HOUSEHOLD WASTE AND LOCAL SOLID WASTE COLLECTION IN NIAMEY, REPUBLIC OF NIGER

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ABSTRACT In 2050, the amount of waste generated in sub-Saharan Africa is projected to triple current levels. Waste disposal coupled with urbanisation has led to environmental and social issues in rapidly developing African countries. An analysis of production and consumption taking into account the local conditions and cultural context is the first step in developing a suitable waste management strategy for a given region. This study focused on the composition and treatment of household waste in urban areas of Niamey, Niger, and assessed how household waste collection in Niamey City reflects the climate and local consumption. The current method of waste collection was examined with consideration of the quantity and types of household waste generated. The availability of locally made tools and an abundant labour force, as well as the willingness of residents to pay for disposal services, were the key factors influencing waste collection in Niamey. Due to deficiencies in public solid waste management services, and with the increasing number of young seasonal migrants in search of jobs, the importance of private individuals providing door-to-door household waste collection in Niamey has increased.

Key Words: Municipal solid waste management (MSWM); Harmattan; Plastic bags; Private waste collection; Pay-as-you-throw (PAYT); Willingness to pay.

INTRODUCTION

Urbanisation in Africa is progressing steadily, and it is projected that by 2050 more than half of the population (55.9%) will be living in cities rather than in rural areas (UNEP, 2018: 6). At present, 62 million tonnes per year of municipal waste is generated in sub-Saharan Africa, with an average of 0.65 kg per person/day (Hoornweg & Bhada-Tata, 2012: 8). By 2050, the urban population in sub-Saharan Africa is projected to generate three times the amount of waste it currently produces (Kaza et al., 2018: 73).

Globally, municipal solid waste (MSW) generation continues to increase in conjunction with rapid urbanisation, population growth, and economic growth (Ahmed & Ali, 2004; UNEP & ISWA, 2015). Integrated solid waste management (ISWM) is recognized as an important tool for improving environmental conditions and providing higher quality basic services. However, it is still a huge challenge for most municipalities to secure sufficient funding for effective waste management (UNEP, 2009). Governments spend more than 20% of their budget on waste management but are still unable to meet the demands of ISWM (Achankeng, 2003: 7).

Almost 2 billion people worldwide still lack access to solid waste collection services, with the lowest collection rates being observed in low-income countries

(UNEP & ISWA, 2015: 63). Many studies have stressed the need for municipalities to develop their own "localised" solutions and approaches toward waste management, because waste composition, sources of waste, climate, management capacity, and technical skills differ widely by area (Matter et al., 2013). The physical characteristics of waste, including its density, moisture content, and calorific value, affect the waste collection and treatment strategies, and the 3Rs (reduce, reuse, and recycle) (UNEP & ISWA, 2015: 56).

Private sector involvement, bringing private finance into public services, may improve service quality, and lead to considerable reductions in municipal solid waste management (MSWM) expenses (Oduro-Kwarteng, 2011; Ma & Hipel, 2016: 6). Local authorities are developing policies to encourage involvement of the private sector in MSWM, which at present is typically financed through government subsidies; however, the inadequacy of municipal budgets often delays payments to private contractors, resulting in dysfunctional waste management systems.

Waste management strategies have historically focused on hazardous substances and considered waste to be a source of pollution or a health risk. There is a need for appropriate waste treatment strategies to reduce pollution; the polluter's responsibility for any harm or damage caused must also be clarified. The initial driver of waste management was the need to phase out uncontrolled disposal (Wilson, 2007). ISWM was developed to establish an environmentally sound waste collection and treatment system, with a focus on economic aspects (i.e., cost effectiveness) and law enforcement. Environmental drivers of waste production, such as climate change, are becoming stronger worldwide. ISWM is shifting us towards a more sustainable model, moving from "end-of-pipe" solutions to the more integrated concept of "resource management" (Wilson, 2007; Oteng-Ababio, 2014).

In this study, specific MSWM scenarios were analysed, encompassing "end-of-pipe" waste disposal systems and "up-stream" resource consumption. A better understanding of sources of waste, especially households, and their demands and preferences for particular waste services is required. Thus, this study specifically focused on urban household waste, with the intention of clarifying how waste is connected to urban life in Niger. The quantity and characteristics of household waste in Niger were also assessed. Through a case study of a household waste collection scheme operated by a local private enterprise in Niamey, an assessment of how households interact with the current MSWM system was conducted.

STUDY AREA

The study area was Niamey, the capital city of the Republic of Niger. It is located in the south-west region of Niger on the banks of the Niger River. Niger is a landlocked country; its vast surface area of 1,267,000 km^2 makes it the sixth largest country on the African continent. The Sahara Desert accounts for more than two-thirds of the territory, and only about a quarter of Niger has a semi-arid climate that is suitable for cultivation or pasture (Mohamed et al., 2002).

Niamey is in the Sudan-Sahel zone, with distinct rainy and dry seasons (Oyama, 2012). The dry season is 8 months long, and lasts from October to May. The region is also exposed to strong winds. The Intertropical Convergence Zone (ITCZ) moves northwards from June to September, bringing rain to the region; this 3–4 month period is the rainy season. Niamey has an annual mean minimum temperature of around 23.7°C, mean maximum temperature of 36.8°C and annual precipitation is 573 mm (average of 5 years (2012–2016) calculated from INS (2017)).

RAPID URBANISATION AND HOUSEHOLD CHARACTERISTICS IN NIGER

In economic terms, Niger is classified as a low-income country. The population is growing at an alarming pace of 3.8% per year, which is the second highest population growth rate in the world. The current population of 1.9 million is predicted to increase to 6.5 million by 2050 (UNDESA, 2019). The city of Niamey has a relatively short history, dating back to the beginning of the 20th century. The Niamey Urban Community is divided into five municipalities (communes) and 46 villages. The five communes constitute only 0.02% (255 km^2) of Niger's territory, but contain approximately 5.9% of the population (1,164,680 individuals), with a density of 4,567 persons/km^2 compared to the national figure of 16 persons/km^2 (INS, 2016: 20). This high population density results not only from expansion of the city area but also due to both temporary and long-term influx of the rural population seeking a cash income.

