste management process; The first level of source separation is at household: plastic materials, glass, bottles, are considered as valuable and usually sorted out for reuse Several collectors represent the second stage: Street boys, private sector

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208 enterprises, scavengers at municipal landfill, and the korales (Mata-Alvarez *et al.*, 2000).Solid waste
209 segregation at the point of generation is not carried out, 80% of the waste produced is dumped with a low
210 percentage being reused or recycled at the household level (Amiga, 2002). On the contrary, there are
211 households who separated at the household level into organic and inorganic only (Kuma, 2004).

212 The purpose of separated waste is different for different areas and income group. Inorganic wastes like
213 cans are usually sorted for sale (Figure 6). In few households, organic wastes like plant origin are sorted
214 for the purpose of reusing in their gardens and as fuel after the waste gets dried; this is seen in low income
215 households. Animal source (meat and bone) is used to feed domestic animals like dogs. Some households
216 give the waste away to their neighbors who use it for different purpose like for animal feed. The manure
217 is to plaster walls and floors and for fuel when dried up, whereas the grass and chatt leaves is fed to
218 domestic animals in rural Kebeles (Basha, 2007). In Addis Ababa city, from households who separated
219 waste at source level 40% for selling; 8% for recycling; 16% for reusing; 36% easing for
220 collection(Debere *et al.*, 2013).

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221

222 **Figure 6:** Households solid waste separation practice in Addis Ababa city. Source: (Desta *et al.*, 2014)

223 **2.1.3 Transportation**

224 Cities in low-income countries often lack sufficient transportation and equipment to collect
225 wastes(Segosebe & Vanderpost, 1991). Waste collecting trucks are not available to the level demanded
226 as indicated in Table 2there are about 79 trucks the department uses to collect and transport the refuse
227 from the source of origin to the final disposal site. According to (Bogale & Tefera, 2014), the truck work
228 efficiency was estimated to be less than 40% of work truck-days (there are 26 work truck days in a month
229 excluding Sundays) capacity indicating larger proportion of working days are lost due to maintenance
230 problems, negligence of drivers, frequent accidents during traffic concentration. All the trucks carry only
231 a single container of maximum capacity of 8 m³ or 2160 kg at the time of disposal. Most of the trucks

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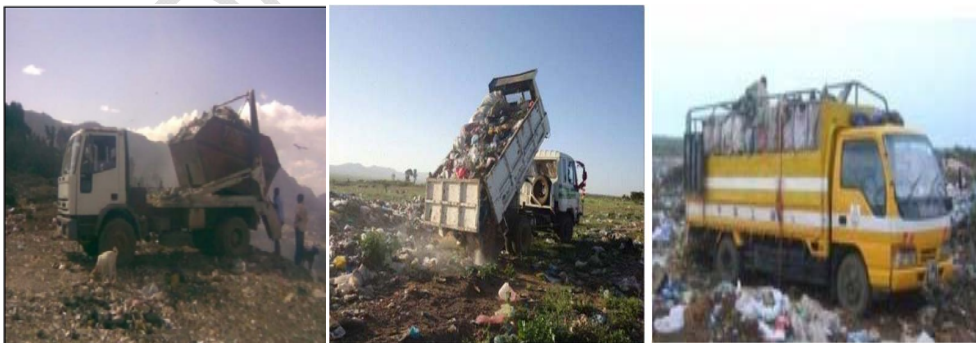
232 have no cover for waste containers so that they are dropping wastes in the city in their way to the disposal
 233 site as shown in **Figure 7** (Regassa *et al.*, 2011).

