Waste Management Research in a Future Megacity
– Experiences from Addis Ababa, Ethiopia –

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Abstract

The article explores the current situation of the waste management system in Addis Ababa, Ethiopia. As in most urban centers in developing countries, in Addis Ababa the fate of postconsumer materials, organic waste and other residuals is not well known. This is a result of the lack of a system of data collection throughout the waste management chain. Since there is no systematic recording and assessment of the amount of waste collected and transported by the municipal or private enterprises, and the final disposal site lacks a weighing bridge to register the amount of residues landfilled, there is almost no robust data that helps assess the performance of the waste management system. Moreover, the fact that waste pickers and itinerant valuable material buyers and the amount of materials they salvage are invisible to the authorities, making it difficult to determine to what extent the streams of valuable materials recovered and recycled. The article gives an overview of the waste management system of Addis Ababa, and provides quantitative data on generation rates and composition of residual waste from households.

1. Introduction

Although the growth of urbanization in urban centers in developing countries has led to increased stress on natural resources, it opens simultaneously an opportunity window for the exploration of new approaches in order to help direct their efforts towards sustainable development. In order to address this challenge, the German Ministry of Education and Research (BMBF) is funding the *Research for Sustainable Development of the Megacities of Tomorrow* program, which focuses on energy and climate-efficient structures in urban growth centers. Within the scope of this program, the project *Income Generation and Climate Protection through the Sustainable Valorization of Municipal Solid Wastes in Emerging Megacities* (with the acronym IGNIS) takes on a systemic research approach to resource recovery from wastes in large urban centers in developing countries by carrying out a case study in the Ethiopian capital, Addis Ababa. The article provides a survey of the state of knowledge regarding waste management in Addis Ababa.

2. Waste management in Addis Ababa

2.1. General aspects

Founded in 1887, the Ethiopian capital is a fast growing urban center, with a current estimated population of over 3 million inhabitants and an area of 540 square kilometers [2]. It is a fast growing city, with a population growth rate that ranges between 2.1 % [6], 3 % [10] and 6 % [8] per year. Based on the fact that the city currently had a population of 2.74 million inhabitants in 2007 [6] and assuming it grows at a rate of 2.1 % per year, the city will have reached the status of a megacity by 2070. However, if one takes the less conservative scenario of Mai (2006), who believes that the city has a population of 4 million inhabitants and a population growth of 6 % per year, Addis Ababa will become a megacity much sooner, namely after 2020.

Like many African cities, Addis Ababa suffers from insufficient infrastructure and deficient services to guarantee adequate sanitation and waste management. The level of coverage