The net migration to Niamey was estimated to be 200,846 individuals (INS-MEF, 2012a: 30). Cultivable land and livestock resources are in serious decline and no longer provide a stable livelihood for growing families. Men and women in rural areas are moving to urban zones in search of work. The size of informal sector in low-income countries is significant because of poverty, unemployment or underemployment (Ahmed & Ali, 2004). During the long dry season, i.e., the agricultural off-season, men from rural villages, including livestock herders, move to the cities in search of cash to support their families. Many herders lost their livestock due to the severe drought in the 1970s and 1980s, and were thus unable to continue raising livestock as their main occupation. Instead, they now either make a living by caring for the livestock of other farmers, or have fully migrated to cities.

The employment of the urban workforce is reported as 51% self-employed, 11% family and temporary workers and only 26% are salaried employees (INS-MEF, 2012b). This suggests an abundant labour force that could potentially be employed in the informal waste sector. Scheinberg et al. (2011) defines "informal" waste management operation as follows: "private sector activity which is neither sponsored, paid nor recognized by the formal solid waste authorities as being part of the waste management system." These services are operating for profit, exploiting a gap between actual waste management services and the existence of a demand therefor (Ahmed & Ali, 2004).

Previous studies estimated the daily waste generated in Niamey to amount to 123 tonnes in 1983 (Issaka, 2010), and 505 tonnes in 2001 (JICA, 2001). The

president of the special delegation appointed to perform the functions of the mayor of Niamey Urban Community stated that the citizens of Niamey produce 0.75 kg of waste per person per day; of the 1,000 tonnes generated daily, about 40% is collected by the municipality; 60% remains uncollected (Guevanis, 2017).

The present study investigated how households cope with this situation, and the methods they use to deal with waste.

QUANTIFICATION AND CHARACTERISATION OF HOUSEHOLD WASTE

Materials and Methods

The study samples were obtained directly from the sources of waste generation,[1] focusing on residential rather than commercial or institutional sources, or open areas (i.e., areas where street-sweeping was being performed). To allow comparison with previous studies, the wet weight of the waste was recorded, rather than the volume or dry weight. The weight of collected waste was measured on the spot before being taken away for disposal.

The surveyed households were selected from 1 of the 16 quarters[2] in Commune III, Quartier Kalley-Sud, which is located between the city centre and the city border. This quarter is situated in an old area of Niamey, where houses already existed before independence from France occurred in 1960 (Tini, 2003; Issaka, 2010). According to the 2012 census, Commune III has a population of 185,000 and is the smallest of the five communes. The number of households in Commune III in 2012 was 28,638 in total (INS-MEF, 2012c: 16).

The survey was conducted on households in Quartier Kalley-Sud, which were considered as middle-class households (because most of the respondents were professionals in long-term employment with monthly salaries). In contrast, most heads of households in Niamey are self-employed and their incomes are unstable. Bontianti & Sidikou (2008) classified the households of Niamey according to housing type; under their categorisation, middle-class income residents typically occupied brick houses, with several households residing in compounds with a shared courtyard and latrine.

Waste Quantification Survey

The results presented below are based on data collected during the dry season from September to December 2017, and during the rainy season from July to September 2018.

The first survey, conducted in 2017, measured the weight of waste obtained from seven households[3] (Table 1). Waste stored in the bins, cans, and baskets of households was separated once a week during a 10-week period from October 8 to December 10, 2017 (total of 70 days). After recording the contents of the household waste, it was sorted using a sieve, a pair of fire tongs, and rubber gloves into the following 10 categories: paper and cartons, textile and leather, wood, food, leaves, plastics (including rubber and vinyl), metals, glass, batteries

Table 1. Number of household members and family structure of the surveyed households.

House-hold	No. of persons	Family structure						Major occupancies and income source of household head and its members
		By age		By sex of constituents				
		Adult	Child	Adult M	Adult F	Child M	Child F	
H1	8	6	2	3	3	1	1	Husband: public servant, furniture workshop owner / Wife: junior high school teacher / Lodger: furniture upholsterer, student
H2	10	3	7	1	2	2	5	Husband: driver / Wife: housewife
H3	4	4	0	1	3	0	0	Husband: teacher / Wife: housewife
H4	7	3	4	1	2	1	3	Husband: engineer / Wife: housewife / Daughter; hairdresser
H5	7	4	3	2	2	0	3	Husband: policeman / Wife: ready-made meal vendor
H6	10	4	6	2	2	3	3	Husband: haberdasher / Wife: light snack vendor / Lodger: photographer
H7	14	11	3	6	5	1	2	Wife: widow (supported from sons)
Total	60	35	25	16	19	8	17	

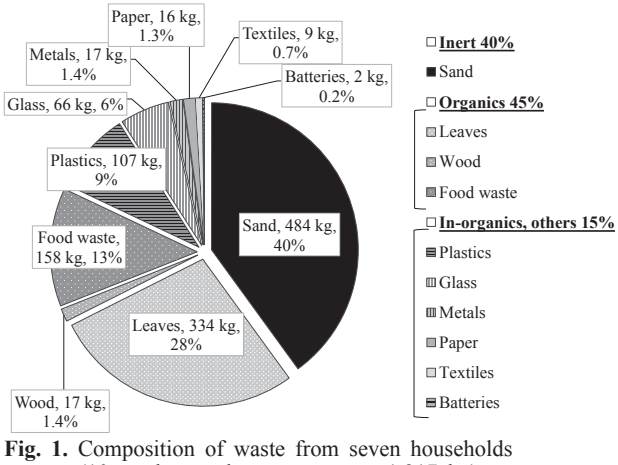

Fig. 1. Composition of waste from seven households (10 weeks; total waste amount, 1,217 kg).

and inert materials (including sand, ash and stones).

