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Making a Case for Diversion of Solid Medical Waste from Households: A Generation Study in Ga South Municipal Assembly, Accra, Ghana

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Abstract

Background: Solid medical waste (SMW) is generated from the healthcare industry but can also be found in households when activity involving patient care occurs. Its hazardous properties require special treatment to minimize hazards to the environment. To achieve this, SMW must be safely diverted from households using a systemic approach, which should be informed by the quantities generated and factors associated with generation. Objective: To characterize household SMW in terms of quantity and composition and to describe the factors associated with its generation. Methods: Manual sorting of household waste was conducted in 60 households to measure quantities of SMW and its components in Ga South Municipal Assembly, Accra, Ghana. Sample collection took place in the wet season (October, 2014) and dry season (December, 2014/January 2015). Rates of generation and percentage composition computed. Factors influencing generation were evaluated with non-parametric tests and quantile regression analysis. Statistical significance was set at $p < 0.05$. Results: Per capita generation of SMW was 1.77×10^{-3} kg/person/day. Pharmaceutical waste and sharps waste comprised 98% and 2% of SMW respectively. Generation rates were significantly higher in the wet season than in the dry season ($z = 3.129$, $p = 0.002$). Households where medical complaints were reported generated significantly less SMW at the 5th, 10th, 25th and 50th quantiles ($\beta = -2.711$, $p = 0.001$; $\beta = -2.949$; $p < 0.001$; $\beta = -3.429$, $p < 0.001$; $\beta = -4.600$, $p < 0.001$ respectively). Conclusion: SMW was generated in relatively small quantities in households. However, the large proportion of pharmaceuticals with mostly antibiotics raises concerns about drug resistance among other potential hazards.

Keywords

Medical Waste, Ghana, Pharmaceutical Waste, Community

1. Introduction

The health care industry generates waste containing pathogens, toxic heavy metals and chemicals, termed healthcare waste (HCW) [1]. The solid component of HCW arising from activities of health protection, diagnosis and treatment is called solid medical waste (SMW) [2]. The traditional domain of SMW is the healthcare industry, where waste is generated from a variety of healthcare activities. However, a limited variety of healthcare activities can also occur in households such as being found in home based care [3] [4], shortened hospital stay [5], care and treatment of chronic diseases in aging populations [6], and home management of illnesses such as malaria [7]. Although SMW constitutes up to 0.1% of the mixed municipal solid waste stream, its hazardous character attracts public sensitivity and poses a challenge to health and municipal authorities [8]. Examples of SMW found in households include discarded medicines, blood soaked bandages, hypodermic needles and syringes, lancets and insulin pens.

Sharps in the waste stream such as hypodermic needles can cause physical injury and may lead to transmission of blood borne pathogens if present. Expired and unused medicines discarded with household waste, often end up in landfills, where household waste is mostly landfilled. Active pharmaceutical ingredients from discarded medicines in landfills can be discharged into leachate [9]. Environmental hazards associated with pharmaceuticals in SMW include destruction of bacteria necessary for sewage treatment, adverse effects on aquatic and terrestrial life, and air pollution when medicines are burnt at low temperatures [10] [11]. Antibiotic resistance has been demonstrated in viable organisms present in untreated landfill leachate [12]. In Ghana, lack of a waste segregation system in most residential premises suggests that SMW is mixed with household waste. In some cases, final disposal occurs at illegal dumpsites by informal waste porters, who often work without protection. When household waste (HSW) is deposited in poorly maintained landfill sites and unauthorized open dump sites, unrestricted access by scavengers and young children exposes them to community acquired needles tick injuries (CANSIs). Among the reported consequences of this exposure, hepatitis B infection is the most frequently reported, although HIV appears to be the most feared [13] [14].