234 Table 1: Current solid waste collection trucks in Addis Ababa

Sub –cities in Addis Ababa	Container lifter	Side loader	Hino compactor	Renault compactor	Total
Arada	3	2	2	1	8
Addis Ketema	6	3	1	1	11
Lideta	2	2	1	1	6
Yeka	3	2	1	1	7
Kirkos	2	3	1	1	7
Bole	7	1	1	1	10
AkakiKality	3	1	1	0	5
Nefas-Silk Lafto	5	1	0	1	7
Kolfe	3	2	1	2	8
Gulele	6	2	1	0	10
Total	40	19	10	10	79

235 Source: (Mohammed & Elias, 2017)

236 Each sub-city is responsible for transporting to the final dump site “Rapi” (final dumping site) by means
 237 of trucks from garbage containers. The highest level in the transportation system is represented by
 238 municipality. The role of private sector on transportation of solid waste is highly limited (Desta *et al.*,
 239 2014).



240
 241 **Figure 7:** partial view of solid waste transportation trucks.

242 Source: (Birke, 1999; Daniel Fikreyesus *et al.*, 2011)

Comment [D31]: Fikreyesus et al., 2011

243 2.1.4 Waste Disposal

244 Disposal is the ultimate stage in solid wastes management system for those wastes that have no further
245 use to society (Tchobanoglous *et al.*, 1977). Waste disposal is one of the most important management
246 practices, needs to be carefully planned. Most low-income countries make use of open dumping as their
247 form of land disposal (Guerrero *et al.*, 2013). Similarly in Addis Ababa city all solid wastes collected by
248 the municipality is brought to the largest single landfill at Repior "Koshe" open landfill which is south
249 West part of the city, and has been in operation since 1950s receiving over 750 tonnes of waste per day. It
250 has a surface area of 25 hectares. The present method of disposal is crude open dumping (Regassa *et al.*,
251 2011; UN, 2010), hauling the wastes by truck, spreading and leveling by bulldozer and compacting by
252 compactor or bulldozer (Ababa, 2010). A fee has to be paid to be allowed to dump waste at the site. This
253 means that even if an agency or enterprise would collect the waste in a particular neighborhood and
254 transport it to Repi landfill it will still be expected to make a payment, even though it has done the work
255 of the municipality (Cheru, 2016).

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256 If the waste is known to be hazardous, the Region 14 Health Bureau takes a number of precautions before
257 dumping it at the landfill, including using a specific truck for carrying this type of waste and having it
258 protected by police force, burying and digging waste known to be hazardous, and informing scavengers at
259 Repi of the dangerous nature of the waste. Whatever precautions are taken, they will never completely
260 prevent the scavengers to scratch through the waste in search of something they can eat or sell (Amiga,
261 2002; Teka, 1997). The Koshe dump is located adjacent to the community of Koshe, home to some
262 80,000 of the city's poorest people following the horizontal expansion of the city and greatly affecting the
263 residents and institutions (see **Figure 8A**). Many in this community reportedly use the dump as a food
264 source (Cox, 2010).

265 The disposal site of Addis Ababa city is associated with the following problems (Ababa, 2010; Desta *et*
266 *al.*, 2014; Kuma, 2004; Regassa *et al.*, 2011; Teka, 1997):

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- 267 ☒ It is an open field disposal (Not sanitary landfill);
- 268 ☒ No daily cover with soil;
- 269 ☒ Nuisance and health hazard for people living nearby;
- 270 ☒ No leachate containment or treatment protection at the bottom by a geomembrane nor other
271 infrastructures needed;
- 272 ☒ No rainwater drain off and migration occurs through run-off of precipitation;
- 273 ☒ No odor or vector control; No treatment facilities;
- 274 ☒ No fencing, the area is unprotected area for children, women and scavengers