As the first step, solid items (plastic, metal, glass, batteries, paper, textiles, wood and stone) from a waste pile emptied from bins, spread out on a plastic sheet, were segregated by hand. Kitchen waste, such as vegetable scraps and leftovers, were also separated and the remaining pile of leaves and small particles was sieved to separate out the sand. The leaves and small particles were weighed separately. This exercise was repeated for each household. The weight of each type of waste was measured using an electronic balance (CS-10 KWP; CUSTOM, Japan; minimum measured weight: 5 g). Large waste (i.e., that weighing more than 10 kg) was placed in a bucket and weighed using a spring balance (minimum weight: 100 g).

The waste types, in descending order of wet weight, were as follows: sand (484 kg, 40%), leaves (334 kg, 28%), food waste (158 kg, 13%), plastics (107 kg, 9%), and other materials, such as glass, wood, metal and batteries (total weight of all waste categories combined, 1,217 kg; Fig. 1).

Table 2. Weekly fresh weight of household waste and the associated collection fee for seven households (5 weeks, total waste amount, 699 kg).

House-hold ID	Counted days		Date measured (October 8–November 12, 2017)					Total wet weight (kg)	Weekly average weight (kg)	Total collection fee*	Weekly average price*	Cost per kg*
			Oct. 15	Oct. 22	Oct. 29	Nov. 5	Nov. 12					
H1	35	Total	42.8	45.6	120.7	19.1	21.9	250.0	50.0	5,225	1,045	21
		Sand	13.0	19.1	63.4	0.0	8.7	104.3 (42%)	20.9			
H2	35	Total	30.3	22.1	21.8	23.5	18.1	115.7	23.2	2,400	480	21
		Sand	12.1	8.8	5.0	7.7	5.9	39.4 (34%)	7.9			
H3	35	Total	4.1	2.7	6.6	8.9	10.5	32.7	6.5	700	140	21
		Sand	1.0	0.3	2.9	1.2	6.0	11.4 (35%)	2.3			
H4	21	Total	N.D.	13.1	8.8	10.1	N.D.	31.9	10.7	525	175	16
		Sand		7.0	6.0	0.0		13.0 (41%)	4.3			
H5	28	Total	16.1	3.6	14.8	22.4	N.D.	56.9	14.2	900	225	16
		Sand	4.2	1.4	4.3	7.4		17.3 (30%)	4.3			
H6	21	Total	N.D.	9.8	9.9	N.D.	9.1	29.0	9.7	800	267	28
		Sand		3.2	4.2		0.0	7.4 (26%)	2.5			
H7	35	Total	55.0	29.8	50.3	18.4	28.4	181.9	36.4	2,525	505	14
		Sand	0.0	19.1	30.1	7.7	20.0	76.9 (42%)	15.4			
Total	210		148.2	126.6	232.8	102.4	88.0	698.1	139.6	13,075	2,615	19
Average	30							99.7 (39%)	21.5	1,868	405	20

* CFA francs.
N.D.: No data available for that week. Other data are independent, representing measurement for that week (7 days).

Table 3. Average weight of generated waste per capita (kg/person/day).

Household ID	H1	H2	H3	H4	H5	H6	H7
No. of actual members	8	10	4	7	7	10	14
No. by equivalence scale	3.9	4.1	1.9	3.2	3.0	4.1	6.5
Waste generation							
No. of weeks	5	5	3	4	3	3	5
Weekly average (kg)	50.0	23.2	6.5	10.7	14.2	9.7	36.4
Coefficient of variation (%)	73.8	17.3	44.3	28.2	59.8	6.9	38.5
No. of days	35	35	35	21	28	21	35
Daily average (kg/household/day)	7.1	3.3	0.9	1.5	2.0	1.4	5.2
Actual per capita (kg/person/day)	0.9	0.3	0.2	0.2	0.3	0.1	0.4
Adult equivalent per capita (kg/person/day)	1.8	0.8	0.5	0.5	0.7	0.3	0.8

The average weekly generation per household and cost per kg was calculated for a 5-week period within the overall 10-week study period (Table 2).[4] The weekly average of seven household was 21.5kg, and the weekly average cost was around 400 CFA francs (0.7 USD) per household at the average 20 CFA francs per kg.[5] The daily average weight generated per capita (kg/person/day) varied from 0.1 to 0.9 kg, with an average of 0.39 kg per person/day (Table 3). Household size greatly influenced the per capita result. The average number of persons in the seven households studied was 8.5, while the average size of a household in Niamey is 6.1. The distribution of household size in Niger is as follows: 1 to 4 persons: 31%, 5 to 10 persons: 55%, and over 11 persons: 14% (INS-MEF, 2012c). Considering that over 40% of household members are minors (i.e., under

14 years of age), waste generation per capita was recalculated using a modified Organisation for Economic Cooperation and Development (OECD) equivalence scale to capture the consumption of households by adult equivalent size.(6) The adjusted per capita waste amount generated was in the range of 0.3 to 1.8 kg, with an average of 0.87 kg per person/day.

Composition of Inert Material

The results showed that sand, ashes and stones accounted for the majority of the inert material; much of this material was wind-blown sand. The courtyard shared by the households, and the alley between the compounds, was unpaved, with exposed sandy ground (Fig. 2). The Harmattan is a dry wind that blows from the north and north-east during the dry season. The Harmattan causes air turbulence and wind erosion at ground level; moreover, blown sand becomes trapped in refuse heaps on the ground (Oyama, 2012). The wind scatters dust and removes leaves from urban trees, and sand is further mixed into household waste upon sweeping.

