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## On the use of household expenditure surveys to monitor mismanaged plastic waste from food packaging in low- and middle-income countries

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## LETTER

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On the use of household expenditure surveys to monitor  
mismanaged plastic waste from food packaging in low- and  
middle-income countriesJim Allan Wright<sup>1,\*</sup> , Simon Damkjaer<sup>2</sup> , Heini Vaisanen<sup>3</sup> , Quaranchie Adama-Tettey<sup>4</sup>,  
Mawuli Dzodzomenyo<sup>5</sup> , Allan G Hill<sup>6</sup> , Lorna Grace Okotto<sup>7</sup> , Joseph Okotto-Okotto<sup>8</sup>   
and Peter Shaw<sup>9</sup>

<sup>1</sup> GIS and International Development, School of Geography and Environmental Science, University of Southampton, Building 44, Highfield, Southampton SO17 1BJ, United Kingdom

<sup>2</sup> Research Fellow, School of Geography and Environmental Science, University of Southampton, Building 44, Highfield, Southampton SO17 1BJ, United Kingdom

<sup>3</sup> Social Statistics and Demography, University of Southampton, Building 58, Highfield, Southampton SO17 1BJ, United Kingdom

<sup>4</sup> Behaviour Change Communication Practitioner, Ministry of Sanitation and Water Resources, Accra, Ghana

<sup>5</sup> Ghana School of Public Health, University of Ghana, Legon, Accra, Ghana

<sup>6</sup> Population and International Health, Social Statistics and Demography, University of Southampton, Building 44, Highfield, Southampton SO17 1BJ, United Kingdom

<sup>7</sup> School of Spatial Planning and Natural Resource Management, Jaramogi Oginga Odinga University of Science and Technology, Bondo (Main) Campus, P O Box 210-40601 Bondo, Kenya

<sup>8</sup> Victoria Institute for Research on Environment and Development (VIREED) International, P O Box 6423-40103, off Nairobi Road, Rabuor, Kisumu, Kenya

<sup>9</sup> School of Geography and Environmental Science, University of Southampton, Building 44, Highfield, Southampton SO17 1BJ, United Kingdom

\* Author to whom any correspondence should be addressed.

E-mail: [j.a.wright@soton.ac.uk](mailto:j.a.wright@soton.ac.uk)

**Keywords:** domestic waste, food consumption, household expenditure survey, low and middle income countries, mismanaged plastic waste

Supplementary material for this article is available [online](#)

**Abstract**

**Background:** substantial increases in plastic production have resulted in plastics proliferating of in the environment, with subsequent seabed plastic deposition and ingestion by marine fauna. There is an urgent need to monitor mismanaged plastic waste from household consumption. Household expenditure survey analysis has quantified mismanaged plastic waste generated from household packaged (bottled or bagged) water consumption, but not from consumption of other products. **Methods:** to evaluate whether household expenditure surveys can quantify mismanaged waste from other widely consumed commodities, we quantify mismanaged plastic waste from the domestic consumption of cooking oil alongside packaged water in urban Greater Accra, Ghana, and all cities nationally in Kenya using two household expenditure surveys. **Results:** household survey-derived estimates indicate packaged water consumption generates considerably more plastic waste than oil packaging in Greater Accra, whereas oil packaging generates more plastic waste than packaged water in urban Kenya. **Conclusion:** by successfully transferring a survey analysis protocol from packaged water to cooking oil, we conclude that there is ample potential for expenditure surveys to be used internationally to quantify mismanaged plastic waste from households. However, uncertainties affecting mismanaged waste estimates need to be accounted for.

**1. Introduction**

Growing concerns regarding plastic in the environment [1] are related to mismanaged waste [2]. This problem stems from the high level of plastic

production, with over 360 million tons produced globally in 2020 [3]. The resultant proliferation of plastics has led to widespread impacts [4] and contamination [5]. Impacts include seabed deposition of plastics, micro-plastic ingestion by and

entanglement of marine fauna [6], with subsequent micro-plastic transfer to marine invertebrates [7] and ultimately species at higher trophic levels including humans [8].

The uncontrolled release of plastics into the environment relates in part with available waste management systems, which differ markedly between economically developed and developing countries [9]. Open burning of solid waste in low- and middle-income countries (LMICs), for example, releases atmospheric particulates that adversely affect citizens' health [10]. In the absence of waste services, predicted population growth and changing urban consumption patterns in LMICs may exacerbate mismanaged waste disposal.

Extensive reliance on small-scale, ad hoc studies or country-specific datasets means that ongoing, international monitoring of domestic waste and its management lacks consistency in study designs [11]. Since primary fieldwork to monitor domestic waste generation and disposal is costly, household expenditure surveys could form a more cost-effective and internationally standardised means of monitoring mismanaged waste arising from domestic consumption of specific products.

Household expenditure surveys ask a nationally representative sample of households to estimate spending on consumption of goods and services. They include Household Budget Surveys (HBS), Income and Expenditure Surveys (IES), and the World Bank's Living Standards Measurement Surveys (LSMS) [12]. Consumption modules have also been implemented within some Multiple Indicator Cluster Surveys [13]. There are now 137 openly available LSMS surveys for 37 countries (figure 1); HBS and IES have similar availability. By 2013, 43 of 49 sub-Saharan African countries had conducted at least one consumption and expenditure survey [12], although surveys take place only every three to ten years, so can be outdated. Since many HBS, IES, and LSMS also record household waste services or disposal [14], they have potential for characterising waste generated from consumption of specific products, particularly in households lacking waste services. We previously used household expenditure surveys in Ghana, Liberia, and Nigeria to characterise plastic waste generated through packaged (bagged or bottled) water consumption among households lacking waste services [15]. However, it is unclear if household expenditure surveys could be used to quantify plastic waste generation from household consumption of other products and in countries outside West Africa.

This study therefore aims to assess (a) whether household expenditure surveys can be analysed to quantify plastic waste generation from consumption of a different product (cooking oil) among households lacking waste services; (b) how quantities of plastic waste generated from cooking oil compare

with those from packaged water consumption among such households.

