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Blood flows: mapping journeys of menstrual waste in Blantyre, Malawi

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ABSTRACT

The interplay between menstrual waste and urban sanitation infrastructure is largely hidden from view. Qualitative research has highlighted socio-cultural aspects of menstruation, but few quantitative studies have mapped the physical situation at scale. This study surveyed 258 women in Blantyre, Malawi about their menstrual absorbent choices, disposal practices, and socio-demographic characteristics. A Sankey diagram visualised flows of menstrual waste in the urban environment and identified ultimate disposal points. Most participants used either disposable pads and/or old cloth and disposed of them by either burning and/or throwing in pit latrines. Pad and cloth use were associated with age, education, employment, marital status, and household wealth. Younger women's preference for disposable pads suggests that demographic shifts may cause volumes of menstrual waste to increase. However, differences in waste volume produced by disposable and reusable absorbents was less than previously assumed. The volume of menstrual waste discarded in pit latrines, and cultural barriers to disposing it elsewhere, highlights challenges for the pit emptying industry and faecal sludge value recovery sector, with the problem anticipated to be most acute in high-density settlements. Widening access to sustainable disposal strategies, affordable reusable menstrual products, and tackling stigma, are key to addressing this social and environmental challenge.

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Menstruation; solid waste; sanitation; faecal sludge; gender

Introduction

Sustainable management of pit latrines by periodic emptying is critical to delivering universal sanitation in rapidly densifying urban areas, as space constraints mean that continuing to abandon full pit latrines is infeasible (Chunga *et al.* 2016, Berendes *et al.* 2017). However, the ubiquitous presence of menstrual waste in pit latrines poses a challenge to easy and safe emptying (Tembo *et al.* 2019). When full pits are emptied by mechanical methods, such as pumps, discarded menstrual cloth can wrap around the propelling blades of these devices and cause them to malfunction (Sisco *et al.* 2017). As pit emptying businesses are unlikely to be able to afford pumps with powerful maceration capabilities, manual emptying of the waste is instead necessary to avoid blocking the pumps (Chipeta *et al.* 2017). Furthermore, the presence of menstrual absorbents and other solid waste in faecal sludge makes it economically challenging to reuse the material (Tembo *et al.* 2019). Compost and biogas are valuable resources in low-income peri-urban contexts that can be produced from faecal sludge, but the presence of solid waste can affect both the quality of these products and the profitability of their production operations (Strande and Brdjanovic 2014).

Menstrual absorbents are highly sensitive and private materials due to cultural etiquette, and also because many believe that they can be used to perform witchcraft rituals, causing severe personal harm to the owner (Scorgie *et al.* 2016, Chinyama *et al.* 2019). Menstruating women therefore require disposal options for their absorbents that are discreet, convenient, and considered safe from witchcraft (Roxburgh *et al.* 2020). There is therefore a need to combine insights from social sciences and engineering in order to sensitively and appropriately address gendered sanitation issues such as menstrual waste management (Tilley *et al.* 2013). In recent years, advances in qualitative studies have given detailed insights into the socio-cultural aspects within which menstrual waste is generated and managed (e.g. Scorgie *et al.* 2016, Chinyama *et al.* 2019, Roxburgh *et al.* 2020). However, there is still a lack of quantitative data on how menstrual waste moves through the physical environment in urban areas. This information is necessary to and inform the conceptualisation and design of improved menstrual waste management systems.

The aim of this study was to understand, at scale, how women currently manage menstrual waste,

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 Supplemental data for this article can be accessed [here](#)

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identify interactions and potential conflicts between menstrual waste and other urban infrastructure. There were three objectives to the study. Firstly, to characterise and quantify the menstrual absorbent choices and disposal methods of women in the city of Blantyre and explore associations with a variety of socio-demographic characteristics. Secondly, to investigate how preferences for different menstrual absorbents have changed over the last decade. Thirdly, to map the menstrual waste disposal pathways, identifying interactions with sanitation and solid waste infrastructure in urban environments, and locating its ultimate destination(s).

Method

Questionnaire survey

Data were collected through the use of a questionnaire survey with female members of the general public in Blantyre (the second largest city in Malawi), conducted in March 2020 (Roxburgh *et al.* 2020b). The design of the questionnaire was informed by previous qualitative work, including semi-structured interviews with 31 women in Blantyre to identify the main types of menstrual absorbents and disposal routes used (Roxburgh *et al.* 2020). Participants were assisted to complete the questionnaire by the enumerators.

The questionnaire gathered information on menstruation and menstrual practices, including: whether the participant experienced menstrual cycles (and if not, whether they had experienced any within the last two years), what absorbents participants used during their last period, and for disposable options (e.g. disposable pads and tampons), how they were discarded. For reusable options (e.g. menstrual cloth or reusable pads), participants were asked to think back to when they last discarded one of these items and explain what they did with it. Many participants utilised multiple absorbents and multiple disposal strategies during their last period. For these cases, where the participants struggled to complete the questionnaire, the enumerators had a discussion with the participant about their menstrual practices in order to help them to assign percentages to the relative usage of each absorbent, and the approximate proportion of absorbents assigned to each disposal pathway. If participants were old enough to have been menstruating 10 years prior to the survey, in 2010, they were also asked to recall what absorbents they had used then. To do this, the enumerator asked the participant their current age, and then asked them to think back to when they were [their current age minus 10] years old. They were then asked if they could recall what menstrual absorbents they were using at that time in their life.

Participants discarding menstrual absorbents in pit latrines, bins, or rubbish pits were asked what usually

happens to these receptacles once they become full. If pit latrines were emptied, and the contents removed from site, participants were asked to specify whether their pit emptying service is usually carried out using a manual bucket and spade, or by another device such as a machine.

Demographic information was also collected, including age, highest educational level attained, source of personal income, and marital status. Asset ownership was used as a proxy for household wealth, measured by asking participants whether any member of their household owned a mobile phone, TV, or vehicle (motorbike, car, or truck). Participants were also asked what kind of toilet they had at home, and about the regularity of their solid waste collection service. The survey was conducted with 258 female participants, aged 18 or above, recruited from seven different areas of the city. The questionnaire was administered by two female residents of Blantyre, who were fluent in Chichewa. The questionnaire took about 15 minutes to complete, and the refusal rate was approximately 25%.

The seven recruitment locations were purposefully chosen to represent the most populous wards in the city, but also to cover a diversity of neighbourhood types in terms of wealth, density, and sanitation/solid waste infrastructural characteristics. The two largest informal settlements in Blantyre (Bangwe and Ndirande) were included, along with peri-urban areas (e.g. Chigumula). Originally, a larger sample size was planned, but the COVID-19 pandemic meant that data collection had to be terminated sooner than expected, and one neighbourhood (Bangwe) was relatively oversampled as a result. However, the sample size of 258 is considered representative of the female population of the Blantyre urban area (which was estimated at 400,132 in 2018 (National Statistics Office, 2019)) with a margin of error of 6%, and a confidence level of 95%.