Very few households have indoor dustbins; waste and sweepings are usually placed outdoors, often in old and broken buckets, basins and baskets. Households have an outdoor kitchen and use wood and charcoal for cooking. In all of the surveyed households, women and girls cleaned inside and outside the house, sweeping the ground with a traditional broom made of twigs to remove litter and fallen leaves from their compound every morning and evening, and after cooking

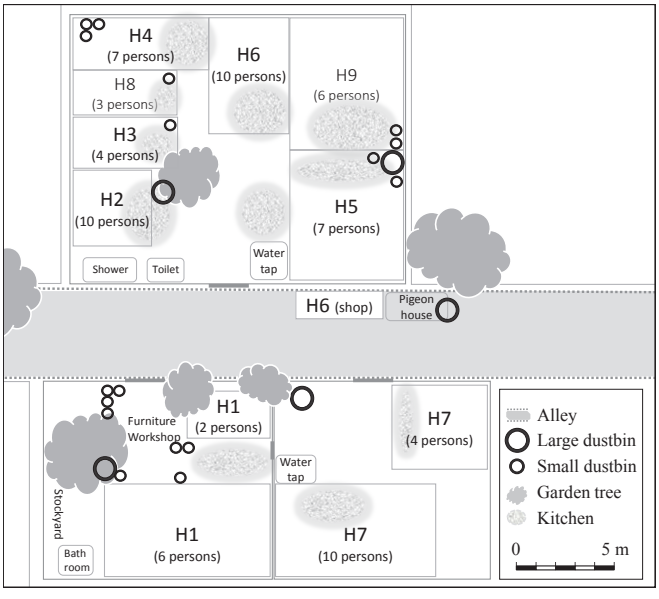

Fig. 2. The shared housing compound and the position of the bins and kitchens in seven households.

(Blundo, 2003; Bontianti & Sidikou, 2008: 51). Because of this daily routine, members of the household typically threw their waste on the ground and rarely used waste bins.

The second largest fraction of material comprised leaves. During the dry season, leaves from Neem (*Azadirachta indica*) and Khaya wood (*Khaya senegalensis*) that grow in courtyards are abundant in the waste stream. In this survey, fallen leaves accounted for 28% (334 kg) of all household waste. The third largest fraction was food waste, mostly kitchen waste and the leftovers of cooked food that was no longer edible. Organic waste, including leaves, food and wood, together accounted for 45% (509 kg) of the total weight of household waste. The organic material in waste was derived from several sources, such as garden trees planted for shade, domestic animals (sheep or goats), traditional housing materials, firewood and charcoal used for cooking, and small business activities (e.g., furniture workshops and street vendors).

Plastic Content of Household Waste

The 2017 survey confirmed that plastics were the principal non-organic waste, being present in higher amounts in the waste stream than metals, glass, or batteries. Most of the plastic constituents of the waste were polyethene (PE) bags rather than hard-to-decompose plastics, such as polyvinyl chloride (PVC), polypropylene (PP) and high-density polyethylene (HDPE), which are used in bottles, pipes or buckets.

To further investigate the plastic content of the waste stream, the number of plastic bags contained in household waste from the seven households was counted during the 2018 survey over a 1-week period (September 17–23, 2018; Table 4). The total weight of that waste was 246.5 kg, with plastic bags accounting for 21.9 kg, i.e., 8.9% of the total weight. In descending order of number of bags, the waste contained thin transparent PE bags, opaque black PE bags, 500 ml clear PE water sachet bags and thick white 200 ml polyethene terephthalate (PET) bags containing dairy beverages. Each household discarded 12 to 68 plastic bags per day.

Table 4. Number and weight of plastic bags discarded in a week from seven households (September 17–23, 2018; total household waste 246.5 kg).

Household members			Transparent		Opaque		Pure water bags		Milk/yoghurt bags		Total plastic bags		Average of plastic bags consumed (household/day)
ID	Actual	Equiv.	White PE	(kg)	Black PE	(kg)	Clear PE	(kg)	White PETE	(kg)	Bags	(kg)	
H1	8	3.9	128	2.7	89	1.6	21	0.1	8	0.1	246	4.5	35
H2	10	4.1	135	0.8	19	0.4	19	0.2	0	0.0	173	1.4	25
H3	4	1.9	64	0.5	33	0.8	1	0.0	1	0.0	99	1.3	14
H4	7	3.2	56	0.7	30	1.0	6	0.0	0	0.0	92	1.7	13
H5	7	3	288	2.0	87	2.7	93	0.7	10	0.4	478	5.8	68
H6	10	4.1	36	0.6	45	1.5	3	0.0	0	0.0	84	2.1	12
H7	14	6.5	203	3.7	76	1.1	63	0.3	13	0.1	355	5.3	51
Total	60	27	910	10.9	379	9.1	206	1.4	32	0.6	1,527	21.9	–
												Average	31.2
												Standard deviation	20.0

The weight of an individual plastic bag is less than 0.1 g. Thus, the total weight of the 1,527 plastic bags should have been less than 153 g, but after use the bags weighed 21.9 kg. This high weight was due to materials remaining inside the bags. Although solid contents were separated upon measurement, liquid or extraneous matter (e.g., sand) adhering to the bags was not removed.

Use of plastic bags is strongly related to the consumption habits of residents, *inter alia*, the purchase of food. Transparent white plastic bags and opaque black plastic bags are provided as shopping bags at the local market. The groceries are first placed separately into small bags by the store clerk, and then into shopping bags.

There are three reasons for the extensive use of plastic bags. First, they are inexpensive, with the cheapest costing only 100 CFA francs (for 100 bags; 0.17 USD). Second, and perhaps most importantly, they are convenient for carrying and preserving food. Grains, beans, salt, sugar, vegetable oil, seasoning pastes and spices are sold by the gram, or in quantities equivalent to empty measuring cans, cups, bowls or spoons. Fresh meat and fish fillets, peeled vegetables and fruits are also sold in bags. Opaque black PE bags with handles are used as shopping bags to carry groceries and other items. Translucent PE bags can carry liquid once the mouth of the bag is tied; their contents are visible, making them convenient to preserve. Typically, women purchase food for meals that will be prepared and consumed on that day (Fig. 3). Small portions can be purchased at low prices. Few households own a freezer or refrigerator to preserve food, and women in Niamey still prefer to buy fresh food each time they cook.

