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Composition of plastic waste discarded by households and its management approaches

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ABSTRACT

Among the emerging environmental issues within Sub-Saharan Africa is the haphazard disposal of plastic waste, some of which end up downstream in the marine environment leading to negative effects. Notably there have been cases of humpback whales getting entangled in 'ghost' fishing nets, and endangered turtles ingesting plastic wastes in Watamu beach in Kenya. The aim of the current study was to assess the composition and management of plastic waste discarded by households in Watamu ward. Stratified random sampling was used to collect data from households in four sub-locations within Watamu ward. Data were analysed using descriptive and inferential statistics (the Freeman-Halton extension of the *Fisher's* Exact test). The composition of plastics usually discarded as waste by households in order of dominance were low density polyethylene, polyethylene terephthalate, high density polyethylene and polypropylene (FH=37.959, p = 0.000). From the results, only 0.7% of respondents recycled their plastic waste. The most preferred disposal method of household plastic waste was open dumpsites (61.4%) followed by burning (12.9%) and discards (6.4%). Majority of respondents (93.6%), re-use some plastic containers for food, water, and oil storage. There was a significant difference in terms of how the respondents re-used their plastic waste in the four sub-locations (FH=36.437, p=0.005). In conclusion, the current plastic waste disposal methods at Watamu are not environmentally friendly and recycling is still at a smaller scale despite its potential to generate income and clean the environment, and promote ecosystem services and human wellbeing.

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INTRODUCTION

Urbanization and increased resource consumption in most developing countries have brought about some environmental challenges such as waste management (Gugssa, 2012; Tiruneh *et al.*, 2015; Bello *et al.*, 2016). The main composition of waste discarded from households in most developing countries, in order of dominance, is food waste, followed by paper waste followed by plastic waste (UNEP, 2009; Bernache-Pérez *et al.*, 2016). Among the contributors to the generation of household solid waste (HSW) include household size and income. As household size increases, the waste generation

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reduces while the higher the income, the higher the waste generation rates (Thanh *et al.,* 2011). It is important to know the composition of these HSW in order to allow for appropriate planning of solid waste management strategies by relevant functions such as county or municipal authorities. In Africa, waste management is usually the responsibility of devolved county or municipal authorities, and these entities have often failed to live up to the required standards as managing waste is usually beyond their capacity (Rotich *et al.,* 2006; Remigios, 2010). This scenario is true for Kenya where waste management in urban areas is wanting (County Government of Kilifi, 2018; County Government of Mombasa, 2018). Waste collection trucks are in most cases unable to access many residential or commercial areas where wastes are generated and placed in dustbins or pits because of poor roads, and, oftentimes, the available trucks are overwhelmed by the scope of service demands. This has led to the accumulation of wastes in temporary holding centres, collection sites, outlet drains and open grounds which is a health hazard and poses negative impacts on human well-being and compromises ecosystem services (Rotich *et al.*, 2006; Selin, 2013). In addition, waste management in Africa faces problems that have to do with less responsive politics, socio-economic and legal frameworks that require urgent attention (UNIDO, 2009). Globally, the presence of plastics in disposed waste materials has grown over the years as production and use of plastics has risen. By 2016, plastic production in the world rose to around 280 million tonnes (PlasticsEurope, 2017), and this increase has been matched with a steady increase in industrial production and demand-driven consumption resulting in a proportionate rise in plastic waste in solid waste streams in large cities (Fobil and Hogarh, 2006). In Kenya, plastic waste is mostly disposed of unsegregated (KNCPC, 2006; Wachira *et al.*, 2014). As a result, plastic waste is an emerging environmental challenge as it is usually disposed of haphazardly by residents in both rural and urban areas leading to its build-up and accumulation in residential neighbourhoods and negative effects on ecosystem services and human well-being. Plastics pose a unique problem in waste management as they are not easily biodegradable. Whole pieces or parts of physically shredded pieces of plastics leak into the oceans, and globally this has been estimated at around 8 million metric tons/year (Jambeck *et al.*, 2015). Similarly, globally around 93 to 236 thousand metric tons of these plastic wastes are microplastics (Sebille *et al.*, 2015). In the rapidly developing coastal countries, the emerging challenge in managing plastic wastes is associated with a substantial volume that ends up into the oceans, with the largest estimated quantities known to come from a relatively small number of middle-income, high lifestyle consumer groups (Jambeck *et al.,* 2015). This is attributed to the fact that these rapidly developing countries, which also have some of the lowest waste collection rates on the planet, do not have effective waste management systems, and if they do, these are at best informal, less coordinated, and poorly planned activities (Gugssa, 2012; Jambeck *et al.,* 2015; Quartey *et al.,* 2015). Plastics are also known to degrade slowly, during which time they release toxins to the environment. Recent studies have shown that plastic degradation triggered by ultraviolet light leads to the production of some methane (Yun, 2018) which is a greenhouse gas. It is in this line that the United Nation has come up with sustainable development goals (SDGs) that address the issues of development in a sustainable way. The SDGs that concern environmental waste management relevant to plastic production and management are clustered around Goal 11 (Sustainable Cities and Communities), Goal 12 (Responsible Consumption and Production), Goal 14 (Life below Water) and Goal 6 (Clean Water and Sanitation). The social consequences of these plastic waste build up along coastal areas is multifaceted. The main social consequence is on occupational health, welfare and security: coastal communities in rapidly developing countries, especially the vulnerable groups such as women, youth and the unemployed urban poor, live very close to the areas where dumping of wastes is common and these groups are more severely impacted by these poorly managed wastes. Over 90% of waste is often disposed in unregulated, unsegregated, and, oftentimes, illegal open dumpsites or openly burned (Remigios, 2010; UN Environment, 2018) as has been seen in Kenya at the coastal city of Mombasa's main dumpsites of Kibarani and Mwakirunge. Poorly managed waste serves as a breeding ground for disease vectors and even promotes urban violence, which unfortunately has negatively affected women and girls. The other consequence is the opportunity losses. In Kenya, for example, tourism is a major contributor to the national Gross Domestic Product (GDP), contributing up to 10% in a good year as happened in the year 2014