Participants were recruited through two different methods. For the first method, questionnaire administrators selected streets to provide a cross-section of neighbourhood types across each recruitment location and knocked on the door of every '*n*'th house (adjusted according to settlement density) to invite a woman from the household to participate. For the second method, the questionnaire administrators approached women in public spaces (primarily at hair salons and marketplaces), similarly selected to represent a societal cross-section within each recruitment location, and invited them to participate. This complementary recruitment procedure was intended to eliminate bias that might result from only recruiting women found at home during the daytime. Approximately half of participants were recruited through each method.

Ethical consent for the survey was obtained from the University of Stirling General University Ethics Board (reference number: GUEP 806), and from the Malawi National Committee on Research in the Social Sciences and Humanities (reference number: NCST/RTT/2/6, protocol number: P.03/20/464), prior to commencement of fieldwork. As the survey involved discussion of a culturally sensitive topic, care was taken at the recruitment stage to ensure that participants were fully informed of what the survey would involve, that they could withdraw their participation at any time, and that they were not obliged to answer all of the questions. The enumerators were both female and had previous experience of carrying out research on menstruation or similar sensitive research subjects.

Data analysis

The types and combinations of menstrual absorbents used by participants were characterised using descriptive statistics and visualised using a tree map. The composition and flows of menstrual absorbents through disposal pathways to destinations were visualised using a Sankey diagram. The destinations of menstrual waste were determined using the data gathered from participants on how they disposed of their menstrual absorbents, and what happened to their disposal receptacles.

For menstrual absorbents discarded in pit latrines, the pit emptying method (i.e. mechanical or manual) was used as a proxy to indicate whether the pit emptier was formal or informal, and therefore whether the pit contents were likely to have been taken to a wastewater treatment works for disposal (i.e. mechanical) or dumped into the environment (i.e. manual).

For the subset of participants who experienced menstrual cycles ten years prior to the survey, changes in their menstrual absorbent uses over the last decade were also visualised using a Sankey diagram.

Significant associations between demographic, recruitment, and infrastructural variables and use of the two most common absorbents (pads and cloth) and disposal methods (burning and throwing in pit latrines) were tested using Chi-square tests for independence. Yates' Correction for Continuity was used for tests where characteristics were defined by just two levels (e.g. whether the participant was recruited at home or in a public place), in order to compensate for potential overestimation of the Chi-square value when used for a 2×2 table (Hoffman 2019). Post-hoc testing was carried out for tables greater than 2×2 by calculating p-values from adjusted residuals and comparing these to an α value adjusted using the Bonferroni correction, in order to compensate for potential type 1 family wide errors (Holm 1979, García-Pérez and Núñez-Antón 2003). As the

Bonferroni correction is sometimes considered conservative, results which were significant in the absence of the correction are also indicated. Finally, binary logistic regression models were constructed to model the use of pads and cloth as a function of demographic variables.

Statistical analysis was carried out using SPSS (IBM SPSS Statistics Version 26), Sankey diagrams were created using MetaFlow (Graphical Memes Version 1.2), and the tree map was produced using the 'geom_treemap' function from the R package 'treemapify' (R Package Version 2.5.3) (Wilkins 2019). The dataset is available to download (Roxburgh *et al.* 2020b).

Results

Characterisation of participants

The demographic characteristics of participants and details of their sanitation and solid waste services are shown in Table 1. Almost all participants (90%, $n = 233$) were still experiencing menstrual cycles at the time of the survey (i.e. they had not yet reached menopause or otherwise ceased to menstruate) and were therefore able to respond to the questions on the basis of recent personal experience. The sample population was weighted towards younger participants, with the majority (56%, $n = 144$) being under the age of 30. This corresponds to the general age profile of Blantyre city, which is skewed towards a younger demographic. Almost all participants (97%, $n = 250$) had received at least some education, with over three-quarters (78%, $n = 202$) attending secondary school. Almost a third (30%, $n = 78$) had received some kind of higher education, attending either a technical college or university. Less than a third (28%, $n = 73$) were formally employed, with just over a quarter receiving support from their husband, friends or family (27%, $n = 68$) and the largest percentage involved in business activities or farming (36%, $n = 92$). Of the assets used as a proxy for household wealth (ownership of a mobile phone, TV, or vehicle), only a small percentage of participant households (3%, $n = 9$) had none. Almost all (94%, $n = 242$) had a mobile phone, and the majority (72%, $n = 186$) had a TV. Vehicle ownership was less common (29%, $n = 74$) and assumed to occur amongst wealthier households. Almost half of participants were married (48%, $n = 124$). All participants had toilets at home, and for the majority (87%, $n = 255$) this was a pit latrine. Over half of participants had no waste collection service in their area (51%, $n = 131$, and less than one-fifth (19%, $n = 49$) had their waste collected more than twice a month.

Menstrual absorbents used by participants during their last period are shown in Figure 1. Almost three-quarters of participants (72%, $n = 187$) used only one

Table 1. Demographic characteristics and sanitation services of participants ($n = 258$).

| Characteristics | | Participants ($n = 258$) | |
|---|-------------------------------|-------------------------------|-----|
| Recruitment location | Bangwe | 61 | 24% |
| | Blantyre | 15 | 6% |
| | Chigumula | 30 | 12% |
| | Chirimba | 38 | 15% |
| | Machinjiri | 33 | 13% |
| | Mbayani | 46 | 18% |
| | Ndirande | 35 | 14% |
| Survey conducted | At home | 121 | 53% |
| | Public space | 137 | 47% |
| Menstrual status | Menstruating | 233 | 90% |
| | Stopped in last 2 years | 10 | 4% |
| | Stopped more than 2 years ago | 13 | 5% |
| | Missing ^c | 2 | 1% |
| Menstrual absorbents used during last period | Pads | 157 | 61% |
| | Cloth | 130 | 50% |
| | Cotton ^a | 21 | 8% |
| | Tampons | 13 | 5% |
| | Reusable pads | 11 | 4% |
| Age | 18–29 | 144 | 56% |
| | 30–39 | 70 | 27% |
| | 40–49 | 26 | 10% |
| | 50–59 | 13 | 5% |
| | 60+ | 4 | 2% |
| | Missing ^c | 1 | <1% |
| Highest educational level attained | None | 5 | 2% |
| | Primary school | 48 | 19% |
| | Secondary school | 124 | 48% |
| | Technical college | 41 | 16% |
| | University | 37 | 14% |
| | Missing ^c | 3 | 1% |
| | Piecework ^b | 25 | 10% |
| Main source of personal income | Business or farming | 92 | 36% |
| | Employment | 73 | 28% |
| | Husband | 25 | 10% |
| | Family and friends | 43 | 17% |
| | Never married | 86 | 33% |
| Marital status | Married | 124 | 48% |
| | Previously married | 46 | 18% |
| | Missing ^c | 2 | 1% |
| | No assets | 9 | 3% |
| Household asset ownership | Mobile | 242 | 94% |
| | TV | 186 | 72% |
| | Motorbike | 21 | 8% |
| | Car or truck | 53 | 21% |
| | Missing ^c | 5 | 2% |
| | Pit latrine | 255 | 87% |
| | Flush | 56 | 22% |
| Household toilet | No toilet | 0 | 0% |
| | Missing ^c | 11 | 4% |
| | Never | 131 | 51% |
| | Less than twice a month | 50 | 19% |
| | More than twice a month | 49 | 19% |
| Regularity of waste collection by Blantyre City Council | Missing ^c | 28 | 11% |