In recognition of these health hazards, some safety measures have been applied elsewhere. For instance, collection of sharps waste is available for households in some parts of the United States [15] [16] [17]. In Sweden, take-back programs facilitate the return of unwanted medication through pharmacies and even if they were to be discarded in household waste, only 1% of household waste is land filled [18]. However, similar waste management options do not exist in many developing countries including Ghana. Various studies have demonstrated that family and household size [19] [20] [21], household income [19]-[24], and educational status [20] [21] [22] influence household waste generation. Being a component of the household waste stream, these factors could affect generation of SMW. The present study aimed at providing empirical data on the quantity and composition of SMW in households. It also identifies factors associated with generation of SMW.

2. Methods

2.1. Background of the Study Area

Ga South Municipal Assembly (GSMA) was created in 2009 in south western Accra. It has a total population of 411,377, of which 48.9% are males (unpublished document, Ghana Statistical Service, 2014). It is predominantly urban, comprising of towns with populations ranging between 5000 and 20,000. Estate development and commerce have outpaced the earlier agro-based economy (unpublished document, Municipal Planning and Coordinating Unit, 2014). Unpublished reports from the Municipal Assembly Waste Management Department, estimate total solid waste generation at 19.43 tonnes daily, which is managed by public-private partnership.

2.2. Sample Selection

A household was the sampling unit in consistency with earlier studies [20] [25] [26]. For waste stream analysis, a minimum of 50 sampling units (households) per 500 households has been suggested by Igbinomwanhia (2011), giving a ratio of 1:10 [27]. On this basis, sixty households were selected from a pre-existing sampling frame of 600 households in October, 2014. In the sampling frame, twenty households each were selected by multi-stage sampling from 30 enumeration areas (EAs) in the municipal assembly during an earlier phase of the field work [28]. Households for the waste stream analysis were selected by ballot. Two households were selected from each of the 30 EAs, making a total of 60 households. Once a household was selected, a member of the household was informed and consent obtained to collect household waste. All households informed accepted to participate in the study.

2.3. Household Waste Collection

Identification numbers were assigned to participating households comprising four digits. The first two digits represented their location (numbered 01 to 30) and the second two digits were their serial numbers from the sampling frame (numbered 01 to 20 in each location). Black household bin bags of dimension, 725 × 975 mm, and 80-litre plastic household bins were labelled with the assigned numbers. Each selected household was informed about the collection schedule (6 am to 8 am), given one bin and two bin bags, and asked to store their waste as routinely done. They were advised to keep the bins covered to prevent stray animals from tampering with the waste. A pilot study conducted a week earlier in nine households indicated that daily collection of household waste did not yield meaningful quantities of SMW. Therefore waste collection was conducted weekly in 2 phases that lasted a total of five weeks. The first phase lasted two weeks in October, 2014 (wet season); and the second phase lasted three weeks from December, 2014 to January, 2015 (dry season). New bin bags were provided during waste collection for the following week's collection. Retrieved bin bags with content were transported to a location appointed for manual sorting.

2.4. Manual Sorting of Household Waste

The unsorted content of each household's bagged waste was weighed before sorting. To obtain the quantity of specific waste components, manual sorting was undertaken by four trained field staff on a table overlaid with a wire mesh on a clean plastic sheet. The specific waste components were pharmaceutical waste, sharps waste and offensive waste (Table 1).

The waste components were manually sorted and each fraction was weighed. Measurements were estimated on the basis of wet waste (w/w) in kilograms (kg) using a scale GBK 120 with a precision of 0.005 kg (Adam Equipment Company, 2013) for total household solid waste (HSW) and an additional scale with a capacity of 5 kg and a precision of 0.001 kg for household SMW. At the onset of the survey both scales were calibrated against standard weights of 5 Newtons (0.5099 kilograms) and then standardized between measurements. Electronic records were created to store weekly records of waste measurements. Parameters were analysed using the Statistical Package for Social Sciences (SPSS) version 22.