- 275 ✗ No large scale composting facility available as a disposal option;
- 276 ✗ Blows litters and spreading wastes outside the site and on the surrounding;
- 277 ✗ organic waste that goes to landfill sites not only pollutes the land and water but also contributes to
- 278 global warming by producing methane (CH₄);
- 279 ✗ The site is getting full; because this At least 48 people have been killed by a landslide at a
- 280 massive garbage dump on the outskirts of Ethiopia's capital, Addis Ababa, March 13,2017 (see
- 281 **Figure 8B**)².
- 282 ✗ Surrounded by housing areas and institutions (see **Figure 8C**);
- 283 ✗ More than 200 - 300 waste pickers per day work continuously and obviously living nearby the
- 284 site and interfering the operation of the work for collection of salvageable materials such as
- 285 wood, scrap metals and discarded food (see **Figure 8D**);
- 286 ✗ There is no any machinery (compactor or graders) that regularly works at the disposal site. In
- 287 addition to these uncontrolled burning of solid waste creates smoke and other types of air
- 288 pollution (there is continuous burning of the dumped waste due to internal ignition by the waste
- 289 itself) (see **Figure 8E**);
- 290 ✗ All of waste collected from the city is dumped in this single place without separation of even
- 291 organic waste;
- 292 ✗ The dump site is nearby, adjacent to the Akaki River (nearest fresh water source for landfill);
- 293 ✗ Nuisance and health risk for persons proximate and it has poor landfill site management straight
- 294 without any protection for man and animals.

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²**Figure 8A** - Rescue workers watch as excavators dig into a pile of garbage in search of missing people following a landslide when a mound of trash collapsed on an informal settlement at the Koshe garbage dump in Ethiopia's capital Addis Ababa, March 13, 2017.



Figure 8: Addis Ababa solid waste disposal site (Koshe landfill). Source: (Daniel Fikreyesus *et al.*, 2011; Mohammed & Elias, 2017; Wondafrash, 2017).

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In fact this site is now becoming in the center of the city following the horizontal expansion of the city and greatly affecting the residents and institutions (see **Figure 8C**). Yet, the city still utilizes this site as the only open disposal location (Alemayehu, 2001). As a result, the aesthetic quality of the city and the health condition of the inhabitants are under grave threat. The health hazard in turn created a financial burden to the city costing over one billion Ethiopian Birr which is more than 40 million USD every year (Debere *et al.*, 2013). Consequently, waste management is a major priority to the City Administration of Addis Ababa and is keen to solve this long-lasting problem in the city (Amiga, 2002). Due to the indiscriminate disposal of waste in the area, the organic waste that goes to this dumpsite not only pollutes the land and water but also contributes to global warming by producing greenhouse gases like methane if it is remain left untreated. The dumpsite being located on the intermittent stream, the catapult of polluted water flowing from waste disposal area can obviously inject hazards to livestock and people living in the lower basin of the stream (Alemayehu, 2001; Kuma, 2004; Regassa *et al.*, 2011).

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Therefore, the existing condition is now pushing the city government of Addis Ababa authority thinking of upgrading the existing site to control the negative impacts of the existing situation

314 and may propose an environmentally safe sanitary landfill in accordance with local conditions
315 and technological and financial capabilities.

316 2.2 Solid waste generation and composition

317 2.2.1 Solid waste generation

318 There is 5% rise urban waste generation per year. So, collection of municipal solid waste is key part in
319 supporting public health(Desta *et al.*, 2014).In line with this, solid waste management is becoming a
320 major public health and environmental concern in urban areas of Ethiopia though only 2% of the
321 population received solid waste collection services(Kassa, ,2010).Currently the daily solid waste
322 generation in the city of Addis Ababa is estimated to be 0.45 kg/capita/day, the density ranges from 205
323 to 370 kg m⁻³ and the daily waste generation has reached to 2,750 m³ (Debere *et al.*, 2013). Therefore,
324 considering the city's population of 3.5 million people(Ethiopia, 2008),it is estimated that approximately
325 one million m³ of solid waste is generated per year (Kassa, ,2010).

326 Within urban centers in developing countries, 30% to 60% of the generated solid wastes are left
327 uncollected(Henry *et al.*, 2006; Ngoc & Schnitzer, 2009). This has been proved to be true in Addis
328 Ababa as only 70% of generated wastes (which is 792 tonnes/day from a total of 1132 tonnes/day
329 generated) are collected and transported and dumped at the biggest landfill in the country and the rest
330 30% is not being collected and burned, buried or disposed informally in a manner of polluting the
331 environment because of dumped in non-allowable spaces, like exposed areas, channels, drains, roads,
332 streets sides, rivers, sanitary drainage channels and other exposed areas, and becoming a growing
333 concerns in Addis Ababa city(Fikreyesus, 2011; UNEP, 2010). About 86% of the total waste generated is
334 degradable (easily decomposable). This implies stile small proportions of the urban dwellers are served
335 and large quantity of solid waste left uncollected. From this, we can conclude that the problem of solid
336 waste management cannot be solved only by mere effort of municipal government(Amiga, 2002).