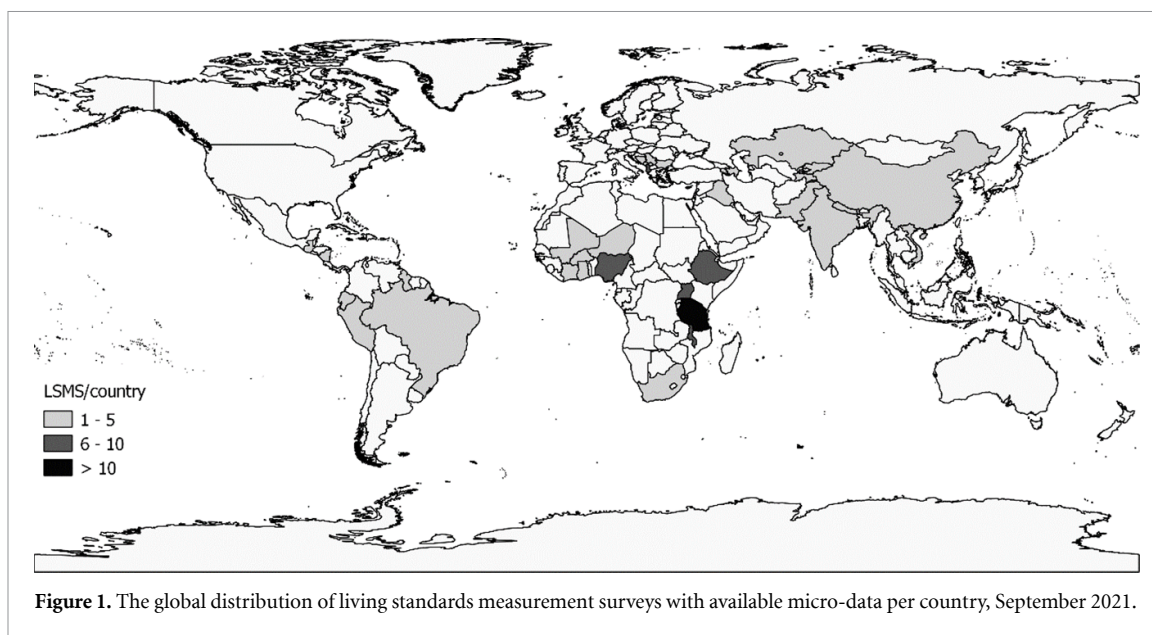
This study focused on packaged water and cooking oil in Greater Accra Region, Ghana and urban Kenya, thereby exploring household expenditure survey use beyond West Africa. As case study products, we chose cooking oil given its ubiquitous use worldwide, while packaged water consumption is rapidly increasing in many countries (e.g. Laos, Turkey, and Indonesia), forming the main drinking water source for most urban Ghanaian households (58%) in 2019 [16]. Water is sold in bags in Ghana [17], typically in 500 ml plastic sachets [15]. In Kenya, packaged water is mostly bottled [18]. In Ghana and Nigeria, palm oil is generally packaged by vendors or smallholder farmers [19, 20]. Thus, these case studies present contrasting situations for evaluating the potential of household surveys in estimating plastic packaging waste.

## 2. Method

### 2.1. Secondary data sources

Data pertaining to household consumption patterns and waste disposal practices are available for both Ghana [21] and Kenya [22]. The Ghana Living Standards Survey 7 (GLSS7) is the latest in a series of nationally representative surveys quantifying household consumption. In 2016–17, the GLSS7 sampled 1000 enumeration areas (EAs) across Ghana's ten regions based on probability-proportional-to-size sampling. In each EA, 15 households were randomly selected, resulting in 14 009 sampled households [23]. Respondents reported food and beverage purchases in the preceding week over six consecutive weeks and their main means of solid waste disposal. Only the urban Greater Accra region was evaluated in the present study, the Ghanaian region where sachet water consumption is concentrated [15]. In Kenya, given the more even regional distribution of packaged water consumption, we analysed data for all cities.

The Kenya Integrated Household Budget Survey (KIHBS) 2015–16 is also a nationally representative cross-sectional household survey. Its clustered sampling design included 24 000 households in Kenya's 47 counties [24] chosen from 2400 randomly-sampled clusters. In each cluster, 16 households were randomly selected, of which ten were sub-sampled to participate in the main KIHBS. The survey response rate was 91%. The questionnaires addressed sociodemographic characteristics, wealth, economic standing, and consumption expenditure. Adult household respondents reported spending on itemised services and goods, including cooking oil and packaged water, in the seven days before interview. Householders also completed diaries recording their purchases and expenditures.



## 2.2. Field data collection

For water sachets in Greater Accra, each 500 ml plastic sleeve was estimated to weigh 1.7 g of high- or low-density polyethylene (HDPE/LDPE) [15]. For other packaging units, 97 and 16 samples of water and oil packaging were collected from markets and kiosks in Kisumu (Kenya) and Greater Accra (Ghana) respectively, from July to September 2021 (Online Resource 1). The empty containers were cleaned and weighed, and the lids and labels were removed.

## 2.3. Data analysis

For both cooking oil and packaged water, purchases were used to infer packaging by classifying the measurement units into four groups:

- (a) Specific containers: in Ghana, these include manufacturers' sachets for packaging oil and water, reused branded water bottles, and plastic bags hand-tied by vendors.
- (b) Measurement and packaging by vendors (e.g. tins, heaps, beer bottles, branded bottles).
- (c) Standard units (e.g. litres or gallons)
- (d) Unspecified units (e.g. 'single'; 'piece').

For each product, the mean packaging inefficiency (weight of plastic packaging per unit volume of product) was calculated to convert the consumption data to plastic waste quantities. Published data on cooking oil and water packaging volumes and weights were also obtained for comparison. Search terms relating to the two products ('oil' or 'water'), containers (e.g. 'bottle', 'sachet', 'container') and weight were combined and searches made using Web of Science, Google Scholar and Google. Promotional statistics and data presented without a stated methodology were excluded.

High, medium, and low plastic use scenarios were generated to convert quantities purchased to amounts of packaging, reflecting the uncertainty associated with the survey measurement units. Since most water purchases in Greater Accra were recorded in standard units (sachets or bags of 30 sachets), the associated low, medium, and high scenarios were almost identical. In Kenya, where measurement units for water purchases were mostly in litres, we generated high (0.5 l bottles), medium (1.0 l bottles), and low (1.5 l bottles) waste scenario estimates. In Greater Accra, oil purchases mostly comprised vendor-measured units, so we assumed the widespread use of sachets or hand-tied bags for low and medium scenarios and plastic bottle use for a high waste scenario. In Kisumu, our fieldwork showed that oil was mostly sold in plastic jerrycans. Therefore, in Kenya, our three scenarios assumed: all oil sold in small 1 l jerrycans (high waste); all oil sold in the largest possible jerrycan (medium waste), and half of the oil sold in the largest possible jerrycan and half sold in the largest possible plastic bottle (low waste).