(WTTC, 2015). When waste in general, and plastic waste in particular, remains uncollected, it pollutes the aesthetic value of towns as destinations. Moreover, when plastic waste finds its way to the beaches and the oceans, it leads to degradation of the oceans and beaches which is a set of touristic. In Kenya, cases of humpback whales getting entangled in abandoned 'ghost' fishing nets, endangered turtles ingesting plastic wastes, and beaches littered with countless types of plastics have been reported by fishermen along Watamu beach, Kenya. Polluted beaches and towns often repel tourists because of their appearance that is not aesthetically pleasing and thereby reducing revenue. In areas where this loss has been quantified such as in the Goeje Island (Republic of Korea) and the Asia Pacific Economic Communities (APEC), revenue losses were up to €29-37 and US$622 million per year respectively were recorded (Watkins *et al.*, 2015). This causes people dependent on the tourism industry to lose their daily source of income. Kenya has a strategy and action plan for plastic waste management under the auspices of the National Environment Management Authority (NEMA). This strategy seeks to promote the recycling and re-use of plastics that will not only create a clean environment but also enable the government to generate lots of income from recycling and exporting plastics (KNCPC, 2006; NEMA 2018). The ban on thin-carrier plastic bags in Kenya (NEMA, 2017) has been lauded as a decisive step by the government to help clean up the environment. In addition, the amended Environmental Management and Coordination Act (EMCA, 2015) of NEMA has put more stringent penalties for environmental offences (such as not complying with the Plastic Carrier Bags Ban) in section 144 of the Act (EMCA (Amendment) Act, 2015). Probably the next phase of the campaign against plastic pollution should shift to marine plastics, as the envisaged re-use and recycling is not helping as much as it should (Gugssa, 2012). In order to achieve both national targets and UN targets, Kenya has to invest in coordinated and synergistic initiatives and activities that are informed by science and local data, on the scale and impacts of plastic pollution so that interventions are targeted to problem areas and the choice of intervention is appropriate to the plastic problem involved, such as on hotspot sources, kinds of build-up in dumping areas, types and composition of plastic involved, existing monitoring programs as well the fate of plastic disposed and their impacts on the environment and on human health. This, therefore, underpins the need for a proper plastic waste assessment to inform management interventions to reduce the 'backlog' of plastic waste already in existence (Kershaw *et al.,* 2011). This study will add knowledge and data for this initiative. Plastic waste may constitute various items such as plastic straws, plastic bottles, plastic carrier bags, food wrappings and containers as well as tiny invisible micro-plastics occurring in air and water. Plastics have been categorized either as thermoplastics or thermosets (UNEP, 2009; Brems *et al.*, 2012; Hansen *et al.*, 2013; PlasticsEurope, 2017). Thermoplastics, when heated, do not undergo chemical reactions and can, therefore, be re-moulded several times (UNEP, 2009; Hansen *et al.* 2013) while thermosets under different temperature regimes may undergo chemical reactions to form new substances (Hansen *et al.* 2013). Thermoplastics include polyethylene (PE) such as low density polyethylene (LDPE) and high density polyethylene (HDPE), polyethylene terephthalate (PET), polypropylene (PP), polyamides (PA), polycarbonate (PC), polyvinyl chloride (PVC), polystyrene (PS) and polytetrafluoroethylene (PTFE), among others, while thermosets include silicon, melamine resin and vinyl ester (Hansen *et al.*, 2013; PlasticsEurope, 2017). It is important to note that thermoplastics contribute to the total plastic consumption by about 80%, and are used for typical plastics applications such as packaging (Table 1) but also in non-plastic applications such as textile fibres and coatings (Brems *et al.*, 2012). Previous studies done in Kenya on plastic waste have looked at the plastic waste sources and factors causing the problem of plastic bag waste as well as its sustainable management, the circularity level of Kenya's plastic material flow, as well as innovations centred around plastic waste (Bahri, 2005; Odhiambo *et al.*, 2014; Oyake-Ombis *et al.*, 2015; Horvath *et al.*, 2018). However, the types and composition of plastic waste discarded by households have not received adequate focus. This is more so critical as, besides impacts on the environment and on human health, plastic waste is also a threat to Kenya's tourist development as mentioned earlier. This study adds to the knowledge gaps in the composition of plastic waste discarded, current reuse levels and recycling initiatives by households in Watamu. The study site, Watamu, is a tourist town along the Kenyan coast, and, whose plastic-driven anthropogenic activities have a potential of impacting touristic assets: marine life in the protected Watamu