The third reason for extensive use of plastic bags relates to the pleasure of consuming cold drinks in a hot climate; a popular small business activity for housewives who own freezers is to sell iced tap water and frozen homemade juices (popsicles) in PE bags. Cold drinking water, commonly referred to as "*pure water*" is sold daily for 25 CFA francs (0.04 USD) a bag. Thick polyethylene

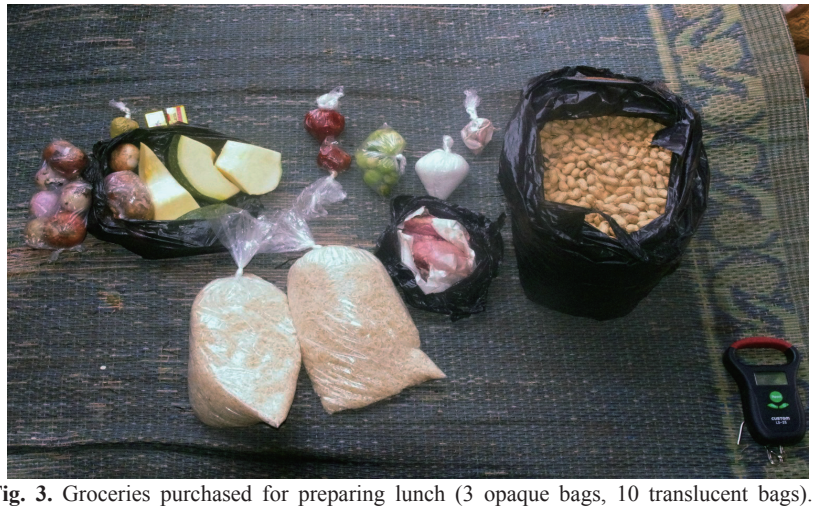

Fig. 3. Groceries purchased for preparing lunch (3 opaque bags, 10 translucent bags).

Table 5. Frequency with which food items were found in the waste of household No. 1 (2017–2018*).

Type	Name of Food item	Discarded form	Frequency out of 23 weeks
Take-away meals and snacks purchased on the streets		In white translucent PE bags	
Breakfast	Bread	Leftover	12
	Porridge (*fura, koko*)	Leftover	7
	Rice flour pancake (*masa*)	Leftover	6
Ready-cooked staple food	Couscous	Leftover	8
	Pearl millet, rice pudding (*tuwo*)	Leftover	6
	Rice with beans	Leftover	3
Ready-cooked side dish	Sauce (tomato, okra, etc.)	Leftover	13
	Boiled moringa leaf	Leftover	7
Snacks	Roasted meat, chicken, skewers	Wrapping paper, spit	9
	Grilled or boiled corn	Skin, core in aluminum foil	4
	Fried potatoes	Wrapping paper	3
Drinks	Pure Water	Liquid in PE package	17
	Yoghurt	Liquid in PETE package	16
	Milk powder	Powder in paper carton	4
	Homemade juice (hibiscus, ginger)	Liquid	4
Fruits	Banana	Skin	13
	Watermelon	Rind	9
	Orange	Peel	7
Groceries (ingredients) purchased at the market		In black opaque PE bags	
	Onion	Skin, roots	18
	Rice	Cooked leftover	15
	Lemon	Peel	14
	Egg	Shells	12
	Pasta	Cooked	11
	Eggplant	Rind, calyx	10
	Carrot	Rind, roots	9
	leaves of *Corchorus* spp.	Stem	9
	Pearl millet, sorghum	Thick pudding	9
	Pepper, sweet pepper	Calyx	9
	Beef	Bones	8
	Medicinal plants	Dried plants	8
	Oiled sardines	Tin	8

* Duration of the survey is from October to December, 2017, and from July to September, 2018.

terephthalate (PETE) pouch bags are used as packages for local dairy products and sold for 125 CFA francs (0.22 USD) each (UNIDO, 2009). PET bottles contain 500 ml of gaseous juice and are sold for 500 CFA francs (0.87 USD). Empty PET bottles are commonly reused by street vendors selling homemade frozen drinks, including frozen milk drinks, for 250 CFA francs (0.44 USD).

In addition to the use of plastic bags for shopping, mass consumption of plastic bags occurs in the context of buying prepared food product (ready-cooked meals, and ready to eat snacks, drinks, fruits; Table 5). Translucent PE bags were found in waste with the remains of the prepared food, while black opaque PE bags were usually found with inedible parts of purchased ingredients for cooking. Plastics bags are used extensively to wrap cooked food because of their low bulk density and inertness, which makes them a convenient carrier material with a low risk of contamination (Fobil & Hogarh, 2006). Plastic bags are used by female street vendors, who set up stalls along the street. Some customers are unmarried

single men who do not cook for themselves, while others are housewives who take away pre-cooked food and serve them as a complementary dish at breakfast, lunch or dinner. Students buy their lunch and snacks at stalls located near schools. Cooked food is sold throughout Niamey and its consumption is part of daily life.

LOCAL COLLECTION SYSTEM OPERATED BY RESIDENTS

Residents' Preferred Waste Disposal Methods

Sand and organic matter together accounted for 80% of Niamey's household waste. Household waste containing large amounts of sand and organic substances can decompose and decrease in volume once buried, as occurs in rural villages. However, only 1.5% of households in Niamey used this disposal method (INS, 2016: 112). According to an interview with an elderly lady (household No.7; interviewed on September 23, 2018) living in Niamey since the 1960s, burial of waste in close proximity to a house was once common practice. Before residential areas became densely populated, waste was simply discarded a short distance from the houses. Waste containing organic matter rapidly generates a strong odour and also attracts insects and rodents, such as flies and mice. It was traditionally the duty of the boys in the household to dispose of the waste. Over time, the amount of land available for waste disposal outside the housing compounds decreased. Plastics and inorganic waste products that do not decompose began to accumulate in the city. The residential environment became increasingly unsanitary and uncomfortable as waste accumulated, leading to a demand for a waste disposal site as far from housing complexes as possible. Heavy waste is not easily carried by hand over large distances. It was also mentioned during the interview that residents started using pushcarts and donkey carts instead of baskets. Because many residents did not own these carts, she and her neighbours started employing the services of waste collectors with pushcarts.