2.5. Waste Survey

A waste survey was conducted by four trained data collectors using a purpose designed 32-item questionnaire to obtain respondent and household characteristics. Sociodemographic characteristics were household income, respondent's educational status and room occupancy. Characteristics related to health were: medical complaints, children aged below 5 years in household and National Health Insurance Scheme (NHIS) membership status. The questionnaire was pre-tested and administered in each household, mostly in the evenings. An eligible

Table 1. Sub-classification of solid medical waste in the study.

Waste Sub-streams	Description	Examples
Pharmaceutical waste	Expired, unwanted or left over medicines which were discarded. It also includes containers contaminated with residue/contents of pharmaceuticals and drug vials.	Syrup bottles, blister packs with residue/content, drug vials, loose tablets
Sharps waste	Items that cause cuts or puncture wounds which have been discarded.	Needles, syringes with needles attached, broken glass vials, blades, shaving sticks
Offensive waste[a]	Discarded items which have come in contact with body fluid, although not known to be infectious but causes offense to those who come into contact with it.	Plaster, soiled tissue, condoms, sanitary pads, diapers

a. Solid medical waste comprised pharmaceutical waste and sharps waste; offensive waste was analysed separately.

respondent was an adult aged 18 years or older who was either well-informed about housekeeping arrangements or resident for at least one month in the household. If there was more than one eligible respondent, selection was done by ballot.

2.6. Data Management and Analysis

Descriptive statistics of the sample households were generated. Other variables computed were household daily waste generation rate, per capita daily generation rate, percentage waste weight (%). Monthly household income was arbitrarily assigned categories based on the range of incomes obtained from the sample (GHC 20 - GHC 900; $76 - $236.85). There were three categories: low (≤GHC 200; $52.63), middle (GHC 201 - GHC 300; $52.89 - $78.95) and high income groups (>GHC 300; >$78.95), somewhat similar to [29], except that the upper limit for the middle income category in [29] was GHC500.

The data were analyzed using non-parametric tests. The Kruskal-Wallis H test evaluated variation in daily generated quantities of SMW across assigned income groups. Seasonal variation was assumed a priori in household generation of SMW and evaluated with the Wilcoxon signed ranks test. Household characteristics that might influence generation of SMW were determined in two steps. First, within-variable differences in household SMW generation were tested using the Wilcoxon rank sum test. Each characteristic namely medical complaints, National Health Insurance Scheme (NHIS) membership, education, presence of under-fives, type of house and room occupancy, had "1" assigned to the risk category and '0' to the reference category. A p-value < 0.05 indicated significant variation in household generation of SMW. In the second step, quantile regression was used for multivariable analysis, applying the statistical model in Equation (1) [30].

$$Y = \alpha + \sum_i \beta_i X_i + \varepsilon \quad (1)$$

where Y is the household generation of SMW (kg/household/day), α is a constant term, β_i represents the regression coefficient for ith household characteristic, X_i, and the residual error term is represented by ε [30]. P-values were generated with Stata version 14.0 (Stata Corp College Station, USA), and based on the hypothesis that the computed regression coefficient equals zero. A p-value less than 0.05 implied that variability in household generation of SMW was unlikely to be due to chance.

3. Results

3.1. Participant Characteristics

Sixty households were recruited for the household waste stream analysis. In this sample, 42 (70.0%) households were registered under the National Health Insurance Scheme (NHIS), 17 (28.3%) households reported medical complaints, 23 (38.3%) households had children aged below 5 years and in 48 (80.0%) households the respondents had attained secondary education or higher. Fifty (83.3%) households were single (nuclear) families, 27 (45.0%) households lived in compound houses (multi-unit housing), and 40 (66.7%) households had 4 sleeping rooms or less. The average household size in the low, middle and high income groups was 4 persons, 5 persons and 4 persons respectively.

3.2. Solid Medical Waste Generation

The average quantity of SMW generated in households was 7.26×10^{-3} kg/household/day and each household member generated 1.77×10^{-3} kg/person/day on average (Table 2). Minimum household generation was 0.028×10^{-3} kg/household/day (28 grams) and maximum household generation was 0.074×10^{-3} kg/household/day (74 grams).