Marine Park as well as impacting negatively on local livelihoods that are directly depended on marine resources. This study was undertaken between in Watamu ward, Kilifi County, Kenya in 2017.

Demographic characteristics of the case study site

Watamu ward is located in Kilifi North constituency in Kilifi county that has a population of 1,498,647, of which 775,443 are females (County Government of Kilifi, 2018). Kilifi North Constituency has the highest population in the county (280,337) (County Government of Kilifi, 2018) with 54% of its population having gone through primary education. In Watamu ward, 54.4% of the population have undergone primary education and the sex ratio is 1.031, males being slightly more (Ngugi, 2013). The demographic characteristic of the study site, based on data collected from households in Watamu, is summarized in Table 2. In summary, 52.1% of the household participants were in the age group of 18 – 35 years. A majority of the respondents were therefore young people similar to a study in Ongata Rongai where 46.7% of the respondents were aged between the ages of 21 to 30 years (Wachira *et al*., 2014). This is in line with the fact that 80% of the Kenyan population is below 35 years (Awiti and Scott, 2016). The demographic characteristic showed that 60.7% of the respondents had attended primary school education and 85.8% had lived in the area for more than 10 years showing that most respondents were in a position to give accurate information on management of plastic waste and practices in the area as well as impacts of plastic waste on the environment in Watamu (Table 2). In addition, 50% of the household heads interviewed had one to five members in their households (Table 2).

MATERIALS AND METHODS

Description of the study area

Watamu ward which is located in Kilifi North Constituency in Kilifi County, 105 km north of Mombasa and about 15 km south of Malindi on the Indian Ocean coast of Kenya. The coordinates for Watamu are latitude 3.3425° south of the Equator and longitude 40.0274° east of the Greenwich Meridian (Fig. 1). It is situated between the Blue Lagoon and Watamu Bay and has gently sloping beaches sheltered behind a fringing reef with white calcareous sand of marine origin (coral sand) (Tychsen, 2006). The land mass is approximately 59.20 km^2 and has four sub-locations namely; Jimba, Mbaraka Chembe, Watamu and Chembe Kibabamuche (Fig. 1). Watamu ward has a population of 25,982 people with 5,449 households (Ngugi, 2013). The climate and oceanographic conditions of the Kenyan coast follow a monsoonal cycle driven by the north-south migration of the Inter-tropical convergence zone (ITCZ) (Tychsen, 2006).