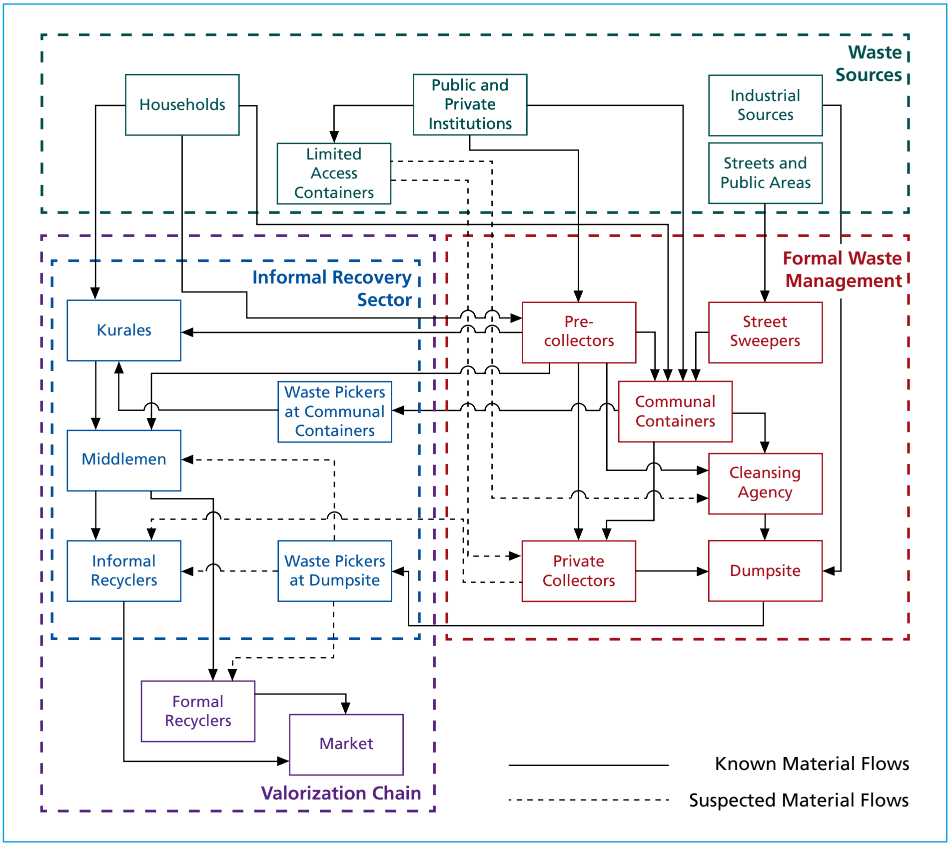

Figure 1: Waste Management System in Addis Ababa

of refuse collection is estimated at around 65 %, while the remainder of the waste ends up on streets, public areas, water courses and the surrounding environment [10]. The overall structure of the waste management system is depicted in Figure 1. The arrows represent the flows of materials between the actors, although not all links between them are visible to the authorities and the general public. In general terms, the system is composed by the sources that generate waste, by the formal waste management agents, and by the actors within the valorization chain.

2.2. Waste generation sources

The sources of solid wastes are households, streets and public areas, public and private institutions, and the industrial sector. The contribution to the total generation of waste by the different sources is estimated to be 76 % for households, 18 % for commercial, institutional and industrial sources, and 6 % from streets and public areas [10].

In terms of quantity of waste generated, households are the dominant waste generators in the city and therefore knowledge about the composition and quantities of the waste they generate is essential. Documented data available on waste generation rates per capita is scarce and is limited to three studies carried out in the 1980s and 1990s. The first study, executed by Norconsult in 1982, states that 0.150 kg per inhabitant per day were generated. Meanwhile, the so-called *Gordon studies* from 1994 and 1995 indicate that the per capita waste generation rates were 0.221 kg/cap/day and 0.252 kg/cap/day [3]. As the data available is outdated and difficult to access, it was necessary to quantify the current amounts of household residual wastes and characterize their composition.

For the execution of a representative waste analysis, five test areas were selected from seven defined housing classes, which serve as proxies for different socioeconomic strata. The five surveyed housing structures are representative for low income, low to middle income, middle income, middle to high income, and low standard condominium housing classes. The first four housing classes are single dwelling units, while condominium buildings are multidwelling units several stories high. The test areas selected had been previously charted and presented a dominating housing class (over 50 %). High income housing class and high standard condominium buildings were left out of the waste quantification and characterization campaign, since they represent a very small percentage of the dwellings in Addis Ababa[1]. The materials collected corresponded only to residual waste, which is the commingled waste mass that is brought out by households for disposal after source separation. It does not correspond to the total potential of household wastes, since some valuable and recyclable materials are extracted for selling to the informal waste recovery sector.

In total 86 samples from 430 households (each sample composed by five households) were taken on the regular collection day in each test area. These samples corresponded to the residual waste generated by more than 1,900 persons over the period of one week, for a total of over three tons. The daily per capita residual waste generation starts at 0.127 kg/cap/day for the low-income group, and increases up to 0.579 kg/cap/day for the middle to high-income level. In comparison to single dwelling housing classes, per capita residual waste generation in low standard condominiums (0.220 kg/cap/day) is located between values of the low to middle income and middle income classes (0.192 and 0.250 kg/cap/day respectively).

1 In the case of high income housing, the only potential test area that could be identified could not be surveyed, since it was a gated community and its administration was not willing to participate in the campaign.

Figure 2 presents a clear comparison of the different test areas by material groups, since the results are presented in terms of kilograms of a waste material per person per year of a given material. The physical composition of household residual waste was determined by sorting it into 14 major fractions, which in turn are composed by 27 subfractions. From the results it is observable that the amount of organic wastes increases as the socioeconomic level increases, on the one hand because increasing purchasing power, and on the other one, especially in the case of middle to high-income housing, because of increasing area of garden within the housing compound. Amounts per person of paper and cardboard, plastics, glass, metals, sanitary products, composite packaging, charcoal, and fines disposed in residual waste also increase as the socioeconomic level rises. In the case of textiles, it can be observed that the amount per person disposed decreases as the socioeconomic level increases.