In Ghana, where each household was visited six times, we also used logistic regression to test for significant differences in the reporting of water or oil purchases per survey visit, using regression coefficients to adjust estimates where required. In Kenya, where the KIHBS recorded the retail outlet for each purchase, we also cross-tabulated purchases against retail outlet. Finally, we estimated the annual weight of plastics generated through oil or packaged water consumption according to the main household waste disposal method, differentiating waste collected via service providers from other forms of disposal. Analyses of plastics by waste disposal method accounted for the GLSS7's multi-stage cluster design via the `svy` commands in Stata [25] to generate nationally

representative estimates with 95% confidence intervals reflecting sampling error. Where multiple packaging assumption scenarios were used, the estimate from the medium waste scenario was presented alongside the widest confidence intervals from any of the three scenarios used. Finally, to explore the economic drivers of lightweight packaging, we examined the price of 500 ml water sachets versus bottles in Greater Accra Region via regression analysis.

### 3. Results

#### 3.1. Quantification of plastic waste generation using household expenditure survey data concerning cooking oil and packaged water consumption

Overall, 5% of urban households reported buying packaged water in Kenya during the seven days before interview and 57% reported buying vegetable oil. In Greater Accra, households reported purchasing water sachets in 71% of the weekly survey visits. Logistic regression indicated no significant differences in water purchase reporting by GLSS7 survey round, but respondent fatigue was evident in reported oil purchases following the first visit (odds ratio = 1.14;  $p = 0.03$ ), so reported purchases from subsequent visits were adjusted upwards by 1.09. Oil purchases were more prevalent in urban Kenya, and packaged water purchases were more prevalent in Greater Accra.

In Greater Accra, most water purchases were recorded as individual 500 ml sachets or sachet bags ( $30 \times 500$  ml sachets) (figure 2(a)). In Kenya, water purchases were typically expressed in metric units (figure 2(b)). After controlling for the discounting of bulk purchases, regression analysis of packaged water prices indicated that bottled water sold for significantly more than sachet water in Greater Accra Region (GHS1.96 or \$0.46 versus GHS0.36 or \$0.08,  $p < 0.001$ ).

A wide variety of cooking oil measurement units is apparent in Greater Accra, particularly for vendor-measured units of palm oil (figure 3(a)). Oil is also packaged by manufacturers in sachets rather than in bottles. Some units signify container reuse, such as the use of beer, Fanta (soft drink), or Voltic (water) bottles. Similarly, *olonkas* (American tins) indicate that vendors reuse containers for measuring. In contrast, in Kenya, measurement units for oils were largely metric, although some vendor-measured units such as *gorogoros* (tins for measuring out quantities, cf. Ghanaian *olonkas*) were evident. In the KIHBS (figure 3(b)), vegetable oil purchased from supermarkets was measured in litres in 83% of reported cases, while vendor-measured units were more common in open markets and kiosks.

In terms of container inefficiency, polyethylene terephthalate (PET) bottles (without lids) used for water packaging in Greater Accra and Kenya were

broadly comparable with published estimates for other LMICs (figure 4; Online Resource 1). Only one set of measurements for oil containers (from Brazil) was identified from literature, precluding similar comparisons for oil containers. Smaller-capacity containers were generally less efficient than larger containers. The most efficient containers were sachets and hand-tied bags, which are used extensively in Ghana for both oils and water. In Kisumu, the jerry-cans widely used for oil were less efficient than bottles (figure 4(b)).

#### 3.2. Plastic waste generation from cooking oil and packaged water consumption

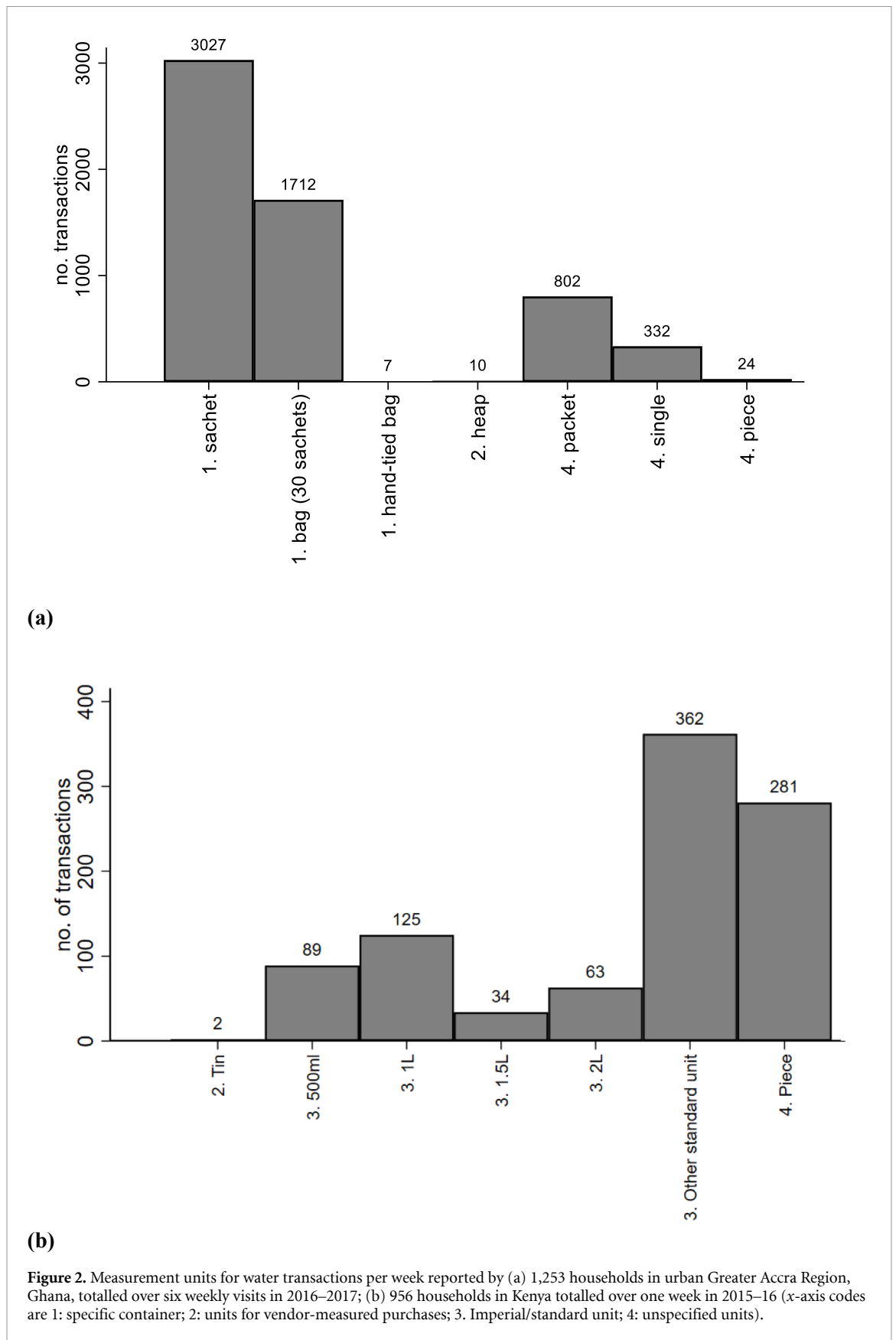
Most plastic waste from sachets in Greater Accra is generated in households that have a formal waste collection system in place, so relatively small proportions are dumped indiscriminately or burned (figure 5(a)). Unlike the GLSS7, the KIHBS records the waste collector type, thereby highlighting the contribution of private companies and informal waste collectors (figure 5(b)).