337 Based on income group classification, solid waste generation rates analyzed show that a mean waste
338 generation rate of 2.1, 1.2, 0.79 and 0.6 Kg/ capita/day for high, upper middle, lower middle and lower
339 income groups respectively, the mean solid waste generation of lower, lower middle, upper middle and
340 high income groups in lower boundary were 0.09, 0.16, 0.11 and 0.7Kg/capita/day respectively and the
341 mean solid waste generation of lower, lower middle, upper middle and high income groups in upper
342 boundary were 4.3, 5.3, 5.5 and 14Kg/capita/day respectively(see Table 4).

343 Table 2: Solid waste generation in Kg/capita/day by income level

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Income level	Waste generation per capita (Kg/capita/day)		
	Lower boundary	Upper boundary	Average
High	0.70	14	2.1
Upper middle	0.11	5.5	1.2
Lower middle	0.16	5.3	0.79
Lower	0.09	4.3	0.60

Source: (Tilaye & Van Dijk, 2014)

With regard to waste generation rate, even though the solid waste trend is expected to increase in general, recent and up to date data were not available. Based on different studies conducted so far, the amount of the solid waste generation rate in Addis Ababa city per day, month and year has been estimated based on the 1993/94 population census of Addis Ababa (see **Table 5**).

Table 3: The solid waste generation rate in Addis Ababa city per day, month and year

City	Population 1993/94	Population 2017 projection by 3.97% growth rate	Solid waste generation Kg/capita/day	Solid waste generation Kg/day	Solid waste generation rate Kg per month	Total solid waste generation kg/year
Addis Ababa	2,255,000	3,595,000	0.456	851,540	2.56×10^7	3.07×10^8

Source: (Regassa *et al.*, 2011)

However, special attention has not yet been paid in the city's development plan to address the street cleaning services. However, streets requiring cleaning in the city have been increasing specially since 2003 and yet, the rates of streets cleaned each day were only 41% in 2007 (see **Figure 9**) (Basha, 2007). In addition to collection of solid waste from transfer stations, street sweeping is also included in municipal solid waste management service offered by Sanitation and Beautification of Addis Ababa city (Debere *et al.*, 2013). Street sweeping takes place every day since it needs to be done more frequently because of there is only some street dustbins and regular generation of solid wastes like napkins, pieces of paper, residual vegetables and fruits such as banana, orange etc. Although there is an increase in the coverage of street cleaning to alleviate the street sanitation problems, the service delivery has not proportionally been stretched hand in hand with the construction of new roads that require regular cleaning in the city (Desta *et al.*, 2014; Tilaye & Van Dijk, 2014).

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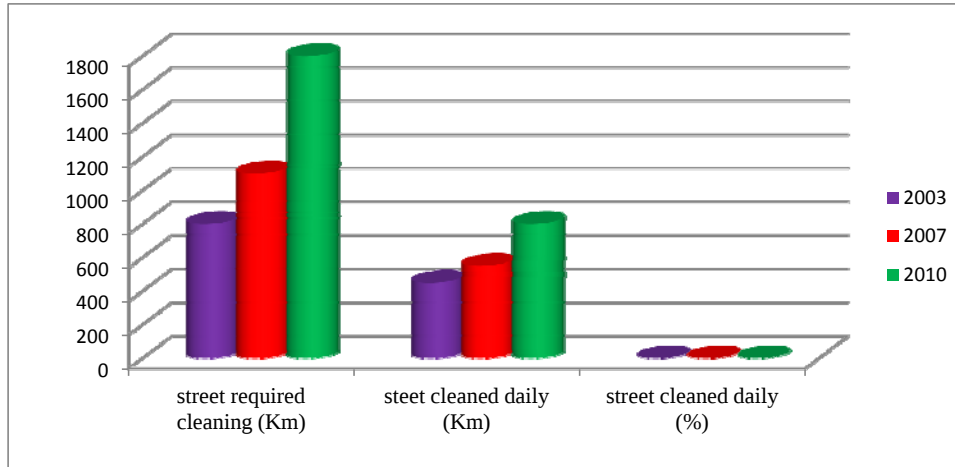