^a'Cotton' refers to homemade pads using cotton wool.

^b'Piecework' refers to small jobs like tailoring, assembling items, or other types of casual day labour.

^c'Missing' indicates that the participant either did not know or did not want to answer.

kind of menstrual absorbent, and the rest used two (26%, $n = 68$) or more (1%, $n = 3$) combinations of absorbents. About a third of participants used pads only (37%, $n = 95$), about another third used cloth only (30%, $n = 78$), and most participants (83%, $n = 214$) used either pads, cloth, or a combination of both. Even when other absorbents (tampons, cotton, or reusable pads) were used, the majority of these participants still used these materials in combination with either pads or cloth, with 95% ($n = 244$) of participants overall using either pads or cloth in some way.

For a subset of participants using exclusively pads ($n = 94$) or cloth ($n = 55$), the number of pads discarded during the last period and cloths discarded during the last year are shown in [Figures 2 and 3](#). The mean number of pads thrown away was 9.1 per period, whilst the mean number of cloths thrown away was 29.2 per year, with skewness of 3.4 and 29.5, respectively. Within this subset of participants, 51% ($n = 48$) used eight or less pads during their last period, and 53% ($n = 29$) discarded more than 12 menstrual cloths over the last year.

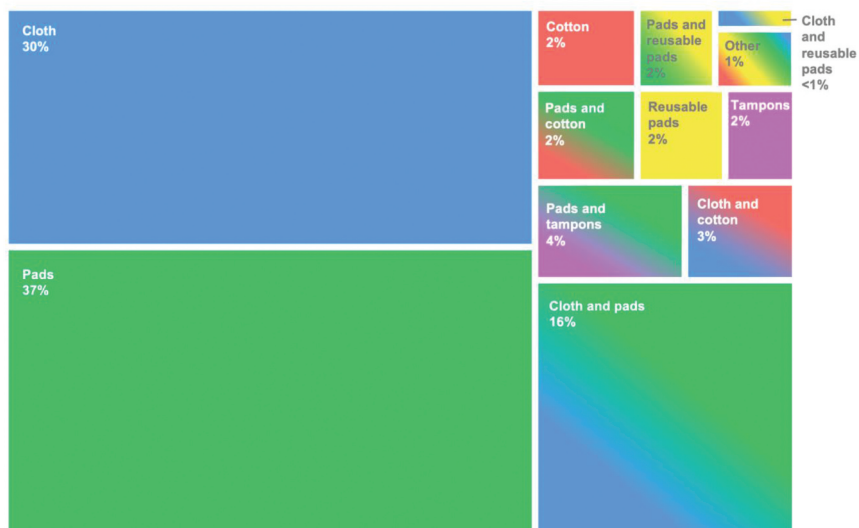


Figure 1. Combinations of menstrual absorbents used by participants at their last period ($n = 258$).

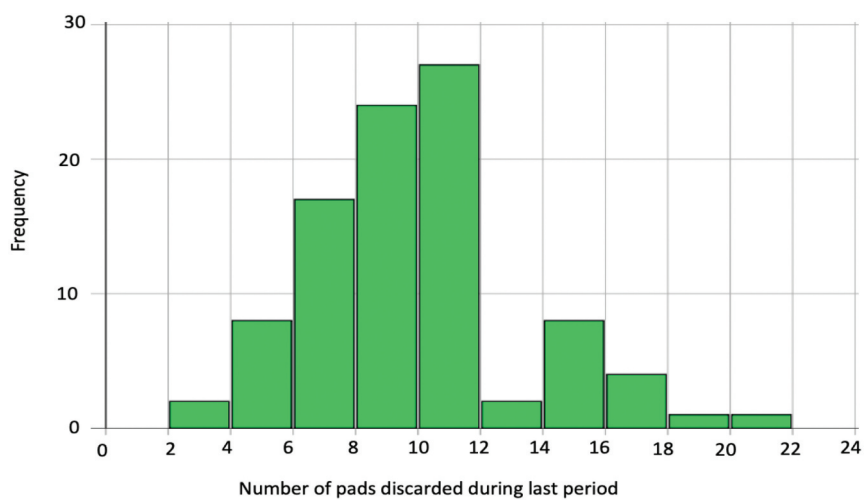


Figure 2. Number of pads discarded during last period by survey participants who just use pads ($n = 94$).

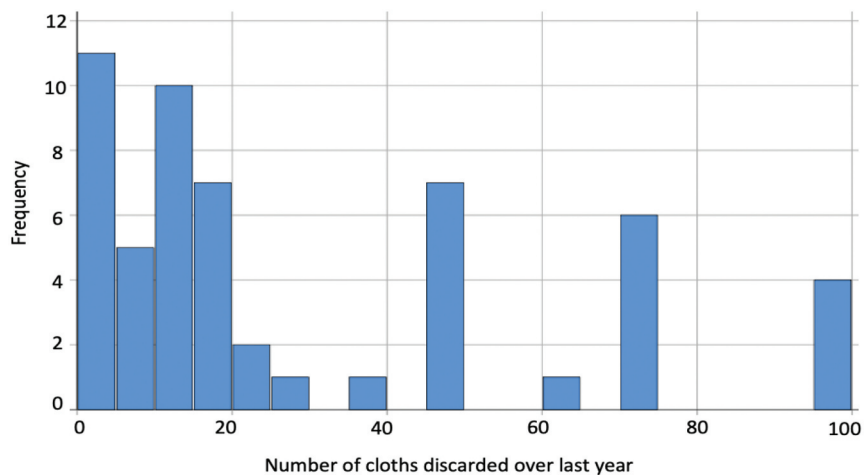


Figure 3. Number of menstrual cloths discarded over the last year by survey participants who just use cloth ($n = 55$).