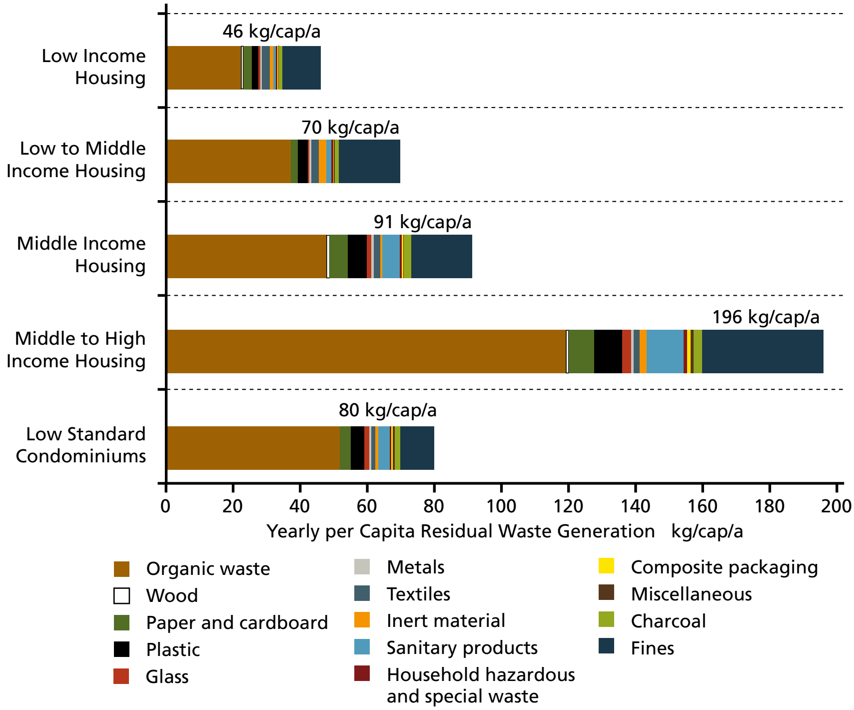

Figure 2: Yearly per Capita Residual Waste Generation in Housing Classes

The composition by mass illustrates that organic waste, i.e. biodegradable waste coming from kitchens and gardens primarily and miscellaneous organic waste, is the largest amount of the residual waste generated by households (48.8 % – 64.7 %), followed by the fine fraction (< 10 mm) (12.3 % – 26.6 %). Paper and cardboard, as well as plastics make up between 3 % and 6 % of household wastes, while wood, textiles, inert material, sanitary products, and charcoal contribute between 1 % and 6 % of the composition of the waste depending on the housing class. Metals appear in negligible amounts because they are not discarded for disposal but are sold to recyclable material buyers, while glass is scarce in waste because a refund system for glass bottles of soft drinks and beer is widespread. Fractions that are present in minimal amounts are composite packaging, hazardous waste, and miscellaneous materials.

From the previous results, it is evident that the resource being disposed of in highest quantities is organic waste. In order to estimate the potential of biowaste in the residual waste that can undergo biological treatment, the amounts of kitchen and garden waste, plus the organic waste contained in the fine fraction are considered. Although organic matter in residual household waste is not limited to these fractions, organic waste included in the sorted fraction of miscellaneous biowaste has been neglected, since it contains bones, skulls, fecal matter, and cooked food scraps waste, which are unsuitable for biological treatment, especially composting. Kitchen and food waste lie between 30.8 % and 56.8 %, while garden waste goes from 4.2 % to 27 %, depending on the housing class. Using the laboratory results of the moisture and volatile solids contents analyses carried out on the fine fraction, it was estimated that the organic matter under 10 mm is between 9.3 % and 17.1 %. From these three values the content of organic matter for biological valorization was calculated, which lies between 58.9 % and 72.4 % of household residual waste.

