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An exploratory study of the impact and potential of menstrual hygiene management waste in the UK

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ABSTRACT

An estimated 15 million people in the UK menstruate over the span of approximately 37.5 years, using every year around 3.3 billion units of single-use menstrual management products (MMPs) (i.e. pads and tampons). A more circular design and sustainable management of these products could greatly reduce their waste and environmental impacts. This research is an exploratory study into the current menstrual products, waste and systems in the UK. The study found that an estimated 28,114 tonnes of waste is generated annually from menstrual products, 26,903 tonnes from disposable products of which about 4% (3,363 tonnes) is lost in the environment by flushing. The less sustainable products within those studied are disposable pads, which are the main contributors to menstrual waste volumes in the UK (21,094 t/y) and produce around 6,600 tCO_2 eq. of GHG. Replacing disposable MMPs with reusable would reduce waste production by 22,907 t/y and avoid about 7,900 tCO_2 eq. of GHG. In addition, even a simple better waste management process, such replacing landfill with thermal treatment, would further reduce emissions by around 5,000 tCO_2 eq. of GHG and produce every year approximately 5,500 MKh with incineration and 18,000 MKh with gasification.

1. Introduction

Waste prevention has been assigned the highest priority under European waste management law. However, the initiatives which have been taken so far have not reduced the regular annual increase in total waste arising across Europe. Menstrual management products (MMPs) (i.e. single-use pads and tampons) are a group of widely used disposable goods and more sustainable and circular options could greatly reduce their waste and environmental impacts. Menstrual hygiene management impacts people on a monthly basis and millions of people worldwide rely on disposable menstrual pads and panty liners for hygiene protection. MMPs have developed throughout history, with different cultures designing their own ways of managing menstruation (Stanley, 1995). The first widely adopted disposable pad was initially invented during the First World War by French Army Nurses but not successfully commercialised until 1921 in the US. These disposable pads were made from cellulose and cotton, similar in composition to bandages (Stanley, 1995). Tampons were developed later, made also from cotton material (Vostral, 2008).

Disposable pads and tampons have provided the convenience of managing menstruation outside the house (Vostral, 2008). However, although they have created significant societal change, their waste production and environmental impact are yet to be fully understood, with many products being sent to landfill, incinerated and flushed by users into water systems. Disposable pads are conventionally designed with a combination of cellulose, low density polyolefins with petrolatum used as the absorbent gel. In addition to environmental impacts linked to their production, the complex combination of these materials and overall mass makes the products difficult to degrade in landfills (Stegmann et al., 1993). Similarly, conventional tampons that are widely available in the UK market use rayon as an absorbent core, which originates from wood pulp in mature forests and requires harsh processing to generate fibres (Chen and Burns, 2006). Organic compostable products offer a more environmentally friendly alternative and, while these are still disposable products, they are designed to naturally degrade, with no contamination from plastic (Chen and Burns, 2006). Though not widely adopted yet, reusable products pose an alternative opportunity to reduce waste from disposable, degradable and not, MMPs. The first menstrual cup designed to catch menstrual flow instead of absorbing it, was patented in 1937 but production was halted due to a shortage of rubber following the Second World War and their use was more widely adopted only in the late 1950's (Stanley, 1995). Reusable

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menstrual underwear is a relatively recently developed MMP. This product is made up of the underwear fabric and an absorbent layer, designed to catch blood flow and prevent leakages. The products are similar to menstrual pads, but designed to last around 2–3 years, depending on use (Hait and Powers, 2019). Previous research into consumer attitudes towards reusable menstrual products and current use patterns found that around 10% of respondents use reusable menstrual products, and that most participants often chose disposable products out of habit (Zero Waste Scotland, 2019). Key factors influencing purchase decisions are reliability, comfort, hygiene and ease of use, whereas key barriers are related to initial cost, leakage, duration of wear, smell and care (Zero Waste Scotland, 2019).

MMP waste, classed as 'offensive waste', when separately collected is sent for incineration or landfill depending on local authority and waste management company policies (WISH, 2015). These single-use products also known as absorbent hygiene product (AHP) waste, are grouped with nappies and incontinence products. Unseparated MMP waste is disposed of mainly with household waste and disposed as such according to the local authority waste management options, either landfilled or thermally treated (DEFRA, 2019). Pollution remains a key problem area for waste management in the UK, with MMP waste including tampons, pads and wipes, flushed down the toilet and contaminating sewers and water systems. According to (Friedler et al., 1996) tampons accounted for around 23% and pads for 3.8% of all unflushable polluting the sewage system. Sanitary pads, mostly composed of plastic, are also washed up in marine areas and can pose a hazard to marine organisms and human health (Ó Briain et al., 2020).

The aim of this work was to asses the waste produced annually in the UK from MMP and identify the potential of reusable products for waste reduction (cups and underwear). The current waste management processes were investigated to identify opportunities for improvements and highlight ways in which energy recovery strategies could be improved.