Menstrual waste disposal pathways

Six final destinations for menstrual waste were identified: being buried, burned, deposited at the wastewater treatment works, thrown into the environment, reaching the landfill site, or being kept. Some menstrual waste reached these destinations directly, but most travelled through an intermediary disposal receptacle, such as a pit latrine, bin, rubbish pit, or flush toilet. Figure 4 shows the composition of menstrual absorbents used by participants ($n = 258$) at their last period, together with their known/anticipated disposal pathways and destinations. Disposal pathways for disposable pads, cotton, and tampons reflect those used during participants' last period, and disposal pathways for cloth and reusable pads are estimated based on how participants most recently disposed of them. Destinations for menstrual absorbents disposed in pit latrines, bins, and rubbish pits are estimated based on what participants anticipate will happen to these receptacles once they are full, and a breakdown of waste destinations is given in Table S1.

The vast majority of menstrual absorbents are either thrown in pit latrines (55%) or burned (41%). Only a small percentage of menstrual absorbents were disposed of by other means (i.e. thrown in bins (2%) or rubbish pits (2%), flushed down the toilet (1%), buried (<1%), or kept (1%)).

The majority of pit latrines containing menstrual absorbents are expected to be either abandoned when full, or their contents dug out and buried nearby, therefore leading to 40% of menstrual absorbents ending up underground (i.e. assigned to the destination 'buried'). Some pit latrines are expected to be emptied and the contents removed, and therefore 11% of menstrual absorbents are anticipated to be taken to the wastewater treatment works by formally registered pit emptiers (identified by their use of mechanical equipment, such as a pumping device), whilst 4% are anticipated to be discarded into the environment by informal pit emptiers (identified by their use of rudimentary equipment, such as a bucket and spade).

Participants who discarded their menstrual absorbents into bins and rubbish pits reported a variety of final destinations for this waste. Menstrual absorbents which are discarded into a rubbish bin or rubbish pit which is ultimately burned is assigned to the destination 'burned' (2%). If households have their solid waste collected by Blantyre City Council, then menstrual absorbents discarded into the bin are presumed to reach the destination 'landfill' (1%). Some households empty their bins into the surrounding environment; menstrual absorbents discarded into bins in this instance are assigned to the destination 'environment' (1%). Some households using rubbish pits do not do

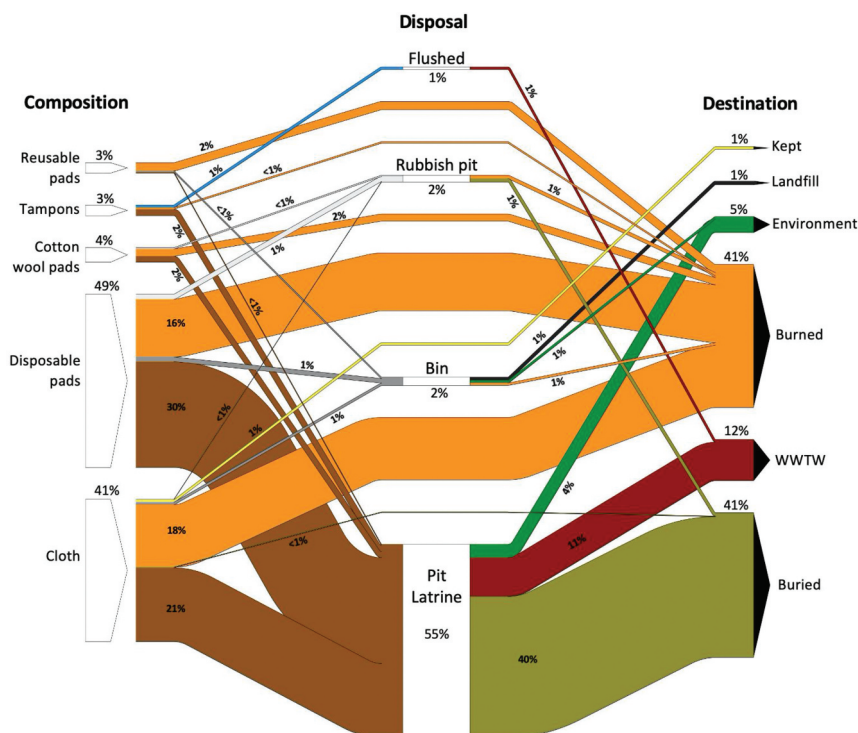


Figure 4. Composition and known/anticipated disposal pathways of participants' ($n = 258$) menstrual absorbents at their last period. Disposal pathways for reusable menstrual absorbents (cloth, reusable pads) are estimated based on how participants most recently disposed of their cloth/reusable pads. Destinations for menstrual absorbents disposed in pit latrines, bins, and rubbish pits are estimated based on what participants anticipate will happen to these receptacles once they are full.

anything further (e.g. burning, moving) to the waste in this pit; in these cases, the pit is presumed to eventually be abandoned and covered with earth, and menstrual absorbents discarded into these pits are assigned to the destination 'buried' (1%). The flushed menstrual absorbents (exclusively tampons) are presumed to reach the destination 'wastewater treatment works' (1%).

A small proportion of participants never discard their menstrual cloth, preferring to keep it even when the material is too worn (through repeated washing) to absorb more blood, as the cloth is believed to have uses in traditional medicine practices. Thus, 1% of all menstrual absorbents (predominantly menstrual cloth) are anticipated to be kept for these reasons.

Determinants of menstrual practices

The majority of participants used pads and/or cloth (95%, $n = 244$) and disposed of their absorbents by burning them and/or throwing them in a pit latrine (95%, $n = 246$), and therefore associations between

these practices and demographic/household infrastructure characteristics were explored using Chi-square tests. Results are presented in Table 2, and full details of the omnibus and post-hoc Chi-square tests and Bonferroni corrected alpha levels are given in Tables S2–S4. Only pad/cloth use and burning/pit latrine disposal were assessed, as there were not enough observations to conduct robust analysis of associations between use of other menstrual absorbents (e.g. tampons, reusable pads, cotton), other disposal practices (flushing, throwing in bins, rubbish pits, burying, or keeping), and other characteristics.

As shown in Table 2, significant and strong associations were found between use of pads and all demographic variables, as well as use of cloth and all demographic variables, which were: age, highest educational level, main source of income, marital status, and household asset ownership. Women aged 18–29 were most likely to use pads (71%, $p < 0.001$) and least likely to use cloth (42%, $p = 0.002$), and those who had attended university were most likely to use pads (84%, $p = 0.002$) and least likely to use cloth (11%, $p = 0.001$).