Consumption of palm or vegetable oils in urban Greater Accra mostly takes place within households with waste collection services (figure 6(a)). The confidence intervals for plastic waste generated are wider than those for packaged water, reflecting the uncertainty in interpreting measurement units (figure 5(a)). In Greater Accra, the total amount of plastics generated from oil consumption is much lower than that of packaged water, as is the number of reported oil purchases (figure 3). In Kenya, private collectors handle more waste from vegetable oil than other collectors do (figure 6(b)). Among Kenyan households that lack waste collection services, plastic waste from oil consumption exceeds that from packaged water consumption.

### 4. Discussion

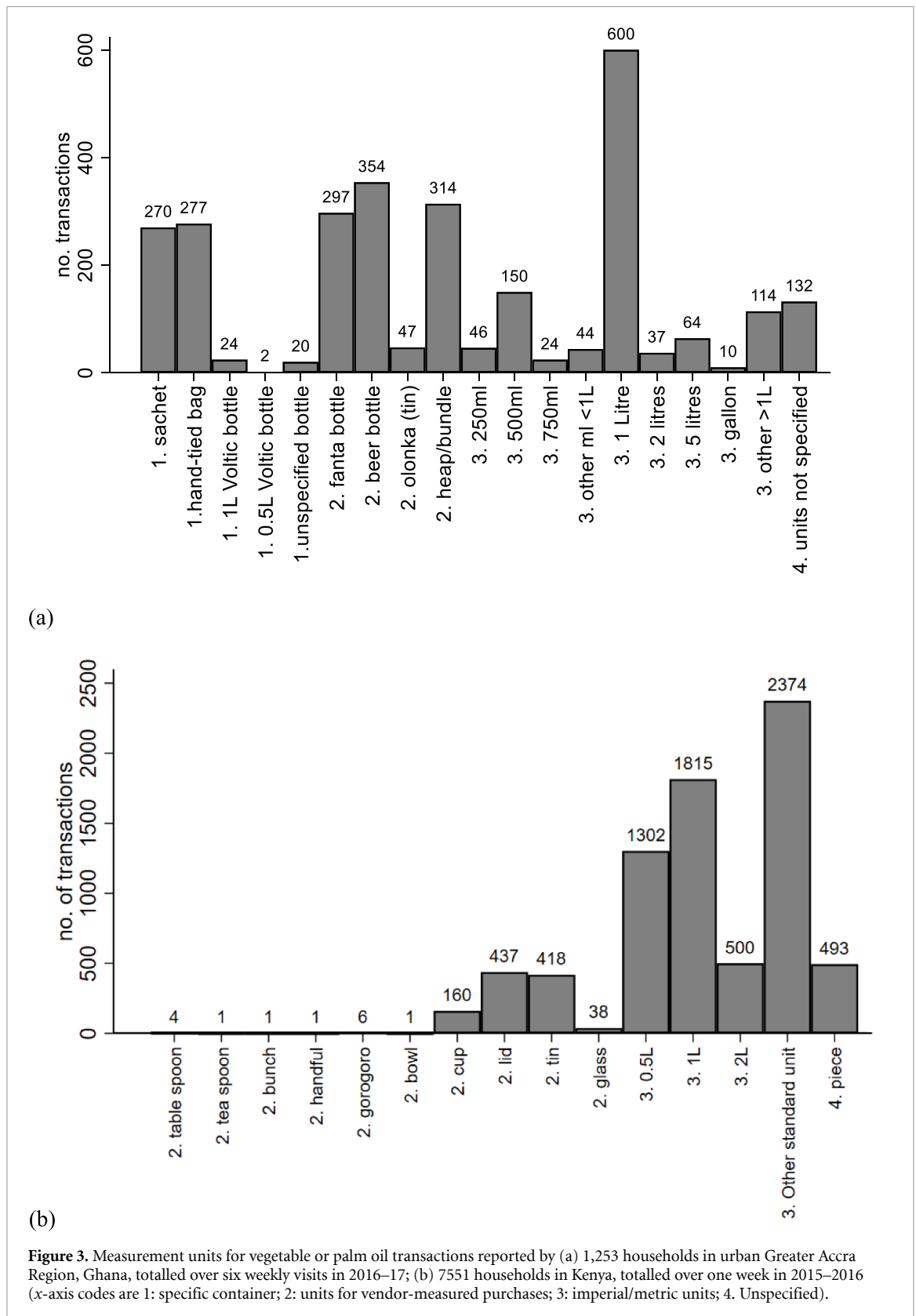
#### 4.1. Plastic waste insights from household expenditure surveys in Ghana and Kenya