Two households were outliers with generation rates of 54.85×10^{-3} kg/household/day (household number = 18/20) and 74.48×10^{-3} kg/household/day (household number = 09/02) respectively. Both households discarded an unusual quantity of medicines in their household waste for unknown reasons. When these households were excluded, average generation was 5.28×10^{-3} kg/household/day and each household member generated 1.34×10^{-3} kg/ person/day respectively (Table 3).

Based on capita generation and population size in the 30 locations (n = 24,183), the average daily quantity of SMW generated was 42.80 kg when outlier measurements were included and 32.40 kg, when they were excluded. No significant variation was found in SMW generated across the income groups per household [$H(2) = 1.40$, $p = 0.497$] and per capita [$H(2) = 3.08$, $p = 0.214$].

3.3. Percentage Composition of Waste Sub-Streams in the Household Waste Stream

During the study period, the average percentage composition of SMW in

Table 2. Descriptive statistics for solid medical waste generation per household (kg/hh/day) and per capita generation (kg/person/day).

Name of parameters	Household generation (kg/hh/day)	Per capita generation (kg/person/day)
Mean (n = 60 households)	7.26×10^{-3}	1.77×10^{-3}
Standard deviation	11.58×10^{-3}	2.64×10^{-3}
Coefficient of variation	1.60	1.49
Median	4.59×10^{-3}	1.05×10^{-3}
Interquartile range	4.85×10^{-3}	1.18×10^{-3}
Minimum (household number = 01/05)	28.6×10^{-6}	8.16×10^{-6}
Maximum (household number = 09/02)	0.74×10^{-3}	0.15×10^{-3}
Coefficient of skewness	4.51	3.72
Coefficient of kurtosis	24.52	17.87

Table 3. Descriptive statistics for solid medical waste generation per household (kg/hh/day) and per capita generation (kg/person/day) without outliers[a].

Name of parameters	Household generation (kg/hh/day)	Per capita generation (kg/person/day)
Mean (n = 58 households)	5.28×10^{-3}	1.34×10^{-3}
Standard deviation	3.98×10^{-3}	1.23×10^{-3}
Coefficient of variation	0.75	0.92
Median	4.38×10^{-3}	1.01×10^{-3}
Interquartile range	4.71×10^{-3}	1.05×10^{-3}
Minimum (household number = 01/05)	28.6×10^{-6}	8.16×10^{-6}
Maximum (household number = 02/03)	1.72×10^{-2}	0.57×10^{-2}
Coefficient of skewness	1.18	1.60
Coefficient of kurtosis	4.10	5.41

a. Two households were excluded from the original sample in Table 2 (household numbers 18/20 and 09/02 with household generation rates of 54.85×10^{-3} kg/household/day and 74.48×10^{-3} kg/household/day respectively).

household waste was 1.07% (offensive waste excluded). Pharmaceutical waste formed the bulk (approximately 98%) of SMW from households. The percentage distribution of sharps waste was similar across income groups. When all income groups were combined, the percentage of pharmaceutical waste, sharps waste and offensive waste in household waste were 1.05%, 0.02% and 4.94% respectively.

3.4. Seasonal Variation in Generation Rates of Waste Sub-Streams

When all income groups were combined, the per capita daily generation rates were significantly higher in the wet season than in the dry season for pharmaceutical waste, solid medical waste and offensive waste. Sharps waste showed no seasonal variation ($z = 1.938$, $p = 0.053$) (Table 4).

3.5. Factors Associated with Quantity of Solid Medical Waste

Preliminary analysis showed that medical complaints, type of house, and room occupancy might influence the distribution of SMW (Table 5).

After multivariable analysis, reported medical complaints emerged as the only significant factor influencing generation of SMW. Households that reported medical complaints generated significantly less SMW than households that did not report medical complaints, controlling for type of house and room occupancy (Table 6). The greatest difference was observed at the 75th quantile, when outliers were excluded ($\beta = -5.107$; $p = 0.005$) (Table 7).