Table 2. Correlations of absorbent use and disposal choice with demographic/household infrastructure characteristics and recruitment location.

| Characteristics | By type of absorbent | | By disposal method | | | |
|------------------------------------|---------------------------|-------------------------------|--|--|----------------------|--|
| | Use pads ($n = 157$) | Use cloth ($n = 130$) | Burn menstrual absorbents ($n = 118$) | Throw menstrual absorbents in pit latrine ($n = 158$) | | |
| Recruitment location | Bangwe | 38 (62%) | 32 (53%) | 27 (44%) | 44 (72%) | |
| | Blantyre | 7 (47%) | 8 (53%) | 8 (53%) | 6 (40%) | |
| | Chigumula | 19 (63%) | 14 (47%) | 18 (60%) | * 11 (37%) | |
| | Chirimba | 17 (45%) | 26 (68%) | 12 (32%) | * 32 (84%) | |
| | Machinjiri | 21 (64%) | 14 (42%) | 15 (46%) | * 15 (46%) | |
| | Mbayani | 29 (63%) | 21 (46%) | 21 (46%) | 30 (65%) | |
| | Ndirande | 26 (74%) | 15 (43%) | 17 (49%) | 20 (57%) | |
| Survey conducted | At home | 74 (61%) | 65 (50%) | 50 (42%) | 79 (50%) | |
| | Public space | 83 (61%) | 65 (50%) | 68 (50%) | 79 (50%) | |
| Waste collection by BCC | Never | 79 (60%) | 66 (50%) | 60 (46%) | 75 (57%) | |
| | < 2 x month | 28 (56%) | 27 (54%) | 20 (40%) | 36 (72%) | |
| | > 2 x month | 34 (69%) | 22 (45%) | 26 (53%) | 28 (57%) | |
| Household toilet | Pit latrine | 134 (60%) | * 122 (54%) | * 97 (43%) | *** 149 (97%) | |
| | Flush | * 42 (75%) | *** 16 (29%) | 31 (55%) | 30 (54%) | |
| | Age | ** 102 (71%) | * 60 (42%) | * 53 (37%) | ** 102 (71%) | |
| Age | 18–29 | 36 (51%) | 38 (54%) | 34 (49%) | * 36 (51%) | |
| | 30–39 | 14 (54%) | 17 (65%) | ** 21 (81%) | ** 8 (32%) | |
| | 40–49 | 5 (39%) | ^a 10 (77%) | 8 (62%) | ^a 9 (69%) | |
| | 50–59 | ^a 0 (0%) | ^a 4 (100%) | ^a 1 (25%) | ^a 3 (75%) | |
| | 60+ | ^a 1 (20%) | ^a 5 (100%) | ^a 4 (80%) | ^a 1 (20%) | |
| Highest educational level attended | None | *** 13 (27%) | *** 41 (85%) | 20 (42%) | 35 (73%) | |
| | Primary | 82 (66%) | 64 (52%) | 50 (40%) | 79 (64%) | |
| | Secondary | 29 (71%) | 13 (32%) | 24 (59%) | * 19 (46%) | |
| | Technical college | * 31 (84%) | ***^a 4 (11%) | 18 (49%) | 22 (60%) | |
| Main source of personal income | Piecework | * 8 (32%) | ** 19 (76%) | 9 (36%) | 18 (72%) | |
| | Business/farm | 54 (59%) | 49 (53%) | 43 (47%) | 55 (60%) | |
| | Employment | 50 (69%) | * 25 (34%) | 36 (49%) | 42 (58%) | |
| | Husband | 12 (48%) | * 18 (72%) | 10 (40%) | 18 (72%) | |
| | Family/friends | * 33 (77%) | 19 (44%) | 20 (47%) | 25 (58%) | |
| Marital status | Never married | *** 67 (78%) | *** 26 (30%) | 33 (38%) | 82 (66%) | |
| | Married | 73 (59%) | 68 (55%) | 53 (43%) | 57 (66%) | |
| | Previously married | *** 16 (35%) | *** 35 (76%) | * 30 (65%) | ** 19 (41%) | |
| Household asset ownership | No assets | **^a 1 (11%) | ^a 7 (78%) | ^a 5 (56%) | ^a 4 (44%) | |
| | Mobile | * 24 (44%) | ** 40 (73%) | 28 (51%) | 27 (49%) | |
| | TV | 83 (68%) | 60 (49%) | 57 (46%) | 82 (67%) | |
| | Motorbike | ^a 9 (69%) | ^a 6 (46%) | ^a 3 (23%) | ^a 9 (69%) | |
| | Car or truck | * 39 (74%) | ** 14 (26%) | 22 (42%) | 33 (62%) | |

Bold font indicates difference is significant at alpha level corrected by sequential Bonferroni method, or Yates' Correction for Continuity (for 2 × 2 tables). * $p < 0.05$; ** $p < 0.01$; *** $p < 0.005$.

^aThere were not enough observations to determine whether the difference was significant.

Those in piecework (i.e. small jobs like tailoring, assembling items, or other types of casual day labour) were least likely to use pads (32%, $p = 0.002$), and those in formal employment were least likely to use cloth (34%, $p = 0.001$). Those who had never married were most likely to use pads (78%, $p < 0.001$) and least likely to use cloth (30%, $p < 0.001$), whilst those who were previously married were least likely to use pads (35%, $p < 0.001$) and most likely to use cloth (76%, $p < 0.001$). Excluding participants of households without mobile phones (for whom there were not enough observations to confirm associations), participants of households who owned a mobile phone but no other assets were least likely to use pads (44%, $p = 0.002$) and most likely to use cloth (73%, $p < 0.001$), whilst participants of households who owned a car/truck were least likely to use cloth (26%, $p < 0.001$).

As shown in Table 2, no significant association was detected between using pads and the recruitment location, or the use of cloth and the recruitment location, and whether they were recruited at home or in a public space. Participants with flush toilets were most likely to use pads (75%, $p = 0.017$) and least likely to use cloth (29%, $p < 0.001$). No significant association was detected between regularity of waste collection and use of either pads or cloth.

No significant associations (using Bonferroni corrected alpha levels) with method of waste disposal (i.e. throwing in a pit latrine or burning) were detected for whether participants were recruited at home or in a public space, regularity of waste collection, highest educational level, main source of income, and household asset ownership, as shown in Table 2. Associations were detected between throwing menstrual absorbents in pit latrines and two recruitment sites (Chigumula (37%, $p = 0.003$) and Chirimba (84%, $p = 0.002$)), being aged 18–29 (71%, $p < 0.001$), being

aged 40–49 (32%, $p < 0.001$), and being previously married (41%, $p = 0.002$). There was a strong association between owning a pit latrine and disposing of menstrual waste in a pit latrine (97%, $p < 0.001$). Associations were detected between burning menstrual absorbents and being aged 18–29 (37%, $p = 0.002$), 40–49 (81%, $p = 0.001$), and being previously married (65%, $p = 0.003$).