Our household survey analysis provides insights into domestic generation of mismanaged plastic waste. The analysis shows that plastic waste from sachet water consumption (figure 5(a)) far exceeds that from oil (figure 6(a)) in Greater Accra, whereas in urban Kenya, the opposite occurs (figures 5(b) and 6(b)). Although plastic sachets weigh little, sachet water is among the most frequently purchased items recorded in the GLSS7. As noted in the USA [26], the ability to assess the contribution of different food products to mismanaged plastic waste could provide evidence to target regulatory policy concerning food packaging and suitable waste management facilities at specific products of concern. The household survey analysis also quantifies the importance of Kenya's private providers, either working informally or contracted via public-private partnerships [27]. In Kenya, where



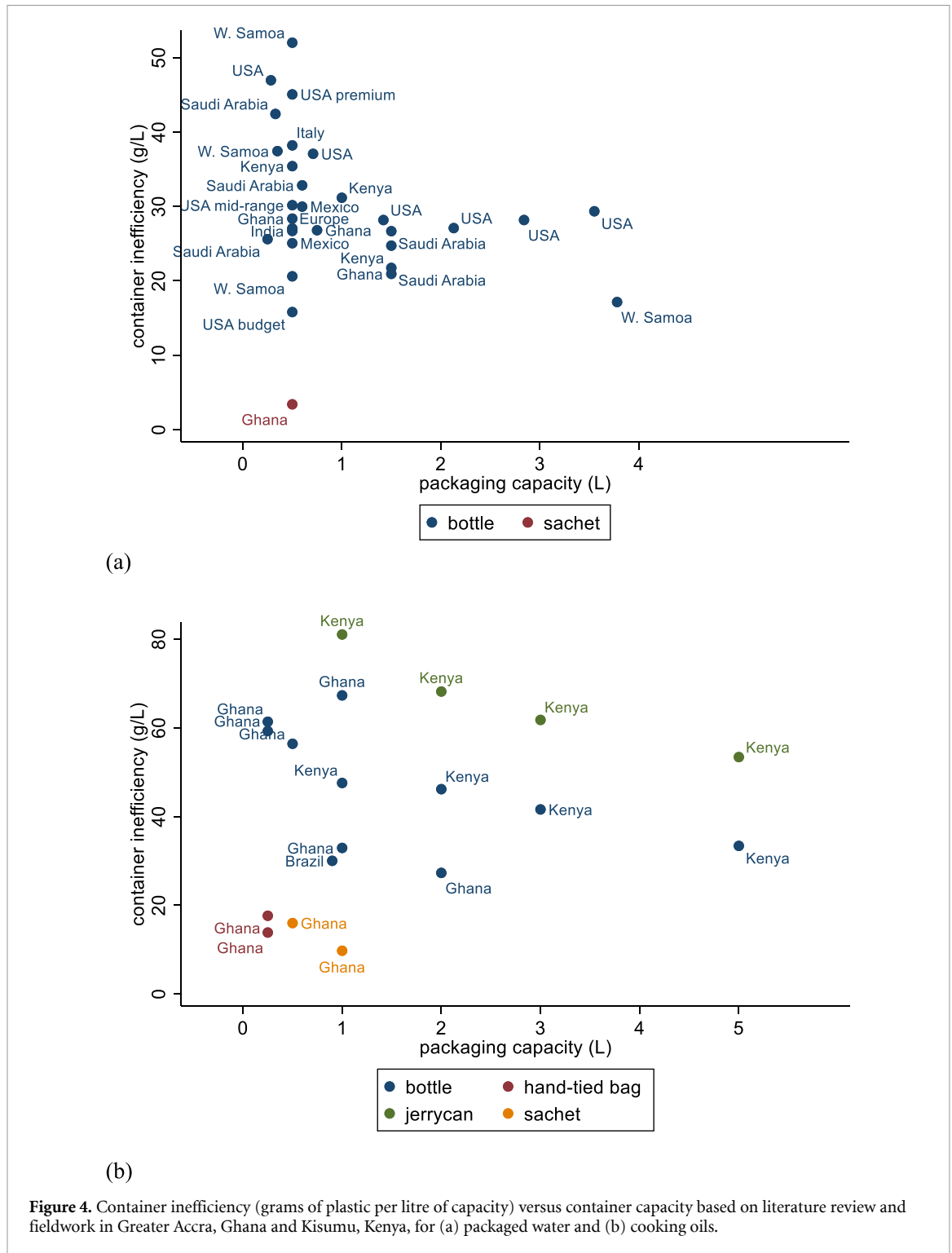
the KIHBS differentiated service providers by sector, private providers collected more oil and water packaging waste than local governments or community associations (figures 5 and 6).

Non-standard measurement units highlight the widespread practice of vendors packaging goods via reused containers. In both urban Kenya and Greater Accra, containers were widely reused in markets



to measure product quantities and, in some cases, reused as packaging. Vendors’ resale of smaller, more affordable quantities of food has been described as the ‘Kadogo economy’ in Kenya, meaning ‘tiny’ in Kiswahili [28]. Vendors used margarine tubs or tins (*Gorogoros* in Kenya or *Olonkas* in Ghana) to measure

out commodities for sale, reflecting reported container reuse by vendors elsewhere in West Africa [29]. Similarly, soda, beer, and water bottles were sometimes reused to sell vegetables or palm oil (figure 3). However, systematic recording of container reuse would likely require ancillary fieldwork. Some widely