3.6. Description of SMW Recovered from Household Waste

Among items recovered from pharmaceutical waste, antibiotics, multivitamins,

Table 4. Per capita generation of waste components (kg/person/day) distributed by season (n = 60 households).

SMW components\ Income group	Low income		Middle income		High income		Total		Wilcoxon signed rank test	
	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Wet season	Dry season	Z	p-value[b]
Pharmaceutical waste	4.31×10^{-3}	1.10×10^{-3}	0.81×10^{-3}	1.06×10^{-3}	1.97×10^{-3}	0.98×10^{-3}	2.79×10^{-3}	1.06×10^{-3}	3.052	**0.002**
Sharps waste	0.06×10^{-3}	0.04×10^{-3}	0.05×10^{-3}	0.03×10^{-3}	0.04×10^{-3}	0.03×10^{-3}	0.05×10^{-3}	0.04×10^{-3}	1.938	0.053
Solid medical waste	4.36×10^{-3}	1.15×10^{-3}	0.87×10^{-3}	1.07×10^{-3}	2.01×10^{-3}	1.01×10^{-3}	2.84×10^{-3}	1.09×10^{-3}	3.129	**0.002**
Offensive waste	34.89×10^{-3}	10.65×10^{-3}	38.86×10^{-3}	10.28×10^{-3}	14.28×10^{-3}	2.90×10^{-3}	30.97×10^{-3}	8.61×10^{-3}	4.960	**0.000**

[a]Values under wet and dry season are in kg/person/day. [b]p-values in bold font are statistically significant at 5% significance level.

Table 5. Solid medical waste (kg/household/day) by household characteristics based on Two-sample Wilcoxon rank-sum (Mann-Whitney) test.

Characteristics	Median quantity of solid medical waste (IQR)[a]	Mann-Whitney test statistic	p-value[b]
NHIS			
No	3.80×10^{-3} (4.71×10^{-3})	−0.008	0.994
Yes	4.80×10^{-3} (5.08×10^{-3})		
Medical Complaints			
No	5.86×10^{-3} (4.80×10^{-3})	3.986	**0.000**
Yes	2.31×10^{-3} (1.89×10^{-3})		
Highest level of education			
None/Basic	3.81×10^{-3} (4.33×10^{-3})	0.213	0.832
Secondary or higher	4.80×10^{-3} (5.09×10^{-3})		
Children aged below 5 years			
Yes	3.89×10^{-3} (3.17×10^{-3})	0.395	0.693
No	4.71×10^{-3} (5.65×10^{-3})		
Type of House			
Compound house	3.51×10^{-3} (3.12×10^{-3})	2.244	**0.025**
Flat/Other	5.94×10^{-3} (6.88×10^{-3})		
Room occupancy (category)			
≤2 person(s) per room	5.28×10^{-3} (5.02×10^{-3})	2.038	**0.042**
>2 persons per room	2.66×10^{-3} (1.72×10^{-3})		
Family type			
Single family	4.67×10^{-3} (4.71×10^{-3})	0.615	0.539
Extended family	3.73×10^{-3} (5.29×10^{-3})		

a. IQR is the interquartile range. b. p-values in bold font are statistically significant at 5% level of significance.

analgesics, antifungal and antimalarial drugs were present, with antibiotics being predominant. For instance, syrup bottles containing amoxicillin and metronidazole (mostly as paediatric formulation), capsules of ampicillin, cloxacillin, doxycycline, and penicillin V tablets were found. Non-steroidal anti-inflammatory drugs (NSAIDs) included diclofenac and ibuprofen. Paracetamol was found

Table 6. Regression coefficients[a] of household characteristics, by OLS and by Quantiles and their respective p-values[b] (n = 60 households).