Figure 9: Length of streets being cleaned each day in different years. Source: own review (2018)

2.2.2 Sources of waste generated

The sources of municipal solid waste generated in Addis Ababa city are households, street, commercial institutes, industries, hotels and hospitals. From total generated solid waste households' account for 70% (803.72 tonnes/day), street 10% (113.2 tonnes/day) of the waste produced in Addis Ababa is collected from various corners of the city roads by street sweepers permanently employed by the city municipality, commercial institutions, 9% (101.88 tonnes/day), industries 6% (967.92 tonnes/day), hotels 3% (33.96 tonnes/day), hospitals 1% (11.32 tonnes/day) and other sources account 1% (11.32 tonnes/day) (Cointreau-Levine, 1994) (see Figure 10). The first level for separation at source in the waste recovery system in Addis Ababa is the household. Out of the total MSW generated 70% by weight and 50 by volume are organic wastes. Recyclable materials (metal, glass, plastics, paper, wood, rubber, etc.) are estimated to be 15% of the weight as well as volume of the municipal solid waste (Agunwamba, 1998).

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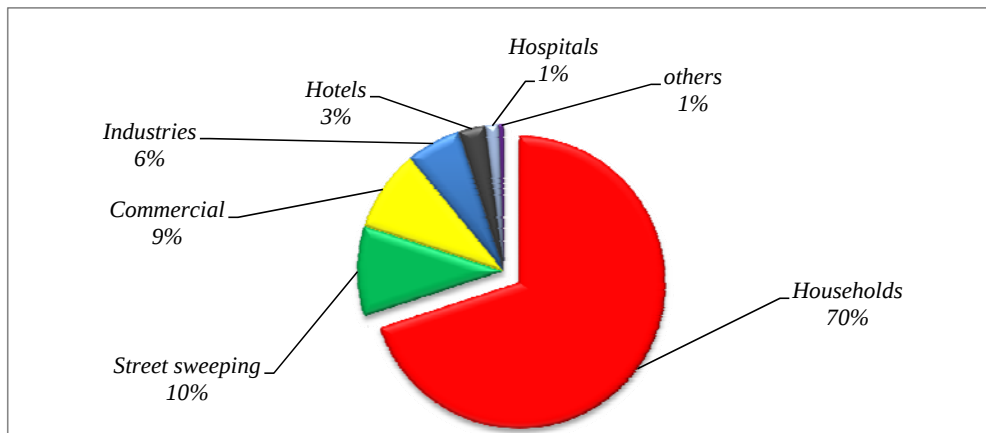


Figure 10: Major sources of solid waste generated and their percentage share

Source: (Desta *et al.*, 2014)

2.2.3 Solid waste physical composition

The physical composition of municipal solid waste in Addis Ababa has been estimated as: vegetables 4.2%, rubber/plastics 2.9%, paper 2.5% (which includes Paper Bags, Newspaper, Office paper, Magazines and catalogues, Phone Books and directories, Other Miscellaneous paper not mentioned), bone 1.1%, wood 2.3%, textiles 2.4%, metals 0.9%, glass 0.5%, non-combustible 2.5%, combustible leaves 15.7%, and all fines 65% (see **figure 11**).