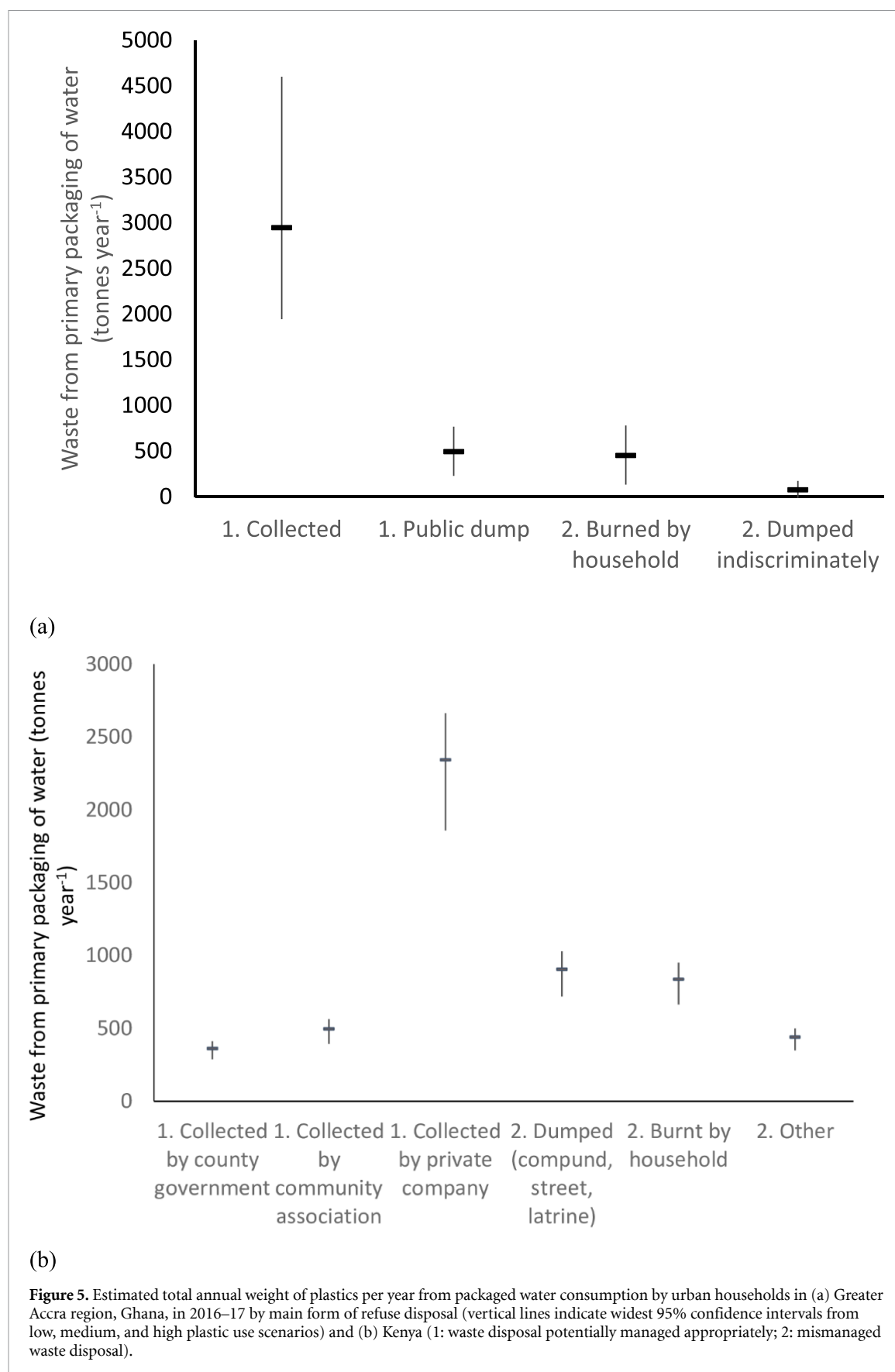


**Figure 4.** Container inefficiency (grams of plastic per litre of capacity) versus container capacity based on literature review and fieldwork in Greater Accra, Ghana and Kisumu, Kenya, for (a) packaged water and (b) cooking oils.

used non-standard packaging units (e.g. hand-tied bags) were not pre-coded into the GLSS7 survey questionnaire, but could be systematically recorded in future surveys.

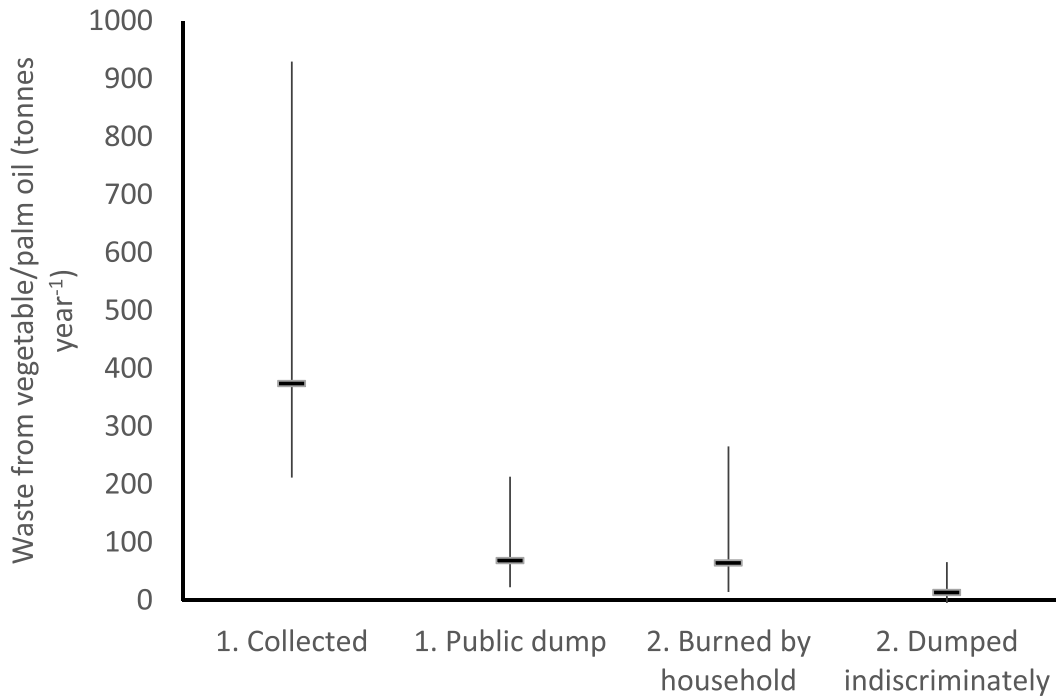
Widespread use of lightweight plastic sachet packaging for both oils and vended water is evident in Greater Accra, whereby savings on packaging materials reduce costs to consumers. Although Ghana's sachet water industry has previously been well documented [30], the use of sachets as a lightweight alternative to PET bottles for other products, such

as oils, has not. In the USA, premium bottled water brands have higher packaging inefficiency than budget brands [26, 31]. Packaging inefficiency for bottled water from Mexico and India is similar to that of mid-range US brands [31]. The present study suggests that higher-volume purchases in LMICs entail less packaging per litre than smaller purchases (figure 4). The GLSS7 data suggest that food or beverage products manufactured for LMIC markets sometimes use less packaging than their high-income country equivalents. However, the substitution of