Direct binomial logistic regression was performed to assess the predictive power of demographic characteristics on the likelihood that respondents used cloth or pads. The binomial logistic regression models, containing the independent variables: ‘age’ and ‘highest educational level’, are shown in Table 3.

The model for pad use was statistically significant, $\chi^2(4, n = 254) = 48.5, p < 0.001$, indicating that the model was able to distinguish between respondents who used and did not use pads. The model explained between 28% (Cox and Snell R square) and 37% (Nagelkerke R squared) of the variance in pad use, and correctly classified 72.8% of all cases. Both variables made unique statistically significant contributions to the model. The strongest predictor of using pads was attending university, recording an odds ratio of 14.688. This indicated that respondents who went to university were over fourteen times more likely to use pads than those who did not, controlling for all other factors in the model.

The model for cloth use was also statistically significant, $\chi^2(12, n = 247) = 82.8, p < 0.001$, indicating that the model was able to distinguish between respondents who used and did not use cloth. The model explained between 31% (Cox and Snell R squared) and 42% (Nagelkerke R squared) of the variance in cloth use, and correctly classified 73% of all cases. Both variables made unique statistically significant contributions to the model. The strongest

Table 3. Binomial logistic regression models for pad and cloth use.

| Variable | B | S.E. | Wald | df | p | Odds ratio | 95.0% C.I. for odds ratio | |
|---|---------|-------|--------|----|---------|------------|---------------------------|--------|
| | | | | | | | Lower | Upper |
| Probability model of whether participant uses pads | | | | | | | | |
| Age | – 0.050 | 0.016 | 10.451 | 1 | 0.001 | 0.951 | 0.922 | 0.980 |
| Highest education: | 1.484 | 0.378 | 28.391 | 3 | < 0.001 | 4.412 | 2.104 | 9.248 |
| None/primary | 1.852 | 0.476 | 15.444 | 1 | < 0.001 | 6.372 | 2.507 | 16.191 |
| Secondary | 2.687 | 0.562 | 15.147 | 1 | < 0.001 | 14.688 | 4.882 | 44.197 |
| Tech college | 0.631 | 0.572 | 22.856 | 1 | < 0.001 | 1.880 | | |
| University | | | 1.216 | 1 | 0.270 | | | |
| Constant | | | | | | | | |
| Probability model of whether participant uses cloth | | | | | | | | |
| Age | 0.079 | 0.019 | 16.535 | 1 | < 0.001 | 1.082 | 1.042 | 1.124 |
| Highest education: | –1.613 | 0.461 | 42.708 | 3 | < 0.001 | 0.199 | 0.081 | 0.492 |
| None/primary | –2.765 | 0.556 | 12.257 | 1 | < 0.001 | 0.063 | 0.021 | 0.187 |
| Secondary | –4.323 | 0.722 | 24.752 | 1 | < 0.001 | 0.013 | 0.003 | 0.055 |
| Tech college | –0.512 | 0.669 | 35.804 | 1 | < 0.001 | 0.599 | | |
| University | | | 0.586 | 1 | 0.444 | | | |
| Constant | | | | | | | | |

B = Unstandardised regression weight.

S.E. = Standard error.

Wald = Chi Square value from the Wald test.

df = Degrees of freedom.

C.I. = Confidence interval.

predictor of using cloth was age, recording an odds ratio of 1.082. This indicates that for every additional year of age, respondents were 1.082 times more likely to use cloth, controlling for all other factors in the model.

Initially, models predicting pad and cloth use were produced containing five independent variables (age, highest educational level, source of personal income, wealth, and marital status), which were selected on the basis that they showed significant correlation with absorbent type (as shown in Table 2). These initial models were statistically significant (χ^2 (12, $n = 247$) = 61.5, $p < 0.001$ for pads, and χ^2 (12, $n = 247$) = 92.5, $p < 0.001$ for cloth), and correctly classified 74% and 73% of all cases for pads and cloth, respectively. However, only two of the independent variables (age and highest educational level) made unique statistically significant contributions to the models, and therefore the other variables were dropped with minimal loss in predictive power. The initial models are shown in Table S5.

Changes in menstrual absorbent use

Figure 5 shows the changes in menstrual absorbent use among a subset of participants ($n = 190$) who experienced menstrual cycles at the time of the survey (2020) and 10 years prior (2010). Among this subset, pads and cloth were the most commonly used materials in 2010 (47% and 49% of absorbents used, respectively) and in 2020 (46% and 42% of absorbents used, respectively), although they shrank slightly as a percentage of total absorbents used. No participants reported using tampons in 2010; however, by 2020 tampons had grown to 3% of menstrual absorbents used, being adopted by participants who had previously used

pads. Uptake of reusable pads grew considerably from a share of <1% in 2010 to 4% in 2020 but remained a small percentage of overall absorbent choice.

Discussion

Quantifying volumes and compositions of menstrual waste is an important part of identifying how this particular waste stream fits within the larger picture of solid waste production and disposal. This study has presented the first empirical evidence of how menstrual waste travels through the urban environment of a low-income country city, in addition to generating novel insights into the usage patterns of menstrual absorbents and characteristics of their user groups.

Identity and empowerment

The patterns between pad/cloth use and demographic characteristics indicate a higher prevalence of pad use among women who are younger, more highly educated, wealthier, and in formal employment. Conversely, there is a higher prevalence of cloth use among women who are older, less highly educated, poorer, and in informal employment. Household economics undoubtedly plays a crucial role; pads can be expensive relative to the average income, and therefore women who are poorer or have less control over household expenditures may be more likely to use old cloth (Hennegan *et al.* 2017). However, the associations between menstrual absorbent use, education, and employment type are particularly compelling. For instance, the linkage between use of disposable pads and being in formal employment might not only be an economic consequence of higher average wages but also a prerequisite: leak-proof and