In the past, the municipal government attempted to collect waste from houses in some quarters. However, collection of household waste as a public service was provided in limited quarters of the city, and in other parts municipal collection was only from city-owned waste containers and public waste deposit points (Tini, 2003; Bontianti & Sidikou, 2008; Ousmane-Adamou, 2015). Individual households and businesses had to transport their waste to the public waste containers or waste disposal sites. However, the number of public waste containers in the residential areas has been in constant decline, from 271 in 1992 to 102 in 2003 (Bontianti & Sidikou, 2008: 66). In Commune III, there were only 16–20 public containers in total, compared to 173 waste containers in Commune I at the beginning of the 2000s (JICA, 2001; Tini, 2003). Today there are less than one public waste container for each of the 16 quarters. With no public waste deposit points near their houses, some residents pile waste at the side of the road during the night or choose to discard waste in open spaces, drains, or other public spaces. These piles of waste in the proximity of houses are clearly visible and make residents feel uncomfortable about dumping their waste in this way.

Waste Disposal Sites and Administrative Responsibilities

Waste containers belong to the city council of the Niamey Urban Community. It is the municipal office's responsibility to supervise the waste containers and disposal sites in the respective communes. In addition, the municipality assumes the responsibility for sweeping the paved main roads, removing waste from drains, and transport of waste in public containers to a final landfill site. Communities and households are assigned the responsibility of delivering waste produced in the residential area to the authorised waste deposit points, or transfer stations (based on an interview conducted at the municipal office of Commune III on September 19, 2018). On the edge of Niamey, there is an official waste disposal site, where collectors dispose of the collected waste. The site is located in the green belt area created during the period 1965–1995 to protect the city from sandstorms, on a 1 km wide belt of planted Neem woods. The green belt extends out for 25 km in an area surrounding the north-east side of the city.

The waste disposal site is managed by the Hygiene and Sanitation Service of Commune III, and only licensed waste collectors are allowed to unload waste following payment of a "tipping fee." The site serves as an intermediate transfer station, and the city council provide trucks to transfer the accumulated waste to a landfill site in the suburbs on the other side of the city. The green belt disposal site is 3 km from Quartier Kalley-Sud and is the nearest authorised area for waste disposal by waste collectors working in Commune III. Previously, open dumpsites were available behind markets in the city. However, under recent reforms, these unofficial dumpsites in the city centre were removed or cleaned up, with the aim of relocating them to the periphery of the city.

Use of the Services of Private Individual Waste Management Operators by Residents

The surveyed households in Commune III revealed that materials with utility or commercial value were segregated at source. For example, metals were sold to scrap metal businesses, PET bottles were reused by homemade juice businesses, and paper and wood were used as fuel for cooking, or as wrapping paper. The remaining unusable refuse was collected and transported to an authorized location by private individuals, called *mas shara* in Hausa or *fisi kuka* in the Zarma language. When residents wish to dispose of the waste stored at their houses, they go out into the street and call out to a *fisi kuka* with a pushcart. They then direct them to the waste bin in their home and request a refuse pickup. Depending on the size and weight of the bin, the *fisi kuka* earns a collection fee of 25–500 CFA francs (0.04–0.87 USD) per bin, but the final price is negotiable. Once the negotiations are concluded, the *fisi kuka* loads the waste into the cart and pushes the cart on foot to the disposal site (Fig. 4).

During the survey period of 2017–2018, waste produced by the seven surveyed households, and by several other households from the same neighbourhood, was collected by a waste collector named Mr. A, originally from a Fulbe village in Tillabéri Province. His career as a *fisi kuka* began in 2013, and he has since developed a network of clients in seven quarters of Communes III and IV. His

Fig. 4. A typical waste collection cart.

Table 6. Visits from a waste collector (Mr. A) and the amount of waste collected (July–September, 2018).

Date	Days between collection	Total wet weight (kg)	No. of dustbins	No. of households	Total collection fee (CFA Francs)[i)]
July 7	–	90.3	13	7	2,500
July 12	5	89.8	12	6	1,900
July 16	4	111.1	19	11	4,500
July 22	6	186.1	16	10	3,550
July 31	9	167.4	16	7	3,750
Aug. 5	5	114.5	13	9	2,650
Aug. 13	8	249.4	16	8	4,350
Aug. 17	4	165.7	13	3	3,950
Aug. 19	2	109.3	9	6	2,650
Aug. 21[ii)]	2	170.0	15	7	4,400
Aug. 23[ii)]	2	284.7	26	13	6,500
Aug. 30	7	121.9	19	8	3,750
Sep. 10	11	167.6	9	6	4,300
Sep. 16	6	132.8	13	9	3,600
Sep. 23	7	209.5	18	10	3,400

i) The total fee herein is the added total of collection fee offered by Mr. A for each measured bucket. Usually the collection fees are negotiated for discount, and occasionally collected on charges to the household's account.

ii) The festival of sacrifice, known as Eid-al-Adha or Tabaski, fell on August 22, 2018. Acute increase in waste could be observed in August before and after the festival.

clients include the seven households surveyed in this study, which he visits 1–3 times a week. Pushcarts are made locally and are available for rent. The total amount of waste loaded onto his pushcart, and the number of waste bins and households he collected from, was recorded (Table 6). The weight of each collection

varied from 90 to 284 kg per visit. In the summer of 2018, he had more than 25 household clients, as well as 3 business clients (restaurants and hotels), and made two daily roundtrips to collect their waste. His daily collection route covered a distance of 6.7–10.6 km.

There is no formal relationship between the *fisi kuka* and the households, with requests for refuse collection (and the promise of collections) made verbally. The collection fee is negotiable, so the collector can choose to leave the waste, while the households can use another service provider if they are unsatisfied with the proposed price.