Tourism is the most important economic activity of Watamu and it employs most of its population. This is followed by small businesses such as shopkeeping, selling groceries and small restaurants (Carter and

Table 1: Types of plastics and their recycling and re-use potential (Seaman, 2012)

Plastic Type	Example of applications	Assigned number and recycling and re-use
PET	Salad dressing containers, processed meat packages, plastic soft drink and water bottles.	1 1) recycled but not re-used
HDPE	Milk bottles, shampoo bottles, detergent bottles, oil jerry cans, and toys	2) re-usable and recyclable
PVC	Fruit plastic packing, sweet trays and blister packaging.	3) not recyclable nor re-usable*
LDPE	Bread bags, frozen food bags, squeezable bottles, fibre, bottles, clothing, furniture, carpet, shrink-wraps and garment bags.	4) re-usable but rarely recyclable
PP	Margarine and yoghurt containers, caps for containers, and wrapping to replace cellophane.	5) reusable but rarely recyclable
PS	Egg cartons, fast food trays, and disposable plastic silverware.	6) reusable but rarely recyclable
Other	This includes an item which is made with a resin other than the six listed above or a combination of different resins	7) none – not recyclable nor re-usable except those with polylactic acid (PLA) coding underneath

*Although it is not recommended to re-use PVC, it can be repurposed for other functions excluding food and children use

Garaway, 2014). Fishing is also a major source of income in the area, with some people doing also other casual jobs, and very few being employed by government institutions (Carter and Garaway, 2014). Kilifi county has the third highest poverty severity in Kenya (severity of poverty as a percent of the national poverty line is 21%) (Njonjo, 2013) and therefore poor people in this county are really poor.

Research and sampling design

The study employed a social survey research design. The target population of the study comprised of residents of Watamu ward. The total household population within the ward is 5,449. The sampling frame consisted of four sub-locations within Watamu ward from which data were collected, namely Jimba, Mbaraka Chembe, Watamu and Chembe Kibabamuche (Table 3). Two methods of survey were used: questionnaires and interview schedules. The main target sampling frame was households, where questionnaires were administered. Additional supporting data were obtained from other strategic partners (stakeholders) where interview schedules were administered. For households, prior to the administration of questionnaires, target population was selected through a methodological sequence:

Table 2: Demographic Characteristics of Watamu residents

Demographic profile	Category	Females (n=102) Frequency (%)	Males (n=38) Frequency (%)	Total (n=140) Frequency (%)
Age	18 – 35 years	52 (51.0)	21 (55.3)	73 (52.1)
	36 – 45 years	32 (31.4)	7 (18.4)	39 (27.9)
	Above 45 years	18 (17.6)	10 (26.3)	28 (20.0)
Education	None	26 (25.5)	3 (7.9)	29 (20.7)
	Primary	63 (61.7)	22 (57.9)	85 (60.7)
	Secondary	12 (11.8)	12 (31.6)	24 (17.2)
	Tertiary	1 (1.0)	1 (2.6)	2 (1.4)
Duration of stay in the area	1 – 5 years	5 (4.9)	5 (13.2)	10 (7.1)
	5 – 10 years	7 (6.9)	3 (7.9)	10 (7.1)
	More than 10 years	90 (88.2)	30 (78.9)	120 (85.8)
Number in household	1 – 5	51 (50.0)	19 (50.0)	70 (50.0)
	6 – 10	47 (46.1)	15 (39.5)	62 (44.3)
	11 – 15	4 (3.9)	3 (7.9)	7 (5.0)
	16+	0 (0.0)	1 (2.6)	1 (0.7)