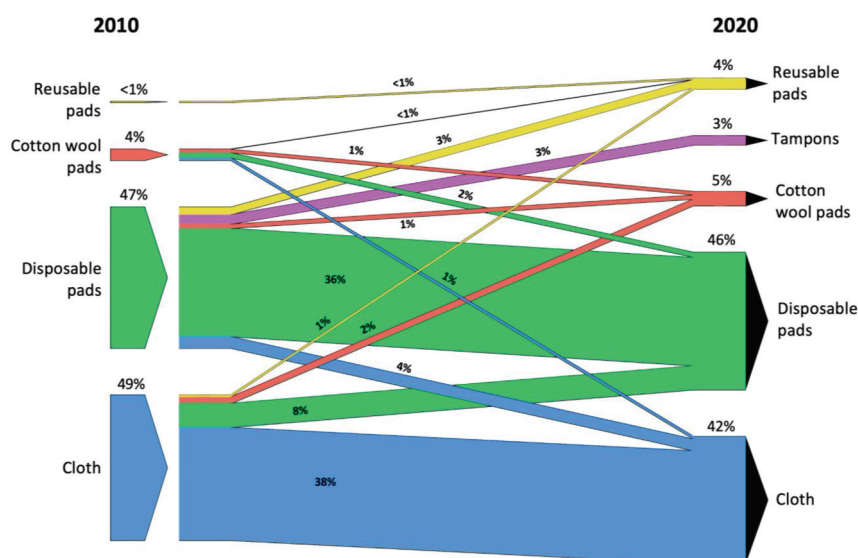


Figure 5. Menstrual absorbents used by sub-set of participants who experienced menstrual cycles at the time of the survey (2020) and 10 years prior (2010) ($n = 190$).

conveniently changeable absorbents are required in order to participate in a workplace (particularly where a safe or private toilet is not always working or available). Whilst the linkages between school attendance and menstrual practices have been extensively examined (Hennegan and Montgomery 2016), there is no such exploration on how access to menstrual absorbents affects other kinds of participation in the economy and civil society. In a Western context, Moffat and Pickering (2019) and Wiseman (2019) have discussed how the menstruating uterus and associated stigma can become a 'leash' restricting women to, or close to, the home when suitable materials or infrastructure are not available to manage and conceal menstrual blood. In a similar way, use of cloth or other improvised absorbents might be anticipated to act as a barrier to participation in certain workplaces due to lack of changing facilities, as has been shown to be the case in schools (Hennegan *et al.* 2017). As menstruation affects women but not men, this constitutes a significant obstacle to gender equality. Furthermore, gendered expectations mean that struggling to manage menstruation is considered a failure of womanhood, which can lead to detrimental impacts being underplayed; this invisibility further compounds the impact of menstruation on gender equality (Hennegan *et al.* 2020).

'Disposable' and 'reusable' in practice

The peak in Figure 2 (monthly pad use) is likely to relate to the number of pads in a packet. Most commercial brands in Malawi sell disposable pads in packs of 10, so the peak at 10 pads may suggest a tendency to budget for and use one packet of pads each month. The subsequent small peak at 15 pads may suggest that some participants budget and use 1.5 packs each month. The peaks in Figure 3 (yearly cloth use) in the centre and right side of the figure reflect the estimations made by participants who use higher numbers of cloths per year. These participants often found it difficult to estimate their yearly disposal, so they instead estimated their number of cloths disposed per month, which was then multiplied by 12 to arrive at a yearly estimate.

Use of disposable menstrual absorbents typically generates a greater volume of waste than reusable ones (Kaur *et al.* 2018). This study supports this assertion, with an average of 9.1 disposable pads and 2.4 menstrual cloths discarded per month by participants exclusively using these absorbents. However, great diversity in behaviour was noted among cloth users, with some discarding up to eight cloths per month and others not throwing any away at all. The former participants appeared to treat cloth more like a disposable material than a reusable one, whilst the latter reserved it for uses in traditional medicine, which has been previously shown to be a valuable commodity (Roxburgh *et al.* 2020). These findings highlight that

there is much that remains undocumented about the diverse behaviour of cloth users. Cloth is a particularly problematic material with regards to removing faecal sludge as it can entangle the blades of pumping devices (Sisco *et al.* 2017), and therefore frequent discarding of cloth into pit latrines poses a very significant conflict with developing safe pit emptying practices.

Some pad users appeared to use notably low numbers of pads. Around half of participants used eight or fewer pads per period, suggesting that many are using fewer than two a day if their period is five days in length. Whilst this might be partly explained by some women having short and/or light periods, some may use small numbers of pads due to financial constraints. Studies of schoolgirls have highlighted the difficulties that they experience in acquiring money to buy pads, and also linked poor menstrual hygiene to periods of longer duration (which require more pads) (Belayneh and Mekuriaw 2019, Crankshaw *et al.* 2020). In this study, however, although wealth was associated with using pads, no correlation was detected between wealth and numbers of pads used. It may be that the wealth metric used (family ownership of a selection of assets) was too coarse to detect a relationship. Furthermore, if women are not in control of the household finances, they may be less able to direct resources according to their menstrual needs, thus further obscuring any potential relationship.

Disposal by faeces and fire

The study highlights two main disposal routes for menstrual absorbents used by participants: throwing in pit latrines (55% of all absorbents) and burning (39% of all absorbents). Pads are more likely than cloth to be discarded in pit latrines, which may reflect the fact that pad users generate waste more regularly and in greater volume than cloth users, and therefore may seek a more convenient disposal strategy than burning. Finding the time and space to burn menstrual waste in secret can be laborious and inconvenient. This challenge can be particularly acute for disposable absorbent users who struggle to find privacy at home, and may resort to hiding badly smelling used pads before a convenient time to dispose of them can be found (Roxburgh *et al.* 2020). Very few menstrual absorbents are mixed with solid waste; less than 5% enter bins and pits and only 1% are estimated to eventually reach the local landfill. Qualitative research has explored the reasons why many women feel uncomfortable with discarding menstrual absorbents alongside solid waste: fears of the waste being seen by others, scavenged by dogs, or being taken for use in rituals have been highlighted as various factors (Scorgie *et al.* 2016, Chinyama *et al.* 2019). Menstrual waste can therefore be seen to have mostly limited interactions with solid waste management

systems and infrastructure. Despite being essentially solid waste, it nonetheless is disposed of differently to other kinds of solid waste due to its sensitivities and perceived dangers.

The greatest proportion of participants discarding menstrual absorbents into pit latrines was found in one of the high-density informal settlements, Chirimba (84%, $n = 32$), whilst the lowest proportion was found in a peri-urban settlement, Chigumula (37%, $n = 11$). Participants living in densely populated areas may be less likely to burn their menstrual waste due to the necessary privacy required to do so secretly and may turn to pit latrines as a disposal method instead. However, discarding solid waste in pit latrines causes them to fill more quickly (Still and Foxon 2012), and high-density areas are also more likely to require full pit latrines to be emptied because the space is insufficient for abandoning and re-digging them. Thus, high-density neighbourhoods may be viewed as particularly critical areas with regards to the challenge of menstrual waste in pit latrines, as the presence of waste in pit latrines complicates the process and increases the cost of removing the faecal sludge (Chipeta *et al.* 2017, Sisco *et al.* 2017). This constitutes an important potential conflict with the requirements of sustainable faecal sludge management systems, and by extension, delivery of safe sanitation for dense urban settlements. The root cause of this, however, is the gendered stigma attached to menstruation and subsequent requirements for privacy. Further research to explore how disposable and reusable menstrual absorbent use is situated within the broader context of solid waste management and sanitation infrastructure in densely populated urban settings is strongly recommended.