Furthermore, during the same survey period, it was unusual to observe a resident transporting their own bin to the public waste containers in Commune III. Most households utilised the service of a *fisi kuka* to dispose of their daily waste. This may be explained by the accessibility of their services (i.e., by the frequent visits of collectors), and by the efficiency of the service arrangement between the client and collector. The structure of the housing compounds allows collectors to easily check when a pickup is required, and because several households share the compound there is always someone available to respond to the collector.

DISCUSSION

Characteristics of Household Waste in Niamey

The average weight of household waste per capita in Niamey was calculated to be 0.39 kg per person/day in the 2017 survey. When adjusted using the modified OECD equivalence scale, that figure increased to 0.87 kg per person/day. The non-adjusted value multiplied by Niamey's 2017 population of 1,164,000 persons yielded an estimate of 454 tonnes of waste generated daily. This figure does not represent all municipal waste, because it was based on data for middle-income households only; it did not consider low and high-income households, or commercial and industrial enterprises.

The observations in this study confirmed that the volume of sand and organic matter in household waste was closely connected to the lifestyles of the residents. The sand was largely transported by the Harmattan wind, and was mixed with organic waste and collected during daily sweeping of the sandy ground. Sand was the major constituent of the waste stream in previous surveys, representing 57% (Tini, 2003) and 70% (JICA, 2001) of the total waste, and was also the largest component of the waste (40%) in this survey.

In a report concerned with improvement of sanitation in Niamey, separation of sand was proposed as a key waste management measure, considering the economics and feasibility of the various treatment options (JICA, 2001). Separation of sand during primary collection inevitably incurs costs, as articulated in the report. However, sand has utility value and costs of separation could be recovered by recycling it for use as ground cover at the final discharge site, and as a construction material for the backfill and embankment. Preservation of land is a crucial environmental issue in Niger due to its susceptibility to erosion, flooding and soil

degradation (Issaka, 2010; Oyama, 2012). In addition, the report suggests that sand mixed with fine organic matter could be applied to agricultural fields. Oyama (2015) compared urban areas of Niger, where waste containing nutrients tends to accumulate, with rural areas that have low soil nutrient levels. The finding of this study that sand mixed with organic matter constitutes 85% of household waste confirms the ecological difference between urban and rural organic matter cycles.

The proportion of plastic waste in the household waste stream in Niamey has continuously increased, from 2% (Tini, 2003) to 3% (JICA 2001), and 9% (this survey). The consumption of plastics in Niamey is largely related to food packaging; hence, the majority of this waste is in the form of plastic bags.

To further assess the strengths of, and challenges associated with, MSWM in Niger, we examined the capital cities of two other countries, Japan and Ghana, with high- and lower-middle-income status, respectively. High-income countries in Asia, such as Japan, collect almost 100% of their waste (Kaza et al., 2018: 41). The key characteristics of Tokyo's household waste are its large quantity and the fact that treatment relies exclusively on incineration. Households in the mega-metropolis of Tokyo generated 0.67 kg of waste per person/day in 2014 (MOEJ, 2017). The 3.7 million households in Tokyo generate 2.27 million tonnes of waste per year, equivalent to 6,917 tonnes a day. The household waste in Tokyo's 23 wards can be broken down into food waste (49%), paper (30%), plastics (12%), glass (2.4%), metal (2.0%) and others (Oikawa et al., 2000). Recyclables, such as paper, plastics, glass and cans, which are separated by households or segregated later for resource recovery, account for 20% of all waste; the remaining 80% of the waste stream is sent to incineration plants and the ash is then disposed of in landfills. These waste treatment facilities are considered undesirable in residential areas and are thus located in neighbouring regions or the reclaimed foreshore (Bureau of Environment, Tokyo Metropolitan Government, 2009; Tsukui et al., 2015). Incineration is used as a waste disposal option due to the limited land availability and rising land prices (Kaza et al., 2018: 42). Like Tokyo, Niamey is also facing urban expansion and rising land prices. However, the dominance of sand in Niamey's waste implies that incineration is not a suitable treatment option for that city.(7)

In Accra, per capita waste generation has increased from 0.4 (Fobil et al., 2008) to 0.74 kg per person/day (Miezah et al., 2015). The household waste composition in Accra for the period 2013–2014 showed a decrease in organic matter (61%) and inert materials (5%), while plastics (14%), and metals and glass (6%) displayed increasing trends (Miezah et al., 2015). A high rate of illegal disposal in drainage areas, river channels and open spaces has been documented in Accra (Oteng-Ababio, 2014). In the early 2000s, many initiatives emerged to tackle this issue, driven by non-governmental organisations (NGOs) and youth community-based organisations. According to Oteng-Ababio (2014), plastic recycling projects have generated income for young people. However, opportunities for recycling organics remain poor due to the operational difficulties associated with compost plants and the lack of separation at source.

In all three cities, Tokyo, Accra and Niamey, the increase in organic and plastic waste illustrates increased consumption of food and, by extension, use of plastic

packaging. In Tokyo, single-person households (41%) generate 1.5 times more waste per person than households with more than two people (Tsukui et al., 2015). Additionally, 80% of the plastic generated is packaging (Oikawa et al., 2000). The increasing volume of plastic waste in Accra has been attributed to an upsurge in the use of polythene bags (for take-away food orders) and water sachet bags (Fobil & Hogarh, 2006). In Niamey, single-person households account for less than 10% of all households, but there has been an influx of young male migrant workers who consume take-away food daily, which, along with greater use of plastic packaging, is likely to continue. The above discussion highlights the importance of segregating sand from organic matter mixture and other recyclables in household waste in Niamey.

Waste Collection System in Niamey

Building on the review of waste stream characteristics, this section considers two aspects of locally sustainable waste management in Niamey: 1) the system for waste collection and treatment, and 2) the financial resources that support it.