2. Methodology for data collection

2.1. Demographic data to understand menstruating population numbers

There is a distinct lack of quantitative data available in terms of the menstruating population. In an attempt to quantify the amount of menstrual waste produced annually, secondary data was collected from the UK census and market research reports (ONS, 2020). While the census has predominantly collected data which classifies the UK population by binary male and female sex, there is a lack of gender inclusivity and hence a possibility that some people who menstruate would not be included in this dataset. The data used (Table 1) were based upon the estimated census data of people in the UK on menstruation age, which the UK National Health Service (NHS, 2019), classifies as starting at around 12 years old and ending at around 55 years old (NHS, 2018) and of which it was assumed that 85% menstruate, according to market research reports (Mintel, 2020). These figures (Table 1) are in line with the estimated 15 million people who menstruate and age span of 37.5 years suggested by the Absorbent Hygiene Product Manufacturers Association (AHPMA, 2020b).

Table 1
UK census data of female in menstruation age, National Population projections 2019 (ONS, 2020).

Age Groups	Female population
Aged 50-55	2,837,299
Aged 40-49	4,296,138
Aged 30-39	4,444,178
Aged 20-29	4,267,983
Aged 12-19	2,883,480
Total	18,729,078
85% menstruating	**15,019,716**

2.2. Product definition and composition

The products considered in this study included: disposable menstrual products (pads and tampons) and reusable menstrual products (cups and underwear). Disposable composting products were not considered as they constitute a small part of the market and very little data is available on their management. Data collected about products included: the mass of the product in grams (g), main component materials and the average amount of products required annually. Secondary data was used to gain further understanding about the mass and functional unit of each product. Primary data was collected via email correspondence with a menstrual underwear company customer service team.

2.2.1. Disposable menstrual products

Products sold in the UK must be compliant with the General Productive Safety Directive (EEC Directive 2001/95/EC, 2001). Pads and liners are designed for use for menstruation and are comprised of around 7 key components: the surface cover, acquisition distribution layer, absorbent core, back sheet, release paper, adhesive and in some cases wings. The core components of pads usually feature plastics such as polyethylene, cellulosic fibres such as rayon, viscose or cotton (AHPMA, 2020a). An average of 10 g/pad was used as a representative average weight for this product type (STATISTA, 2020). Tampons feature less core components, typically including: a surface material, absorbent core, string and in some cases wrappers or applicators that are made of either plastic or cardboard (AHPMA, 2019). The outer components are usually made from polyester, polyethylene, rayon or cotton. The absorbent core and string are typically composed of rayon or cotton and the wrapper is usually a film made of cellophane or polyethylene (AHPMA, 2019). An average weight of 5 g/tampon was used in this study (STATISTA, 2020).

2.2.2. Reusable menstrual management products

Menstrual cups were designed to replace tampons and are composed of medical grade silicone. Each cup weighs around 15 g overall, and can be used for up to 10 years (Hait and Powers, 2019). Reusable underwear are designed to be washed and re-worn throughout a period, and can also be used for incontinence. Primary data collected from a company that produces menstrual underwear recommends that 7 pairs are purchased for one cycle, with 3 pairs for a heavier flow (62 g each), and 2 pairs for lighter days (59 g each). To dispose of underwear, the company suggested cutting out the absorbent gusset, which is currently not recyclable, and sending the outer parts of the underwear to a textile recycling centre. An average weight of 60 g was used for this study.

2.3. Menstrual management product quantification and emissions

Secondary data was collected from (STATISTA, 2020) to understand the number of disposable products used in an average menstrual cycle. Statista featured a survey conducted by Kantar Media with a sample size of around 24,191 people. This sample size gave an indication into how many people use tampons and pads as MMPs and spanned from the years 2013 through to 2018.

In the case of disposable products, individual product use varies heavily depending on the flow and cycle of the user. Thus, a functional unit of one year was used for this study. Data collected by STATISTA (2020) in line with (Hait and Powers, 2019) indicated the average person uses between 192 and 240 single use pads and tampons per year. Based upon the existing data, the 'Annual Product Use' (APU) data used for analysis was 196 units for pads and 191 units for tampons. The market research from Mintel (2020) highlighted that people use a combination of both products, however, in this analysis it was assumed that users only use one product type.

Data from STATISTA (2020) suggests that there are 10,631,000 Estimated Users (EsU) for pads, and around 6,124,000 for tampons. To calculate the number of EsU for reusable products, data was collected

Table 2
MMPs user estimation, annual product use and products emissions.

Product	Amount used per cycle	Product life	Annual Product Use (APU)	Estimated Users (EsU)	Estimated GHG emissions ($kgCO_2Eq$/unit)
Single Use Pads	16.5[a]	Disposable	198	10,631,000	0.029
Single Use Tampons	16**	Disposable	191	6,124,000	0.018
Reusable Cup	1	10 years	0.1	1,114,380	0.42
Reusable Underwear	2 + 3	2 years	2.5	1,591,972	0.11

[a] Calculated over 5 years data. **Calculated over 3 years data.

from Mintel (2020) who suggests around 7% of respondents use cups and 10% use reusable pads. The sample size of the research by Mintel (2020) was significantly smaller than data by STATISTA (2020) but gave insights that would otherwise be unavailable. The assumptions for reusable product EsU were multiplied by the census data (Table 1) to generate an estimated amount of reusable product users.