Variable	OLS	q05	q10	q25	q50	q75	q90	q95
constant	9.086	2.720	3.149	4.286	7.149	8.486	13.371	15.829
p-value	0.000	0.013	0.000	0.000	0.000	0.000	0.220	0.417
Medical complaints	−5.935	−2.711	−2.949	−3.429	−4.600	−2.943	−4.914	−10.200
p-value	0.076	**0.001**	**0.000**	**0.000**	**0.000**	0.177	0.668	0.610
Type of house	1.013	0.019	−0.171	−0.771	−1.292	−0.169	3.857	9.143
p-value	0.739	0.984	0.780	0.284	0.270	0.945	0.796	0.737
Room occupancy (category)	−5.152	−1.168	−1.406	−1.594	−3.429	−2.711	−9.651	−12.108
p-value	0.276	0.176	0.012	0.141	0.056	0.312	0.365	0.406
$R^{2\,c}$	0.0756	0.1581	0.1645	0.1208	0.1010	0.0752	0.0769	0.0890

a. All coefficient values for the study attributes are multiplied by ($\times10^{-3}$). b. The probability values (p-value) support the hypothesis that the computed coefficient equals zero. A p-value of 0.05 or less indicates a statistically significant effect at 5% significance level. c. The coefficient of determination (R2) in quantile regression models are Pseudo R2.

Table 7. Regression coefficients[a] of household characteristics, by OLS and by Quantiles and their respective p-values[b] (n = 58 households).

Variable	OLS	q05	q10	q25	q50	q75	q90	q95
constant	6.343	0.857	2.720	3.488	6.628	7.971	11.568	13.371
p-value	0.000	0.391	0.005	0.000	0.000	0.000	0.000	0.000
Medical complaints	−3.236	−0.771	−2.006	−2.631	−4.318	−5.107	−5.940	−2.457
p-value	**0.005**	0.406	**0.030**	**0.001**	**0.001**	**0.005**	0.154	0.666
Type of house	−0.801	−0.086	−0.686	−0.749	−1.343	−1.823	−2.801	3.114
p-value	0.465	0.914	0.318	0.322	0.266	0.281	0.380	0.480
Room occupancy (category)	0.525	1.229	−0.029	0.403	0.320	1.621	2.546	0.743
p-value	0.634	0.214	0.973	0.614	0.776	0.342	0.488	0.868
R^{2c}	0.1523	0.1824	0.1817	0.1559	0.1306	0.1106	0.1035	0.0695

a. All coefficient values for the study attributes are multiplied by ($\times10^{-3}$). b. The probability values (p-value) support the hypothesis that the computed coefficient equals zero. A p-value of 0.05 or less indicates a statistically significant effect at 5% significance level. c. The coefficient of determination (R2) in quantile regression models are Pseudo R2.

in dispensing envelopes, blister packs and as loose tablets. Antihypertensive (nifedipine, lisinopril, amlodipine, bendrofluazide) and antidiabetic (glibenclamide, metformin) medicines were also present in blister packs or dispensing envelopes. Sharps recovered were predominantly used razor blades. A few disposable shaving sticks were also present. Needles (capped and uncapped) and syringes were recovered from a single household bin bag. Offensive waste mostly comprised of soiled baby diapers, with a smaller fraction of blood stained tissue paper, sanitary pads and cotton buds. Other items found in single disposal events included plaster, a long wrap of gauze bandage soiled with serous fluid and a pair of examination gloves. Male condoms and intravenous infusion bags (normal saline) were found on two disposal events. No intravenous tubing or cannulae were seen.

4. Discussion

4.1. Generation of Solid Medical Waste in Households

At the time of writing, no study had described the quantification of SMW in household solid waste in Ghana, therefore our study represents the first generation study conducted in a local community. Households typically generated between 5 and 7 grams of SMW daily. Although these were relatively small amounts, the total daily production of 32.40 kg computed for the study population is substantial. With the outlier households, the daily production of 42.80 kg represents situations where hoarding of medicines may occur in the household. This could result in periodic or one-off disposal of large quantities of SMW. The small sample of households used in the study suggests that the values are indicative, but its composition mostly of unwanted medicines, especially antibiotics raises concern. This is given the fact that nearly all household waste in Ghana is sent to landfills.