With the results of the waste analysis the total amount of biowaste and recyclables in residual waste, which could be recovered and valorized but are currently being thrown away, can be determined. Assuming that 3.5 million people inhabit Addis Ababa, and that the population is distributed as described in Table 1, the amount of residual household waste generated per year reaches over 242,000 tons, which results in an estimated average waste generation per day of 0.190 kg/cap/day. Taking the values computed in Table 1, it can be estimated that the amount of biowaste available for recovery in a year would be around 156,000 tons, which corresponds to 64.2 % of the calculated total residual waste generated by households. In the case of recyclables, per year around 10,500 tons of paper and cardboard (4.3 % of total residual waste), 10,200 tons of plastic (4.2 % of total residual waste), 3,000 tons of glass (1.3 % of total residual waste), and 1,700 tons of metals (0.7 % of total residual waste) are being generated and not recovered prior to disposal. This means that more than 181,000 tons per year of materials suitable for recovery are being subjected to illegal dumping or uncontrolled disposal, which equals to 74.7 % of the total estimated residual waste from households.

Table 1: Estimations of Residual Waste, Biowaste, and Recyclables Potentials

	Unit	Low Income Housing	Low to Middle Income Housing	Middle Income Housing	Middle to High Income Housing	Low Standard Condominiums	Total
Housing Class Participation	%	40	40	10	5	5	100
Population	cap	1,400,000	1,400,000	350,000	175,000	175,000	3,500,000
Residual Waste	Mg/a	64,623	97,878	31,878	34,267	13,996	242,642
Biowaste	Mg/a	38,058	61,481	21,274	24,818	10,090	155,722
Paper and cardboard	Mg/a	3,691	2,987	1,886	1,338	596	10,498
Plastic	Mg/a	2,584	3,615	1,881	1,406	707	10,193
Glass	Mg/a	890	874	559	499	234	3,056
Metals	Mg/a	533	622	271	161	124	1,712
Materials suitable for recovery	**Mg/a**	**45,756**	**69,580**	**25,870**	**28,222**	**11,752**	**181,181**

2.3. Formal waste management

The formal waste management sector is characterized by the primary collection, carried out mainly by precollector associations, the secondary collection, mostly carried out by the city's Cleansing Agency (former Sanitation, Beautification and Parks Development Authority (SBPDA)), the street sweeping and the final disposal operations. It is estimated that up to 10,000 precollectors are in charge of collecting waste from door to door [7], which is then transported by pushcarts to the skipping points where the waste is transferred to containers, or directly to waste compaction vehicles. The transport of waste with skipper trucks or with compactor trucks is responsibility of the Cleansing Agency. Street sweeping is also a task of the waste management authority. All waste that is not recovered by the informal sector and is appropriately collected will end up at dumpsite. Final disposal is carried out at the Repi dumpsite, established in 1968 with an area of 36 hectares [5] and which receives around 65 % of the waste generated [10].

2.4. Resource recovery and valorization

The major component within the valorization chain is the informal recovery sector. The first link within the resource recovery chain are the korales (from the Amaric phrase *korkoro yalew*, which means *do you have any scrap?*), who are buyers of valuable materials that go from door to door recovering metal scrap, glass, plastics and textiles. Bjerkli (2005) estimated that around 5,000 korales are active in the informal resource recovery chain. Some materials are also recovered by the highly stigmatized group of waste pickers who recover recyclables at communal containers or at the dumpsite. It is estimated that between 200 and 300 waste pickers work at the Repi dumpsite salvaging materials [1]. Once korales or waste pickers have collected the materials, they are taken to the market at *Min-alesh Tera* in *Mercato* (central market in Addis Ababa) and sold to middlemen. These middlemen will then sell the materials either to informal recyclers within Mercato or supply industrial enterprises with secondary raw materials. The industrial facilities that reprocess the materials can be found within the city limits, at the outskirts of the city or in other cities in Ethiopia.

3. Conclusions

The collection of information of the waste management system and the associated material and resource flows is a great challenge in any large urban center because of the complexity of this type of systems. The situation in developing countries is more severe as there is lack of robust historical data, and not all material streams are easy to identify and quantify. In order to make this process more manageable, in the case study of Addis Ababa the system has been divided in to three major sectors: waste generation, formal waste management, and resource recovery and valorization. In terms of generation sources, the focus has been set on filling the information gap regarding the production of residual waste from households, since these are the major generators of municipal waste.