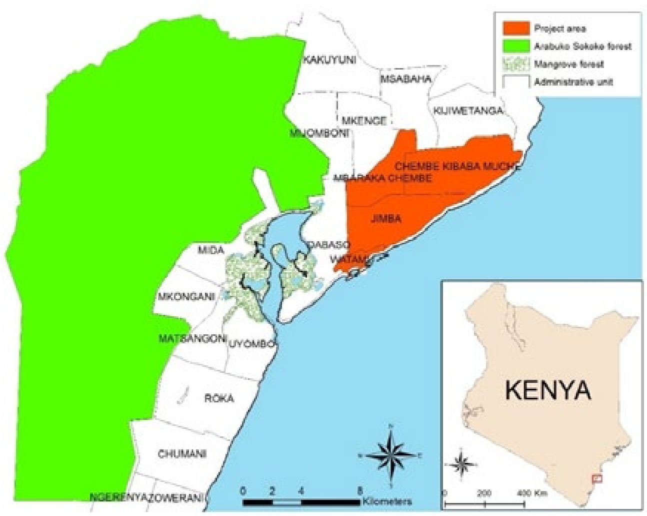

Fig. 1: Geographic location of the study area in Watamu of Kenya

stratified random sampling was used in which the population of Watamu ward was divided into various strata of interest that were identified, that is, their sub-locations (Table 3). This ensured that the entire Watamu ward population was well represented to facilitate a generalisation of the results. Data on the total number of household population in Watamu ward and sub-locations were obtained from a publication of the Kenya National Bureau of Statistics (KNBS) (Ngugi, 2013) and were used to get the proportions of the sample sizes of each sub-location (Table 3). Simple random sampling was used to select households from the sub-location population from which data will be collected using questionnaires. This is in concurrence with the sampling design used in a study by Awodele *et al.*, 2016. Households were selected randomly such that each household had an equal chance of being selected. This helped to eliminate bias in household sample selections. A total of 140 households were sampled by questionnaire. Each household, therefore, constituted a sample size for the administration of the questionnaires. For the additional information from other strategic partners, interview schedule was administered. The study interviewed five hotel managers in Watamu, three fishermen, two boat operators, and one officer from the Department of Environment (Watamu).

The sample size for the study was determined using Mugenda and Mugenda's Eq. 1 (Swaleh *et al.*, 2015).

$$n_0 = \frac{Z^2 \times P(1-P)}{d^2} \tag{1}$$

Z = the standard normal deviation at the required confidence level (1.96 for 95% confidence level)

p = the proportion in the target population estimated to have characteristics being measured (0.5)

d^2 = the level of statistical significance test

The value of *N* according to this formula, assuming the value of *p* is 0.5, and the confidence level is 95%, was calculated as Eq. 2.

$$n_0 = \frac{1.96^2 \times 0.5(1-0.5)}{0.05^2} = \frac{0.9604}{0.0025} = \tag{2}$$
$$= 384.16 \approx 385\ respondents$$

Since the population of households in the study area was less than 10,000 (5,449 households), the sample size was determined using Eq. 3 (Gitonga, 2018).

$$n_f = \frac{n}{1+\frac{n}{N}} \tag{3}$$

n_f = sample size when population is below 10,000

n = sample size when population is above 10,000

N = population size

The value of n was 385 while the value of N was 5449 and calculated as Eq. 4.

$$n_f = \frac{385}{1+\frac{385}{5449}} = \frac{385}{1.0707} = 359.59 \approx 360\ respondents \tag{4}$$

There were time and resource challenges that prompted the study to use 40% of the desired sample size of 360 respondents to come up with 140 respondents as the sample size (Swaleh *et al.*, 2015). This was rounded off from 143.83.

Data collection instruments

Primary data were collected using semi-structured questionnaires. Most of the questions were closed-ended although there were a few open-ended questions. The questionnaire was divided into sections based on the study objectives, with the first section covering demographics. The questionnaires were filled in the presence of the researcher so as to ensure that all questions were understood. In the questionnaire, the household respondents stated the types of plastics that they usually discarded as waste

Table 3: Sample size of the population obtained from four sub-locations in Watamu ward

Sub-location	Household population	Sample size (hp/ thp × 140)*
Watamu	2795	71.8 ≈ 72
Jimba	1270	32.6 ≈ 33
Chembe Kibabamuche	590	15.2 ≈ 15
Mbaraka Chembe	794	20.4 ≈ 20

*hp: household population; thp: total household population but did not classify the plastic types as this was not common knowledge. Instead, this was classified by the researcher based on the known coding classification of plastics established by the Society of Plastics Industry (SPI) (Bashir, 2013). A semi-structured interview schedule was also used to interview some of the respondents, namely, hoteliers, boat operators, Kenya Wildlife Service (KWS) and fishermen. This technique enabled the assessment of people's knowledge, attitude and perception with respect to plastic waste disposal. An observation checklist was also adopted where the researcher recorded issues on plastic waste management as observed during the assessment. Additional information on plastic categories and management were obtained from referenced books, sessional papers, journals, newspapers and the internet. This information was used to get information on the classification codes of plastics as well as their application. Secondary data on the population of households was gotten from the KNBS and used to come up with sample sizes.

Data analysis

The data were analysed using descriptive and inferential statistics. Descriptive statistics included measures of central tendency and was used to explain the variables under study such as in characterizing the plastic waste produced in the study area and describing their sources. Descriptive statistics were also used in describing the existing plastic waste management methods in the study area. Inferential statistics were also used to make inferences from the data obtained, such as establishing the relationship between how respondents re-used their plastics and their respective sub-locations (Freeman-Halton extension of the *Fisher's* exact test).