Looking to the future

The strong correlation between menstrual absorbent choice and age indicates the possibility of a demographic shift in menstrual waste. As older women (predominantly cloth-users) reach menopause, and younger women (predominantly pad-users) reach menarche, the proportion of disposable absorbents being used in the community will increase, leading to a rise in menstrual waste generation (Roxburgh *et al.* 2020). To a certain extent, this rise may be offset by adoption of tampons and reusable pads, as both generate smaller volumes of menstrual waste (due to either being reusable or compact in size) and have increased in popularity over the last decade. However, at present tampons and reusable pads make up such a small percentage of the menstrual waste composition (at just 6% of absorbents used by participants) that their slow expansion is unlikely to have a noticeable impact in the near future. Tampons in particular are likely to have socio-cultural constraints

on their widespread acceptability, due to their use being believed to compromise virginity (Crankshaw *et al.* 2020).

Innovative and reusable menstrual products, such as high-quality reusable pads and menstrual cups, may offer dual benefits by reducing volumes of waste generated whilst also providing improved functionality and convenience over cloth and disposable pads. Reusable pads are washable pads designed to be worn in the underwear, and menstrual cups are a small cup (usually made of medical-grade silicone or similar materials) which is inserted into the vagina to collect blood, and then periodically emptied (Scott *et al.* 2013, Van Eijk *et al.* 2019). Whilst menstrual cups may face similar limitations to tampons in their uptake, reusable pads in particular have potential for extremely broad cultural acceptability due to similarities with traditional practices, and utilise materials to optimise comfort, absorbency, and speed of drying, thus providing improved performance over cloth (Hennegan *et al.* 2017). This study suggests that the user base of reusable pads has expanded over the last decade but remains very small (as shown in Figure 5). The availability and cost of purchasing reusable pads may be a significant limitation in their adoption, as they are not widely available and struggle to compete with disposable pads despite having a lower cost per period over their lifetime. Importantly, further research could be used to determine whether subsidies, tax breaks, or distribution by local organisations could improve uptake, although it is crucial that any such interventions do not distort and damage markets for other local menstrual products. Ultimately, it is important that all women have access to a variety of menstrual absorbent products regardless of their socio-economic status, and widening access to a variety of menstrual absorbents, and in particular, high-quality reusable pads, is an immediate avenue for research and action.

In the case of reusable menstrual absorbents, it is particularly important for users to have sufficient water to wash them (in terms of both quantity and quality), and suitably private locations to wash and dry them. In particular, it is important that the bloodied washing water can be drained discreetly (Nawaz *et al.* 2010). Expansions of water coverage, and in particular, access to piped water at home, are therefore vital long-term infrastructure improvements for menstrual hygiene and well-being, as well as for creating a supportive environment for uptake of reusable menstrual absorbents.

Limitations

The self-reporting method used in the survey had certain limitations, including the risk of inducing social desirability bias. This bias can occur when recalling activities where people might be widely

aware of the need to perform it but in practice do it less often, such as hand washing, and therefore report a slightly exaggerated account of their true behaviour (Chidziwisano *et al.* 2020). In the case of the menstrual flow data, it is likely that some pathways, such as discarding menstrual waste into the environment or into bins, were somewhat under-reported as these are not viewed as ‘respectable’ methods of disposal, and some participants may have felt too embarrassed to admit to doing this. The self-reporting method also may have induced inaccuracies in that many women may be unlikely to accurately remember the exact proportions of different menstrual absorbents used, and the ways in which they were disposed. In particular, the comparison of menstrual absorbents used 10 years ago to those used today must be viewed as indicative, rather than precise, although the trends reported are supported by other independent studies (Crankshaw *et al.* 2020). The challenges of recall bias were mitigated to some extent by the skill of the enumerators, who would carefully discuss the participant’s practices with them in order to determine an estimate. Importantly, the menstrual waste data must be viewed as an illustration of how menstrual waste composition changes and moves in the city, with the potential for further refinement in accuracy and validation through future research. However, whilst it would be misleading to quote precise percentages of flows with certainty, particularly for the less widely used absorbents, it is nonetheless valid to conclude that substantial volumes of pads and cloth are either burned or thrown into pit latrines.

Conclusion

There is currently a paucity of options to manage a growing volume of disposal pads safely, conveniently, and sustainably within urban environments. Menstrual waste predominantly ends up being burned or buried, with detrimental consequences to individual health and urban sanitation systems. This should be viewed as a systematic failure of waste management, with no blame attributed to those who produce the waste, who have a right to go about their lives in comfort and with convenience (Bobel 2018). Women are placed in a difficult position by the severe, gendered societal etiquette which mandates concealment of their menstrual status, whilst their choice of absorbent and means of disposal are further constrained by economics, availability, practical considerations, and the threat of witchcraft (Scorgie *et al.* 2016, Chinyama *et al.* 2019). There is an urgent need to provide a range of menstrual absorbent choices and improved waste disposal options which are sensitive to their socio-cultural-infrastructure conditions, for the benefit of

women, furtherment of gender equality, and protection of urban environmental health.

Choice of absorbent and disposal method are contingent on a range of highly personal circumstances. For instance, reusable absorbents must be washed, and therefore if household drainage is uncovered, then a woman might struggle to conceal the bloodied washing water from her neighbours and therefore prefer disposable pads. However, another woman who has limited privacy to burn menstrual waste at home may find reusable absorbents to be a better solution, and it is therefore vital that a diverse selection of menstrual absorbents is available at a variety of price points (Shannon *et al.* 2020). High-quality reusable products have particular potential to provide widespread benefits to women and the environment, especially in economically and spatially constrained settings like high-density low-income settlements. Participatory research methods also can be used to explore barriers to adoption (e.g. availability and cost) and also support the development of alternative disposal options. Ultimately, however, dismantling the social stigma of menstruation is one of the most important requisites for improving the management of menstrual waste, gender equality, and menstrual wellbeing. Multi-disciplinary collaborations (particularly between solid waste management, sanitation, and gender and health specialists) will be needed to tackle the challenge of finding sustainable disposal solutions for menstrual waste. Supporting markets for reusable pads in order to increase their uptake may be a promising policy intervention avenue, but future research is required to determine what particular interventions will be most effective and sustainable.

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Notes on contributor

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