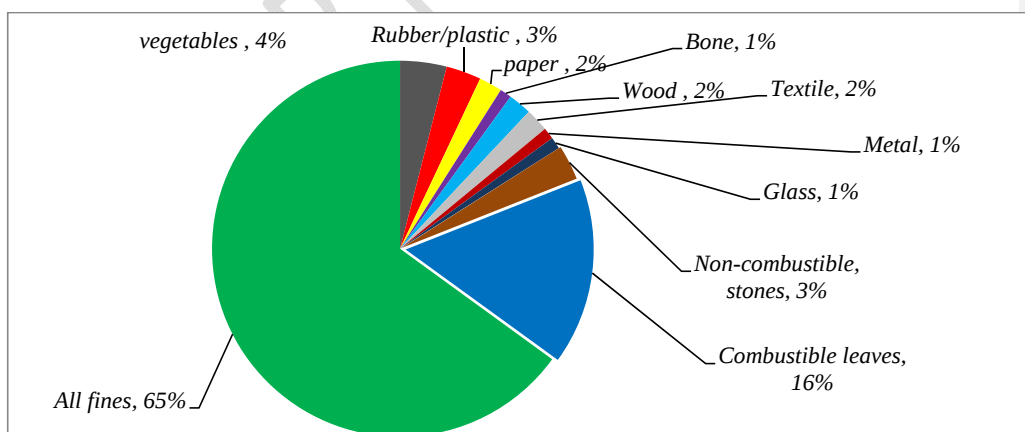


Figure 11: MSW composition streams of Addis Ababa city by percentage. Source: (D Fikreyesus *et al.*, 2011)

Comment [D51]: space, Fikreyesus *et al.*, 2011

386 The waste composition of Addis Ababa is changing over time. For example, the share of organic waste is
 387 decreasing and the share of plastic waste is increasing. See the above waste composition of for
 388 comparison, although the time gap is not significant.

389 Table 4: waste composition of Addis Ababa over different years

Major constituents	Weighted percent composition by weight and year of information					
	1982	1994	1995	2010	2014	2015
Vegetables	8.7	4.185	2.99	4	4.2	4.5
Paper	2.2	2.47	3.37	2	2.9	2.5
Rubber	0.5	1.0	0.28	2	2.4	2.23
Wood	N.A	2.33	2.29	2	2.2	2
Bone	N.A	1.06	1.62	1	1.1	2.5
Plastics	0.7	1.93	1.98	3	2.9	3.5
Ferrous metals	1.5	2.37	1.44	1	0.9	0.35
Glass	0.5	0.445	0.82	1	0.5	0.42
Combustible	25.2	15.13	22.63	16	15.5	21
Non –combustible	6.3	2.53	2.96	3	2.5	2.5
All fines	53.6	65.58	59.44	65	65	58

390 Source: based on own review (2018)

391 **Table 6 presents** an overview of the composition of total municipal solid waste in Addis Ababa and
 392 depicts the origins of the waste material fractions. The large share of ash and soil component in residential
 393 waste (47%) is explained by the predominant use of firewood and charcoal in households. The ash
 394 residues are usually disposed on the ground, later put in the waste collection bag from where it is
 395 collected by solid waste collectors. The seasonal variation is expected to be minimal due to steady
 396 consumption behavior throughout the year (Cheru, 2016).

397 2.3 Problems of municipal solid waste

398 Waste is an unavoidable consequence of the consumption and production activities of a
399 society(Papargyropoulou *et al.*, 2014).Most of the disease-causing agents that contaminate water and food
400 come from human and animal wastes. Without proper management, they result incommunicable diseases
401 (Rushbrook & Finnecey, 1988; Suryawanshi *et al.*, 2013). More than half of the population of less
402 developed countries does not have access to sanitation and more than 80% of the wastewater generated is
403 directly discharged into surface water bodies (Suryawanshi *et al.*, 2013).