RESULTS AND DISCUSSION

Composition of plastic waste in Watamu ward

A Freeman-Halton extension of Fisher's Exact test showed that LDPE discarded was significantly higher than other types of plastic wastes (FH = 37.959, $p = 0.000$) standing at 55% of the plastic waste discarded, followed by PET combined LDPE at 40.7%. HDPE and PP at 2.9% and 1% respectively were of low occurrence in plastics discarded from households (Fig. 2). PPs have a low value, LDPE has medium value, while HDPE and PET have a high value (Merkl, 2016). The two main sources of plastic pollution in the world according to Ocean Conservancy is plastic waste that remains uncollected as well as plastics with a low value such as PP (Merkl, 2016). Compared to HDPE, LDPE has a lesser value and is likely to be left out when plastics are being sought for re-use or recycling. This, therefore, results in more LDPE plastics in the environment compared to HDPE such as is the case in Watamu where 55% of the plastic waste discarded by households is LDPE plastic. In addition, the types of plastics discarded by households in Watamu was consistent with the standard types that are usually discarded by households namely, HDPE, LDPE, PET and PP (Banerjee *et al.*, 2014).

Existing plastic waste management methods: recycling and re-use

There were attempts for re-use and recycle plastics within Watamu in different and novel ways. A Freeman-Halton extension of *Fisher's* Exact test done revealed a significant difference in terms of how the respondents re-used their plastic waste in the four different sub-locations (FH = 36.44, p = 0.005). From this study, the more urbanite groups in Watamu and Jimba households re-used their old plastic oil containers at 42.4% and 56.7%, respectively, for water storage. In the more rural settings of Chembe Kibabamuche and Mbaraka Chembe, reuse of plastics stood at 26.7% and 30% respectively for water storage. There was, therefore, more re-use of plastic for water storage in the urban areas of Watamu ward compared to the rural areas of Watamu ward. The reason for this could be the fact that there were more activities in the more urban areas that generated plastic waste that was available for water storage re-use. This study compares with a study in Beijing, where a higher proportion (at 13.11%) of plastics in urban areas was recorded relative to a low proportion (at 6.02%) in rural areas (Yang *et al.*, 2012). Therefore, there is more plastic waste in urban areas available for re-use compared to rural areas. Urban areas are characterized by the presence of more markets and businesses that usually use plastic products in their daily operations such as plastic oil jerrycans as in the case of restaurants and shops. Therefore, these jerrycans were accessible to the locals in Watamu for re-use in water storage once the oil was all used up. The re-use done by locals is however limited in scope, as demonstrated by Eco-world. The main re-use function was in the HDPE fractions where old buckets were re-used for collecting portable water and storing water (Fig. 3).

Some HDPE buckets were re-used to store foodstuff. Some broken pieces of HDPE were re-used for repair of other plastics whereby broken pieces are first heated to melting temperatures, and the resulting mould applied to repair or maintain leaks or cracks in other relatively good plastics and still others converted broken plastics into dustpans. This may explain why the presence of HDPE was low (2.9%) in the plastic wastes discarded by household in Watamu (Fig. 2). Other re-use functions were from PETs where used containers were re-used for storing fresh juice, oil storage, and general storage. The re-cycling path in Watamu is driven by the presence of a recycling plant, Eco-world, which receives mostly plastics made from HDPE for their recycling needs. Incidentally, information in the plastics literature shows that LDPE has a low recycling value than HDPE and PET (Merkl 2016). Therefore, compared to HDPE, LDPE is likely to be left out when plastics are being sought for sale to recycling firm that exists in Watamu, therefore being thrown away as discards. This, therefore, results in more LDPE plastics in the environment at Watamu. This is corroborated by a study in Vietnam that found LDPEs to be the major component of plastic waste generation among households there (Thanh *et al.*, 2011). Re-purposing plastic items for a different purpose once it has been used is a common form of re-use (Henningsen *et al.*, 2010) and has been adopted by most households informally in Watamu. In corroboration, a study done in Vietnam showed there was limited re-use of plastics that was being undertaken by the households (Thanh *et al.*, 2011). The reason for this similarity could be the high levels of poverty in both areas (Thanh *et al.*, 2011; Njonjo, 2013; Hoornweg and Bhada-Tata, 2012).

Despite the presence of a recycling plant, Eco-world, (formerly known as Watamu Waste Recycling Centre), some households are constrained from taking advantage of this due to low levels of HDPE in their discarded plastic waste (2.9 %) (Fig. 2). In addition, the distance of the plant from some households may also be an additional barrier. Households living further away from the plant may find taking their HDPE plastic wastes to the plant a challenge because of time, cost of transportation and the distance to be covered.