Household generation of SMW showed significant seasonal variation. This confirmed our assumption a priori. Some diseases that exhibit seasonal variation often require the use of medicines, such as malaria and respiratory tract infections. This would result in the generation of SMW from left over or expired medicines. Waste generated would include medicines and/or their containers, but not packaging. The higher generation of SMW in the wet season may be partly attributed to common acute illnesses which tend to peak with the rains, such as malaria, respiratory tract infections and some diarrhoeal diseases. The medicines recovered during the waste stream analysis included therapeutic categories often prescribed or bought over the counter for these conditions. Therefore, the consumption of medicines may be higher in these seasons and left over medicines and their containers generate SMW. It is also possible that at the onset of the survey which was in the wet season, a few households may have utilized the opportunity to discard stored waste items since waste collection was offered at no cost to households, whereas the services rendered by the waste management companies had to be paid for monthly. However, these outliers were limited to less than 5% of the sampled households.

Cussiol *et al.* (2006) sampled municipal solid waste (mostly of residential origin) to quantify potentially infectious waste [31]. Therefore we compared our results with this study. Unwanted medicines referred to as 'chemical waste', accounted for 1.91% of the waste sample in the reference study. We found a lower proportion of 1.05%. It is likely that SMW from other sources may partly account for differences observed in waste composition between the reference study and the present study. The proportion of sharps waste was similar in both studies. However, a lower percentage of non-sharps (offensive) waste was generated in the present study, 4.94% compared to 5.47% in the reference study. The higher proportion of offensive waste was mostly attributed to baby diapers which formed the bulk of waste in both cases.

4.2. Potential Hazards to Health and Environment

Unwanted medicines comprised the bulk of SMW in households. The therapeutic categories of the medicines recovered were consistent with acute and chronic diseases prevalent in Ghana. Acute conditions such as malaria, respiratory infections and diarrhoea [32] are prevalent, as well as chronic conditions, such as hypertension [33] [34] and diabetes mellitus [35] [36]. Syrup bottles labelled with antimalarial, antibiotic and multi-vitamin preparations, were found with minimal residue or some content left over from previous use. As household waste is mostly deposited in landfills and open dumps, such disposal practices can potentially introduce active pharmaceutical ingredients in the environment. The greatest concern is the risk of antibiotic resistance as antibiotics were the largest category of medicines recovered from household waste, particularly the penicillin group. In a similar study of municipal solid waste in Florida, USA, antibiotics as a group was found in the largest quantity, followed by non-steroidal anti-inflammatory drugs [37]. Diclofenac and ibruprofen have been reported in earlier studies to be associated with toxic effects in birds [38], in aquatic life [39] and reduces survival of decomposers [40]. Razor blades were the most common type of sharps waste, as also reported in the study by Cussiol *et al.* (2006) [31]. The presence of needles found loosely in household waste confers hazardous properties on the household waste stream. Hollow needles present in waste predispose waste workers and other persons handling the waste to community acquired needle stick injuries.

Offensive waste is not considered medical waste, but deserves mention because it accounted for a higher overall percentage of household waste (4.94%) compared to SMW (1.07%); and it was often soiled with faecal matter or body fluids. Faecally soiled diapers and used sanitary pads were recovered from the household waste stream analysis, with the former in large quantities. Faecally soiled materials can contain enteric pathogens such as E. coli, Salmonella, and Shigella, which have been reported to survive up to 117 kilometres from source when introduced into flowing water [41] [42]. These agents can cause diarrhoeal diseases in exposed persons through orofaecal transmission. Elsewhere it has been reported that polio and echoviruses were isolated from 11% of faecally soiled diapers [43]. Another study reported the recovery of human papilloma virus from menstrual fluid or vaginal discharge collected in sanitary napkins, although these napkins were not retrieved from waste [44]. The precautionary principle, the potential of microbes to multiply under favourable storage conditions offered by household waste and the non-use or lack of adequate protection by waste workers and scavengers in developing countries posits offensive waste as potentially infectious in these settings [1].