In order to establish the composition and quantities of household waste generated, a waste characterization analysis was carried out in five different housing classes. It can be inferred from the results of the household waste analysis that the waste generation per inhabitant increases as income and purchasing power rise (0.127 and 0.538 kg/cap/d). Furthermore, it can be identified that organic wastes correspond to the largest fraction being produced in households, independent of their income level. This is probably due mainly to the fact that most food is bought fresh from grocery stores, butcheries and vegetable markets and prepared at home. Although very few products consumed are packaged and some materials are salvaged, the presence of product packaging in waste does rise with increasing income.

Regarding waste diversion from final disposal, most material recovery is done by the informal sector, which leads to the reduction of the content of recyclables (metal, glass, plastic, paper, and cardboard) in household waste. However, within the urban metabolism no use is currently being given to biowaste, which is estimated to be 64.2 % of the residual waste generated by households. It becomes obvious that diverting biowaste from final disposal should become the priority of the municipality, and if recovery and valorization of nutrients and energy from biowaste becomes the focus of waste management in Addis Ababa, several economic, social, and environmental benefits will be obtained. First, leachate production and landfill gas emissions would be minimized, leading to decreased environmental degradation from rivers, soil, and ground water pollution, as well as reducing global warming effects. Additionally, the lifespan of current and future final disposal facilities would be increased, reducing the pressure on the city's limited budget for waste management. Furthermore, production and use of humus from compost in agriculture and soil restoration can improve water retention capacity of soils and decreased erosion rates. Another benefit would be the decrease of the use of pesticides and fertilizers, which in the case of Ethiopia are imported from abroad, and to increase crop yields, can help guarantee food security and buffer food prices. Currently, however, the lack of marketing and distribution channels for compost constrain its production and use. In the case of recovery of energy from biowaste through anaerobic digestion, energy supply for households would increase, and the dependence on firewood and charcoal for cooking could be reduced.

In addition to introducing a recovery system for biowaste, coverage of the collection system needs to be increased from 65 %, and the performance of the informal resource recovery sector needs to be strengthened. Improvement of the collection coverage would lead to improved sanitary conditions in the city, while further recovery of the recyclables (paper and cardboard, plastic, glass, and metals), which currently make up 10.5 % of household waste, would increase the availability of raw materials, leading to reduced dependence of imported raw materials. In general, Addis Ababa, as well as other current and future megacities in developing countries, should strive to leapfrog past waste management based on end-of-pipe technologies and move into sustainable resource management.

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5. References

[1] Abiyi, M.: Personal interview. Addis Ababa, August 21, 2009

[2] Addis Ababa City Administration: http://www.addisababacity.gov.et/index.php?option=com_content&view=article&id=188&Itemid=189 (accessed August 27, 2011), 2009

[3] Amera, T.; Genet. B.: The Current Status of Solid Waste Management in Addis Ababa. ENDA-Ethiopia, Addis Ababa, Ethiopia. Unpublished, 2008

[4] Bjerkli, C. L.: The cycle of plastic waste: An analysis on the informal plastic recover system in Addis Ababa, Ethiopia. Trondheim: Norwegian University of Science and Technology. Master thesis, 2005

[5] Demissie, Y.: CDM Project Opportunities on Landfill Methane Recovery and Power Generation for Energy Utilization in Seven Cities of Addis Ababa. Addis Ababa University, Faculty of Science, Horn of Africa Regional Environment Centre. Addis Ababa, 2009

[6] Federal Democratic Republic of Ethiopia Population Census Commission: Summary and Statistical Report of the 2007 Population and Housing Census. Population Size by Age and Sex. Addis Ababa, 2008

[7] Habetwold, A.: Personal interview. Addis Ababa, August 12, 2009

[8] Mai, G.: Der Reformprozess der Stadt Addis Abeba 2003-2005. Herausforderungen, Strategien und Wirkungen der Stadtentwicklung und der Etablierung der kommunalen Selbstverwaltung in Addis Ababa, Äthiopien. Addis Ababa, 2006

[9] Norconsult AS: Addis Ababa Solid Wastes Management Study. IBRD, UNDP, Addis Ababa Central Association. Addis Ababa, Ethiopia, 1982