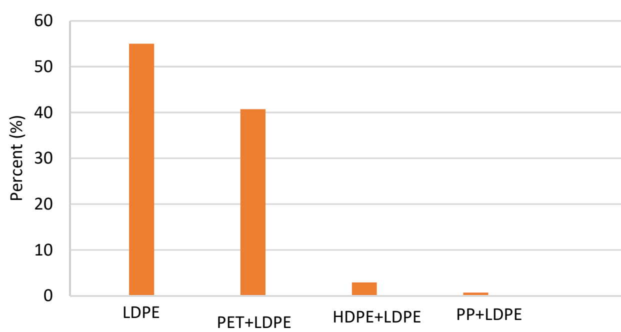

Fig. 2: The proportion of different types of plastics discarded from households in Watamu

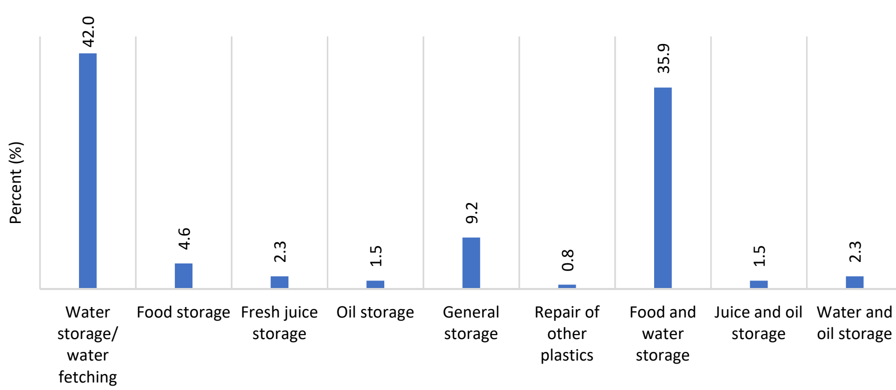

Fig. 3: Re-use methods of plastic items in Watamu ward

During the study, it became clear to the researcher that Eco-world had employed some locals to collect plastic wastes from the beaches to bring to the firm for recycling, in addition to re-working them into other products for sale, artwork and sensitization. These plastic products were used to raise awareness among tourists and locals on the harmful impacts of plastic waste on marine life.

Plastic disposal practices in Watamu

Despite these various re-uses and re-cycling functions demonstrated above, each accounted for only about 0.7% of the total flow of plastics (Fig. 4). Re-use and recycling from households are therefore only practised to a limited extent. The scenario depicted is that about 98% of litter from households is disposed of in the following order of dominance: dumpsite discards (61.4%), burning discards (12.9%), open discards but also burns when they became too much (12.9%), and open litter discards (7%) (Fig. 4). The author observed that households generally did not sort their plastic waste from other types of waste. Other studies in Kenya and in Ethiopia have also reported a lack of source-separation of waste (Aurah, 2013; Odhiambo *et al.*, 2014; Tiruneh *et al.*, 2015)This, in turn, decreases the efficiency of recycling (Banerjee *et al.*, 2014) due to contamination of plastics with other items. A study in Ghana found that the buying of plastic items for re-use encouraged separation of plastics from other items at the source among low and medium-income households (Gugssa, 2012). Therefore, incentives such as buying plastics from households can be used to encourage source-separation. The social arrangement that was observed in the study site was that there were respected elders locally known as "*wazee wa mtaa*" who ensured that households maintained cleanliness in the community when it came to waste management. This explains why 61.4% discarded their plastic waste at the dumpsite. However, the 12.9% who burned their plastic waste show that people do not understand the negative health effects associated with the open burning of plastic waste. The 6.4% who discarded their plastic waste as litter in open areas can be linked to people who have adopted a "throw-away" culture that throws waste anywhere without thinking about the consequences on the environment.

In addition, there was only one designated dumpsite that was located in Watamu sub-location and this could have caused some people living further away to resort to more convenient ways like burning and discarding as litter. The lack of waste collection receptacles such as dustbins may have explained why 6.4% discard plastic waste as litter. This behaviour, if not dealt with may result in more portions of waste getting dumped in open spaces, making the tourist town to lose the aesthetically pleasing value and thereby reduce tourist numbers leading to loss of revenues as was the case in Korea and the Asia Pacific Economic Community (APEC) (Watkins *et al.*, 2015). In a related study in Shambu town in Oromia, Ethiopia, dumping of solid waste and burning in open disposal sites were used as the major methods of waste disposal, with open burning generating harmful dioxins and nitrous oxides (Tsega, 2013). Along the coast of Kenya, not only are the dumpsites are usually poorly located but the collection services of waste are also below standard with only 50% of the solid waste generated being collected because of the inadequate and appropriate waste collection vehicles (Lane *et al.*, 2007). Hence, some areas are not able to be reached in waste collection. Moreover, the private sector dealing with solid waste are usually