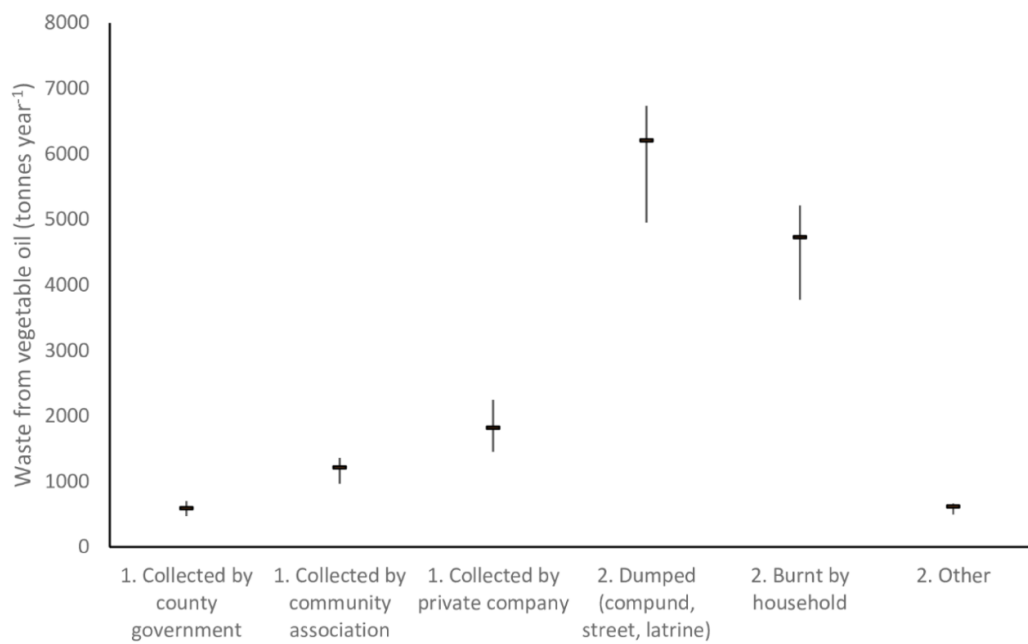


PET bottles with sachets inhibits their reuse potential. Sachet sleeves, thin films of HDPE or LDPE, are recycled to some extent in Greater Accra and collected by waste pickers [32], but not reused. In contrast,

the reuse of PET bottles permits greater value to be gained from the materials and energy used for their production [33] in alignment with waste hierarchy aims and principles [34].



(a)



(b)

**Figure 6.** Estimated total annual weight of plastics per year from palm or vegetable oil consumption by urban households in (a) Greater Accra region, Ghana, in 2017 by main form of refuse disposal and (b) Kenya (vertical lines indicate widest of 95% confidence intervals for low and high plastics scenarios; 1: waste disposal potentially managed appropriately; 2: mismanaged waste disposal).

For urban water delivery, a three-axis framework has been proposed that characterises its quantity, availability, and delivery [35]. Given the widespread use of packaged water in some LMIC cities, our approach could enable the addition of mismanaged

plastic waste from packaged water as a fourth axis. Successive household surveys also provide opportunities to monitor changes in goods consumed by households lacking waste services in different years within a given country.

#### 4.2. Implications for using household expenditure surveys to quantify mismanaged waste from domestic consumption

In applying an analysis protocol developed for packaged water to cooking oil, we also identify some generic issues affecting plastic waste quantification via household expenditure surveys. A typical survey may use standard (e.g. litres) or non-standard units (e.g. bunches) to record food quantities consumed [36]. The quantification of domestic waste associated with packaging requires a conversion table to translate non-standard quantities of specific products into quantities and resin types of plastic waste. Such tables currently do not exist; thus, primary fieldwork is required to quantify the weights of different packaging types associated with commonly consumed foods. However, a multi-country study [37] found that food metrics could be constructed for only 53% of recent household surveys because of the difficulties in constructing conversion tables for non-standard units. Our case study suggests that packaged water is sold in standardised units (figure 2), whereas the units for oils are highly variable (figure 3). Where present, such heterogeneous measurement units pose challenges for the analysis of food and beverage packaging.

Some generic LSMS data quality issues impact their use in domestic waste quantification. For example, ‘prestige errors’ may lead to over-reporting of socially desirable commodities [38]. Many LSMS use a weekly recall period for food consumption questions administered over multiple, repeated household visits. Respondent fatigue has been noted in some household surveys with repeated visits [39] and was apparent in household reporting of oil purchases in the GLSS7. Reported estimates may also be subject to both ‘telescoping’, whereby events before the recall period are reported within it, and ‘memory decay’, whereby consumption details are progressively forgotten as the recall period lengthens [40].

The most widely used recall period in the LSMS is a week [37], which makes it challenging to differentiate between products purchased at different frequencies. Less frequent bulk purchases often entail additional secondary packaging [41], whereas packaging efficiency is generally greater for bulk items (figure 4). However, estimating waste from food consumption as opposed to waste disposal events may be preferable. While many foods are frequently purchased, some waste disposal events may occur less frequently as households accumulate waste before disposal [42].

The commodity codes used in LSMS also likely impact the quantification of packaging associated with domestic waste streams. There is international variation in the number and nature of codes used [37], which reflects the local context and the survey’s primary purpose [40]. Commodity code systems are often harmonised to reflect the purpose of

consumption [14]. However, products with similar purposes may be packaged differently. For example, water sold in bottles uses more plastic per unit product than sachet water and generates PET rather than HDPE plastics [15], both may be recorded under a single packaged water commodity code. While the consumption of food away from home (FAFH) is growing in LMICs [40] and many surveys include commodity codes for FAFH foods, few explicitly capture meals or snacks consumed outside the home [43]. Waste disposal facilities for FAFH will also not be captured by LSMS, preventing mismanaged waste quantification for FAFH via surveys.