[10] United Nations Human Settlements Program (UN-Habitat): Situation Analysis of Informal Settlements in Addis Ababa. Cities without slums subregional programme for eastern and southern Africa. Addis Ababa slum upgrading programme. Nairobi, 2007

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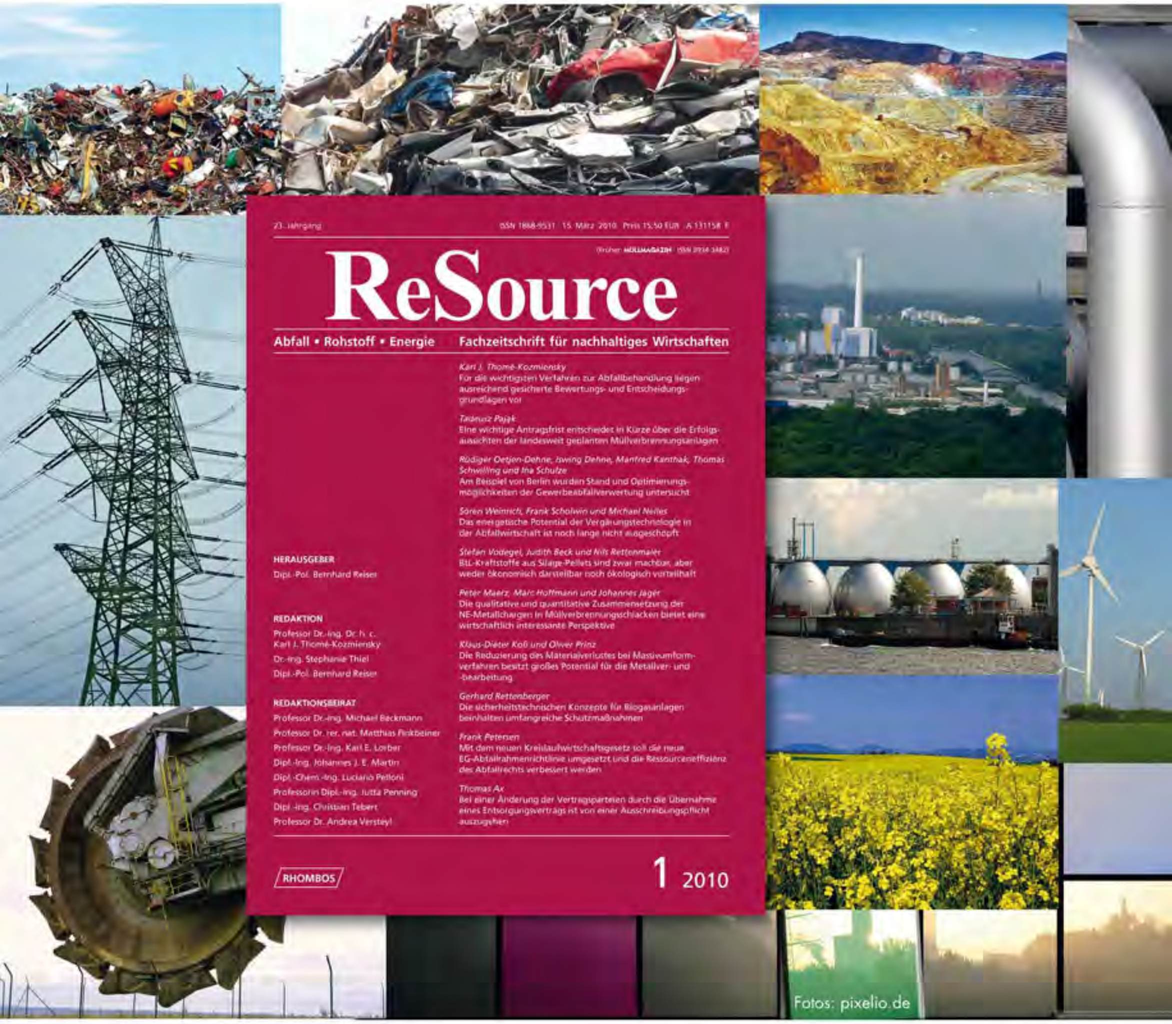

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