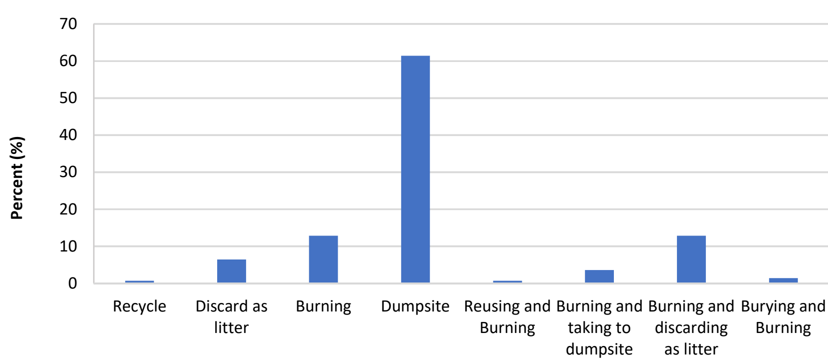

Fig. 4: Plastic waste disposal methods among households in Watamu ward

more focussed on profits as opposed to dumping in designated areas (Lane *et al.*, 2007).

It was also observed that most of the waste was being managed by women. This is comparable to other surveys done in urban locations (Tadesse and Hadgu, 2009; Mukui, 2013), where solid waste management is seen as mostly the duty of the less privileged in society including women and girls. Women, therefore, play a dominant role in the management of plastic waste.

CONCLUSION AND RECOMMENDATION

Most residents do not segregate their plastic wastes from other wastes but instead throw them together with other wastes that usually end up in the open dumpsite, while others discard them as litter or burn them. Incentives such as purchasing the plastics from households should be promoted in order to encourage source-separation of wastes and thereby increase the number of plastics recovered from household wastes for recycling purposes. The recycling done by Eco-world is not sufficient to deal with the plastic waste in the area as they recycle mainly HDPE plastics and some PETE plastics whereas LDPE plastics are the ones mostly discarded in the area. This finding reinforces the Kenyan government action to ban plastic carrier bags that are usually LDPEs. More investments should be encouraged in plastic waste recycling along the Kenyan coast especially those dealing with LDPE plastics to ensure high proportions of recycling is achieved for this type of plastic. This will not only rid the environment of plastic waste but will also provide employment for the youth. Moreover, youth initiatives where plastic wastes are re-used should be encouraged through national policy frameworks to strengthen and support these initiatives that help in the reduction of the plastic burden. Plastic waste is dominant in the marine debris which is usually deposited at the shorelines and have the potential to be used as raw materials for recycling. In addition, locals need to be sensitized more on environmentally-friendly waste management practices which will enable them to know how to handle their plastic wastes as well as to earn income from plastic wastes and thereby promote ecosystem services and human well-being.

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CONFLICT OF INTEREST

The authors declare that there are no conflicts of interest regarding the publication of this manuscript. In addition, the ethical issues; including plagiarism, informed consent, misconduct, data fabrication and/ or falsification, double publication and/or submission, redundancy have been completely observed by the authors.

ABBREVIATIONS

%	Percentage
°C	Degree centigrade
€	Euro
APEC	Asia Pacific Economic Communities
d^2	Level of statistical significance
EMCA	Environmental Management and Coordination Act
Eq.	Equation
FH	Freeman-Halton extension value
Fig.	Figure
GDP	Gross Domestic Product
HDPE	High-density polyethylene
hp	Household population
HSW	Household Solid Waste
ITCZ	Inter-tropical convergence zone
KNBC	Kenya National Bureau of Statistics
KNCPC	Kenya National Cleaner Production Centre
KWS	Kenya Wildlife Service
LDPE	Low-density polyethylene
n	Sample size
N	Population size
NEMA	National Environmental Management Authority
p	Proportion
PA	Polyamides

PC	Polycarbonate
PE	Polyethylene
PET	Polyethylene terephthalate
PLA	Polylactic acid
PP	Polypropylene
PS	Polystyrene
PTFE	Polytetrafluoroethylene
PVC	Polyvinyl chloride
SPI	Society of the Plastic Industry
SDG	Sustainable Development Goal
thp	Total household population
UNEP	United Nations Environmental Programme
UNIDO	United Nations Industrial Development Organization
$US	United States dollar
Z	Standard normal deviation

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