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404 Solid waste management problems in Addis Ababa are results of many contributing factors. These
405 include unplanned construction of houses, uncontrolled location of industries and factories, migration of
406 people almost from all corners of the country, and most importantly, of course, is the inability of the
407 government to find efficient ways to manage and finance environment needs of the people(Kuma,
408 2004).More than 200-300 waste pickers per day work continuously and obviously living nearby the site
409 for collection of salvageable materials such as wood, scrap metals and discarded food. The adverse effect
410 of inadequate waste management service on productivity and economic development of the city is very
411 significant(Amiga, 2002). Inadequate collection, transport or improper disposal of household waste can
412 have adverse health impacts. Potential health hazards from accumulation of polluted water, which provide
413 breeding grounds for mosquitoes and attract flies, vermin(Mazhindu *et al.*, 2012).

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414 According to (Bella Sr, 2000), risks associated with inadequate solid waste management are human
415 health, environmental and aesthetic risks. Human health risks involve disease caused by pathogenic
416 organisms; disease caused by insects, rodent vectors, and water and air pollution related diseases. Man's
417 first line of defense against disease is environmental health, i.e., proper management of solid waste, the
418 provision of safe water and proper disposal of human excreta. All these will block and prevent disease
419 causing organisms from entering the human body. But many preventable diseases and deaths are
420 occurring in the developing world. About 90% of the diseases occurring in developing countries result
421 from sanitary problems(Langergraber & Muellegger, 2005).The health risk from inadequate solid waste
422 management has been felt for long in Addis Ababa. Table 7 shows the top ten diseases that are caused
423 through indiscriminate solid waste management in Addis Ababa. The real picture can be much worse
424 since many cases in the city are not reported to any formal institution due to the existence of health
425 service giving institutions in the city which do not report to the city government and the wide spread
426 practice of self-treatment and traditional healers in the city. The overall picture calls for a major and
427 urgent change in solid waste management in Addis Ababa.

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428 Table 5: Morbidity report due to indiscriminate solid waste collection and disposal from2010- 2012

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No.	Solid waste related Disease	2010	2011	2012
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1.	Parasitic infection	57,887	36,827	36,845
2.	Bronchitis	38,100	28,849	28,780
3.	Skin disease	34,426	27,119	27,047
4.	Bronco pneumonia	30,219	25,744	25,158
5.	Dysentery	20,782	13,596	14,631
6.	Bronchial asthma and allergic conditions	11,607	7,677	6,291
7.	All other respiratory disease	7,932	3,845	7,532
8.	Typhoid	6,596	3,622	4,046
9.	Influenza	3,593	1,905	1,858
10.	Trachoma	1,619	1,015	1,346

Source: (ABABA, 2007)

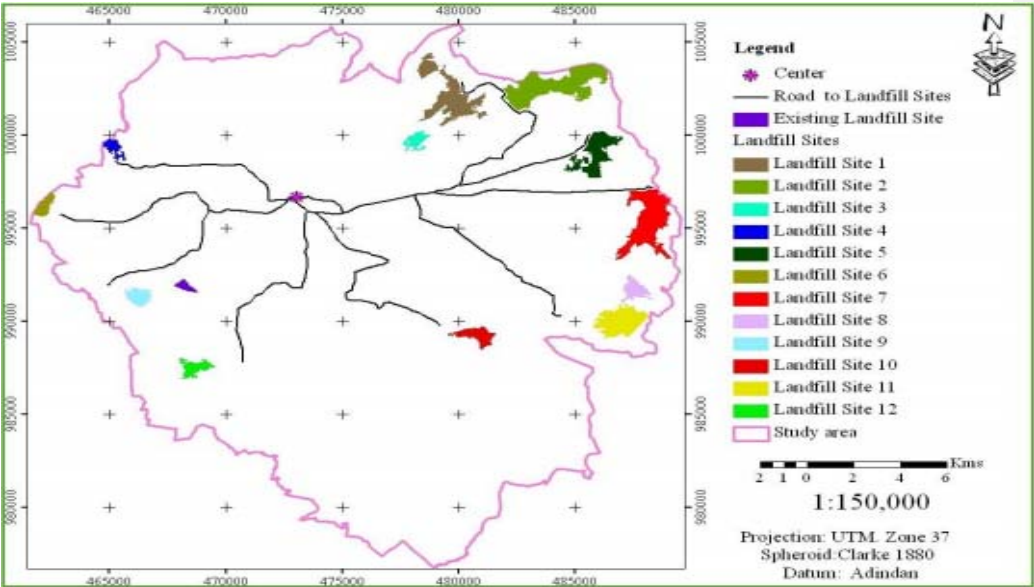
2.4 Measures to Combat Waste Management Problems