Operational costs, including treatment, transport, segregation, and landfill construction and management, are heavily subsidized by the government (Kaza et al., 2018). In Japan, the soaring economic and environmental costs are met by municipal funds, but there has been a gradual shift towards the valorisation of waste sources. By 2015, 80% of Japanese local authorities had started to impose charges on MSW at the household level, in the form of prepaid garbage bags or stickers in pay-as-you-throw (PAYT) systems (MOEJ, 2017). Unit-based pricing (per bag) policies provide an economic incentive to reduce the amount of household solid waste (Okuda & Thomson, 2007; Usui, 2008).

In African cities, primary MSW collection is often non-capital intensive and is conducted by small and micro-scale service providers (UNEP, 2018: 32). Communal and block collections using manual equipment (e.g., pushcarts, tricycles or wheelbarrows) are common in low-income areas and informal settlements where the roads are poor and often narrow (Soós et al., 2013).

In Accra, waste collectors known as "*kaya bolas*" (meaning truck boys, waste pickers or cart pushers), who operate as informal groups of private individuals providing house-to-house waste collection services for a fee, use specially built carts to transport waste (Oteng-Ababio, 2012). In contrast, communal container collection systems serve high-density, low- and middle-income areas, where road access is difficult. Under this system, residents are expected to carry their waste to a communal container that is later emptied into a collection truck. Access to empty communal containers provided by the local municipalities is often inadequate. In some parts of Accra, the communal collection system collects a monthly flat fee from each household. Oduro-Kwarteng (2011) found an association between dissatisfaction with current service quality and the willingness to pay. In these areas, there is an unwillingness among households to register for collection services, which is linked to the low payment rate of those in low-income communities, and to the high rates of illegal and indiscriminate dumping.

Alhassan et al. (2017: 188) found that residents who must walk long distances

to discharge waste were more willing to pay for better waste collection services. Residents benefitting from door-to-door collections were more willing to pay than those in areas without that service (Afroz et al., 2009: 502). Studies in different cities have confirmed that a resident's willingness to pay for improved services increases when the accessibility, quality and efficiency of the primary collection service improves (cf. Afroz et al., 2009; Oduro-Kwarteng & van Djik, 2013).

The housewives of each household are the principal clients for the *fisi kuka* in Niamey. These women are generally responsible for dealing with household waste and must make alternative arrangements in the absence of a regular and reliable collection service. Their direct involvement with waste handling, and concerns regarding health risks, affect resident preferences regarding methods for and approaches to waste management (Muller & Scheinberg, 1999; Adebo & Ajewole, 2012: 234; UNEP & ISWA, 2015: 197).

Wilson et al. (2013) described how the informal sector provides efficient, effective and affordable waste management systems that are tailored to local needs and conditions, and were developed with direct involvement of the service beneficiaries. Collection charges would likely be a burden for most households in Niamey. Even so, due to the scarcity and remoteness of public waste containers and official deposit points, residents are willing to pay for collections. The main clients of *fisi kuka* are the women responsible for maintaining the cleanliness of their compound, and they directly negotiate the collection price with the collectors. The waste collectors with pushcarts are young men who have the tools and strength necessary to handle the increasingly heavy waste; this removes the burden on young boys in the compounds to perform waste disposal chores. Private household waste collection is a much needed service for the residents of Niamey.

CONCLUSION

In summary, private waste collectors in Niamey are valuable because they provide several useful services. First, *fisi kuka* provide a door-to-door collection service, freeing residents from the tiresome chore of disposing of their own waste. Second, the collection fees are negotiable and affordable, and small quantities of waste can be collected depending on the client's willingness to pay. Third, the technology and skills required for waste collection are available locally and can also be acquired by new entrants to the market, allowing seasonal migrant workers to participate in the MSWM business. Finally, due to the partial freedom[8] to operate independently from the public sector, service providers can cover a large area, including both low- and high-income quarters.

Important characteristics of primary waste collectors include their demand responsiveness and close relationships with clients (Ahmed & Ali, 2004). We can conclude that the waste collection services provided by private individuals in Niamey are sustained by the support of residents, mediated by the face-to-face nature of the relationships between the collectors and their clients.

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NOTES

(1) For waste characterisation, two sampling approaches are generally used (Edjabou et al., 2015). The simplest method is to sample directly from the source of waste; the other method involves sampling from trucks or containers at disposal sites.
(2) The administrative divisions of Niamey were created based on the administrative structures and urban planning methods used in France. The Niamey Urban Community includes 5 communes (municipality), which are further divided into 58 quartiers (quarters) and 46 villages.
(3) The waste in this survey was voluntarily provided to the author for the purpose of measuring its weight and recording its contents.
(4) A significant discrepancy in the weight data for waste from household No.1 was apparent, due to the disposal of waste from a home-based furniture workshop. The waste discarded by that household on October 29, 2017 contained a total of 21.5 kg of discarded furniture materials, together with 63.4 kg of sand.
(5) Prices in CFA francs were calculated using the average exchange rate of the last three years (2017–2019): 1 USD = 574.14 CFA francs.
(6) The modified OECD scale assigns a value of 1.0 to the household head, 0.5 to each additional adult householder and 0.3 to each child. Using this equivalence scale, the age of household members can be adjusted for, with the data thus appropriately reflecting the size of the household in proportion to its consumption (OECD, 2008).
(7) If the energy content (lower calorific value) is inefficient or there is an extreme waste profile (i.e., only sand or plastic), the waste is unsuitable for incineration (World Bank, 1999).
(8) The term “partial freedom/independence” refers to the revenue of individuals engaged in private waste collection activities independently of the city council and municipal government. They are not employed by the municipality; however, they are prohibited by law from illegal dumping. As Scheinberg et al. (2011) noted, unlike the conventional “informal” sector, characterised by having an unregulated (not paying taxes) or unregistered (having no trading licence) status, private waste operators in Niamey are under surveillance by local authorities and subject to licencing and tipping fees that must be paid at the official waste disposal site.

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