4.3. Strengths of the Study

This study presents a quantitative and qualitative description of household SMW in a district in Ghana. Only a few studies in Africa have reported on SMW in the community and these often lack quantitative estimates. Empirical data in this study, though indicative, provide baseline data for further generation studies and informs waste management in the district. If SMW should be segregated at source and diverted from the household waste stream, storage and transport capacities can be computed. It draws attention to the large proportion of SMW comprising mostly pharmaceutical waste (mostly antibiotics and non-steroidal anti-inflammatory steroidal drugs) sent to landfills and raises concerns about potential antibiotic resistance and toxicity to wildlife.

4.4. Limitations of the Study

At the onset of the study, some of the households did not place their household waste for collection as agreed. This changed and collection improved in the later weeks. To compensate for these events, single mean imputation for missing data was used to compute the missing weight measurements in Stata version 14.0 (StataCorp LP, Lakeway Drive, Texas, USA).

Due to the small sample size of households for the waste stream analysis, results can only be considered indicative. To obtain quantitative estimates intended for regional planning, larger samples taken over successive surveys are recommended. The non-normal distribution of weight measurements of SMW is due to its generation in relatively smaller quantities compared to healthcare facilities. The clustering of measurements close to zero, and fewer extreme values often resulted in a positive skew. The weight of the medicine containers might have affected the weight of SMW, however these were not disregarded as residue left in them can contain active ingredients. Finally, the assignment of income groups arbitrarily, limits the generalization of the results beyond the study location.

4.5. Conclusion and Recommendations

Generation of SMW is influenced by medical complaints and is higher in the wet season than in the dry season. As SMW comprised largely of pharmaceuticals, segregation at source could divert this sub-stream for appropriate treatment and disposal to minimize any potential environmental and/or health impact. The relatively smaller quantities of sharps confer some hazardous properties on household waste and should be safely diverted from the waste stream. The impact of continual deposits of SMW generated at computed rates in the study area is unknown, but extant literature and waste composition rationalize concerns about antibiotic resistance and toxicity to wildlife. Therefore, it is pertinent that future policy on the management of SMW takes into account quantities generated in the community, rather than focus on healthcare institutions alone.

Declarations

Ethical Considerations and Clearance to Conduct the Study

Ethical approval for the study was obtained from the Noguchi Memorial Institute of Medical Research (NMIMR) Institutional Research Board. Written permission to conduct the study was obtained from the Municipal Chief Executive (MCE). Clearance was obtained verbally from community chiefs during a meeting convened by GSMA. At the meeting, the purpose of the study and the stages in the study were briefly explained. Individual informed consent was obtained from all persons prior to questionnaire administration. Respondents were interviewed in the privacy of their homes and only eligible households participated in the study. Participants' rights to withdrawal from the study were upheld and all participants were treated with respect.

Competing Interests

All authors declare that they have no competing interests.

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Authors' Contributions

EAU conceived, designed and analyzed the study. Methodology was reviewed by GG and JNF. Data collection was coordinated by EAU. All authors made significant contributions to the writing of the manuscript. The final manuscript was reviewed and approved by all authors.

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List of Abbreviations

CANSIs: Community Acquired Needle Stick Injuries
DANIDA: Danish International Development Agency
EAs: Enumeration Areas
GSMA: Ga South Municipal Assembly
GSS: Ghana Statistical Services
HCW: Healthcare Waste
MCE: Municipal Chief Executive
NHIS: National Health Insurance Scheme
NMIMR: Noguchi Memorial Institute of Medical Research
OLS: Ordinary Least Squares Regression
SMW: Solid Medical Waste
WHO: World Health Organization