2.4.1 Landfill Sites Selection

Addis Ababa has no sanitary landfill sites. With this context, the development plan of the city has proposed the establishment of four landfill sites in the eastern, northeastern, west and southwest part of the city. Though none of them has so far been established, the proposed plan to construct these landfill sites did not even properly take into account their subsequent impacts on the local environment and the inhabitants. It was simply planned to establish the sites without knowledge base and impact forecast viewpoint. That was why the city had latter recognized the problems and decided to cease this plan before implementation and set another new plan to construct the landfill site. Finding suitable sites for landfills is one of the most difficult tasks in solid waste management as the sanitary landfill site selection must address social, environmental and technical concerns. Therefore, GIS based assessment should be employed for different criteria including geology, soil, slope, land use, and stream network (Javaheri *et al.*, 2006). Similarly in Addis Ababa City, there are problems of solid waste disposal sites selection. There are no standard transfer stations in the city. Institutions and industries follow their way of removal of waste and the available dumping sites are not well planned. Applying and integrating GIS and remote sensing techniques to select the best possible solid wastes dumping is one way of solving the problem (Kabite *et al.*, 2012). By this analysis, the most suitable sites were located in southern and south east of the city and are bare and grass lands (Figure 12).

Regarding to the suitability analysis of solid waste dumping site in Addis Ababa City to Rivers, the farther lands from lake and river banks got more preferences for solid waste dumping site suitability. In Addis Ababa city, there is a river at the northern side, River Akaki. Hence, to maintain the environmental health of this water sources at least 2000 m buffered distance should be ringed through straight line

452 calculation. Accordingly, considering only the lake, the green shaded area was the most suitable for solid
453 waste dumping site (see Figure 12).



454
455 **Figure 12:** Final sustainability solid waste dumping landfill site selection by using GIS

456 Source: (Kabite *et al.*, 2012)

457 **3 Conclusion and Recommendation**

458 This review study has attempted to analyze the status and spatial coverage of waste management service
459 of Addis Ababa city in general. In particular, the study explored residents' solid waste physical
460 composition and generation rate, resident's solid waste management practice, and institutional structure
461 and capacity of sanitation, actions or practices on waste management by policy makers, municipality,
462 peoples, private sector, and like organizations of the city. The review shows that even though various
463 studies and programs are undertaken to curtail the problem of solid waste, the service still falls short of
464 the required level. In rapidly growing cities in developing countries, solid waste is a major source of
465 concern due to lack of appropriate planning, inadequate governance, resource constraint, and ineffective
466 solid waste management. The generation of solid waste has become an increasing environmental and
467 public health problem everywhere in Ethiopia, particularly in Addis Ababa city. Solid waste management
468 is mainly provided by the municipality in the city. Traditionally, SWM has been measured and evaluated
469 based on the performance of the service supplier, while the need of the residents has been ignored.
470 Resident households, who are the primary producers and generators of uncollected solid waste and

perhaps the main victims of its deleterious effects, should be allowed to determine their SWM providers and participate in deciding effective solutions for SWM. Very poor solid waste management practices of the city residents due to the first weakness of households is poor handling of temporary storage material of their house, that is, they drop out solid waste around it and they also exposed it to rain and light, did not well covered, and placed near to residence. Second, the greater part of the city residents did not separately store solid wastes other than salable and exchangeable with Liwach and Quraleos. They did not also carry out sustainable solid management activities such as recycling, reusing and composting. Apart from this, they regularly apply temporarily illegal solid waste disposal at about the city main streets. Moreover, they have also low emphasis to clean their surrounding area and nearby road.

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