There are also challenges in measuring domestic waste disposal through household surveys. While LMIC households in cities such as Lusaka, Bulawayo, and Mombasa reportedly separate waste for burning, recycling, or reuse [44], recycling rates are generally low; for example, only an estimated 6% of domestic waste is recycled in Lusaka [44]. Markets for the recycling or reuse of plastic waste vary by product and plastic type. For example, there is extensive informal reuse of water PET bottles in urban Senegal but no reuse of plastics from sachet water [29]. However, in most LSMS, only the main method of waste disposal is typically recorded. Without specific questions on waste separation and secondary waste disposal methods, household surveys may inaccurately estimate mismanaged waste. Furthermore, while surveys such as the KIHBS and GLSS7 identify collected waste, they do not record whether it is safely contained following collection, so overall waste mismanagement may be underestimated.

Household consumption surveys also lack georeferencing. Although Demographic and Health Surveys are released with GPS coordinates for household clusters [45], they lack consumption modules [12]. Conversely, LSMS surveys measure consumption, but their lack of detailed spatial referencing restricts spatial analysis to the provincial level. Studies modelling the onwards environmental fate of plastics typically use river catchments as spatial units [1], and the lack of detailed LSMS georeferencing inhibits the potential integration of derived mismanaged waste estimates with environmental transport models.

#### 4.3. Future approaches to quantifying mismanaged domestic waste via household surveys

Several potential approaches could be used to characterise mismanaged domestic waste via household surveys. First, future analyses could focus on a limited number of case study products sold in standardised packaging of particular concern for national waste management. In the USA, such analyses have identified specific products for which packaging can be reduced [26]. In Liberia, Nigeria, and Ghana, for example, water sachets are typically sold in standardised quantities (individual 500 ml plastic sleeves or 15 l bags of 30 sachets), which facilitates the

quantification of plastic waste generated and cross-tabulation with waste service type(s) [15]. A second approach would be to classify commodities into groups based on their packaging, perhaps in conjunction with data on the retail channels through which they are sold (where available). Analogous to the World Food Programme's Food Consumption Score [12], commodities can be grouped by likely packaging type (e.g. composites, LDPE, HDPE, PET, card/paper, and glass). However, this would require an expert understanding of the commodity packaging.

A third approach records both packaging and waste management facilities through a community or market survey module, similar to those used in household surveys for recording prices or neighbourhood facilities. Market survey observations are sometimes used to convert non-standard units in food consumption modules into metric units [46]. However, this approach would increase implementation costs and present challenges in identifying retail outlets used by the sampled households. Although community and price modules are typically implemented within the EAs selected for an LSMS, these small areas do not generally encompass the services or larger retail outlets used by these households [47].

Minor adaptations to existing household survey designs could enhance their use in quantifying mismanaged plastic waste and thereby inform initiatives to better manage the resources and materials consumed in plastic packaging production. Because most surveys only record the main mode of waste disposal, an additional question pertaining to product-specific waste separation would be valuable. Similarly, more response categories for waste service operators would enable a fuller quantification of their benefits (such as the separate categories for local government, community association, and private waste operators in the KIHBS). Given that the measurement units and packaging varied for oil purchases by retail outlet in Kenya, recording the market channels for purchases has merit. A review of survey codes for non-standard measurement units could aid in the understanding of waste. In the GLSS7, for example, there was no predefined code for hand-tied plastic bags, despite their widespread use for selling palm oil. Proposed commodity codes could be also reviewed against heterogeneity of packaging. In the GLSS7, for example, there are separate commodity codes for bottled and sachet water purchases that facilitate plastic waste quantification. In other countries, even when bagged water is sold, there is often only a single commodity code for recording packaged water.

Finally, estimates of collected and mismanaged waste from household surveys need to be evaluated through triangulation with other data sources; retail sector records on product sales and regulator records on waste composition [26], combined with bespoke household surveys to assess waste generation

[48] are of merit, although these are scarce in LMICs.

## 5. Conclusions

There is considerable potential to exploit existing international household consumption surveys for the quantification of domestic waste. This case study of cooking oils and packaged water in Greater Accra, Ghana, and Kenya demonstrates quantification of domestic mismanaged plastic waste, container reuse and the use of sachets as lightweight, inexpensive packaging. It also highlights the contributions of different service providers in Kenya to domestic waste collection. There are nonetheless challenges arising from variations in survey implementation and content. Some of these challenges could be addressed through the adaptation of household survey protocols, for example, by aligning measurement units on questionnaires with widely used forms of packaging. There is also a need for complementary fieldwork, particularly for market surveillance of packaging, to enable more robust quantification of mismanaged plastic waste. Data enabling the conversion of nonstandard product measurements into standard units via conversion factors are required for a wide range of commonly purchased products and their packaging.

## Data availability statement

All data that support the findings of this study are included within the article (and any supplementary files).

## Acknowledgments

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Author contributions were as follows: Conceptualisation—JW, AH, HV; Investigation—MD, QAT, JOO, LO; Writing—Original draft: JW & PS; writing—review & editing: HV, SD, AH, MD, JOO, LO, QAT; Formal analysis, visualization—JW, PS, & HV; Project administration—JW, MD, JOO, LO; Funding acquisition—JW, AH, HV, JOO, LO, MD, PS.

## Conflict of Interest declaration:

The authors declare that they have NO affiliations with or involvement in any organization or entity with any financial interest in the subject matter or materials discussed in this manuscript.

## Ethical statement


This secondary data analysis of human subjects data was approved by the ethics committee of the Faculty of Environmental and Life Sciences, University of Southampton, UK (Ref: 56 807; approval date: 10 May 2020). All procedures performed in studies analysing data on human participants were in accordance with the ethical standards of the institutional and/or national research committee and with the 1964 Helsinki Declaration and its later amendments.

## ORCID iDs

Jim Allan Wright  <https://orcid.org/0000-0002-8842-2181>


Simon Damkjaer  <https://orcid.org/0000-0002-0758-6038>

Heini Vaisanen  <https://orcid.org/0000-0002-5494-0415>

Mawuli Dzodzomenyo  <https://orcid.org/0000-0002-4709-3182>

Allan G Hill  <https://orcid.org/0000-0002-4418-0379>

Lorna Grace Okotto  <https://orcid.org/0000-0003-0109-3942>

Joseph Okotto-Okotto  <https://orcid.org/0000-0002-4656-8369>

Peter Shaw  <https://orcid.org/0000-0003-0925-5010>

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