Data from Hait and Powers (2019) were used to estimate values for GHG emissions as CO_2 equivalents for disposable pads and tampons and reusable cups, when considering impact from raw materials, manufacturing, transport, use and disposal. No data was available for reusable underwear, so an approximate value was used, derived from incontinency underwear, which has a similar composition (Willskytt and Tillman, 2019).

2.4. Menstrual management products waste

To provide an estimate number of products used annually (Total Units, TU) the total Annual Product Use (APU) per user was multiplied by the number of estimated users (EsU) (Equation (1)). This figure was then multiplied by the mass (M) of each individual product unit in grams to find the total potential waste (TPW) derived annually (Equation (2)).

$$\text{Total units (TU)} = \text{APU x EsU} \quad (1)$$

$$\text{Total Potential Waste (TPW)} = \text{TU x M} \quad (2)$$

2.4.1. The economic cost of MMP to users

To gain further insight into the products available in the UK, document analysis was used to collect pricing data from retailer websites for disposable and reusable products. The price per unit was then multiplied by the APU to generate an estimated annual cost to the consumer. This data was useful when considering period poverty, in an attempt to see if reusable products could in fact save users money in the long term.

2.4.2. Waste management and energy recovery opportunities

Further secondary data was used to determine the ways in which menstrual care waste is managed as a whole in the UK. Landfill and incineration are the main waste management strategies for municipal solid waste (MSW) in the UK, with energy recovery for 31.5% and 43% of the landfill and incineration plants respectively (DEFRA, 2019). Data collected by local authorities was used to illustrate what happens at the end of an MMP's life. Very little data is currently available on the ways in which MMP are disposed of and a quantity was estimated using an approach similar to that of Deloitte (2011). Data from DEFRA (2019) suggests that more waste in England is sent for incineration with energy recovery than landfill, with assumptions being that 56% of waste is now incinerated and 19% sent to landfill. A further 25% of waste from MMP is assumed to be flushed by users, taking into account data by Friedler et al. (1996). Assuming half of the waste is recovered from water streams, this may usually be sent to landfill and eventually account for energy recovery, leaving around 12.5% as the amount of waste that is flushed without further recovery or dedicated processing.

Total waste figures were broken down into disposal categories then multiplied by figures found in work by Aracil et al. (2018) to quantify GHG emissions and potential energy production through different waste management process (landfill, incineration and gasification with internal combustion engines (ICE)). For the reference system (landfill), GHG emissions were calculated from biogas combustion (with or without energy recovery) and biogas leaking from the landfill site, using a collection efficiency of 70%. The gasification model used was a fluidised bed gasifier with an ICE as this produced the best results in the work by Aracil et al. (2018) and would suggest what could be achievable in the best-case scenario. Emission from MMP disposed in landfill without energy recovery were deemed similar to those from the materials lost in the environment and values were extrapolated from (Lou and Nair, 2009).

All reference values are included in Table 3.

3. Results and discussion

3.1. MMPs quantification, waste production and emissions

Estimated menstrual waste accounts for around 28,114 tonnes per year based upon calculations from market data and census data assumptions (4). The most commonly used MMP appears to be pads, which generate around 21,049 tonnes of waste annually, and an estimated 5,854 tonnes of waste are produced from tampon use per year. Using assumptions made from market data, potential waste produced from reusable products stands at around 1,210 tonnes from reusable underwear and just 0.2 tonnes from menstrual cups (Table 4). It is significant to note that while potential waste is significantly lower for reusable products, this is due to the lower annual estimated users when compared to single use products.

A wider range of products classified as disposable but compostable are also available and constitute a more sustainable alternative that non-degradable single use products, however, market share of compostable pads and tampons is still quite limited. Compostable pads will take approximately 18–24 months to completely break down (Davidson, 2012). A complexity with this type of product, is that the production is resource intensive and there is yet to be a wide adoption of industrial composting sites for this type of waste. The quality of the compost is also unknown due to the potential for contamination from blood. Although domestic compost appears to be an environmentally positive action, the outcomes of this type of waste are heavily dependent on user behaviour and access to domestic composting space. This type of products could be more suitable for a gasification energy recovery process, when compared to conventional disposable MMP.

Table 3
Reference data for energy recovery calculations. GHG balance for the waste to energy systems and electricity production.

	GHG (kg CO_2 eq/t MSW)[a]	Net Electricity (MWh/t MSW)
Landfill without energy recovery/ Emissions from MMP lost in the environment	720	–
Landfill with energy recovery	454	0.18
Incineration with recovery	331	0.70
Gasification ICE	281	1.09

[a] Assuming that MMP is incinerated with MSW.

Table 4
Waste and GHG emissions produced by MMP annually.

	Total units used/ year	Total MMP waste (t/year)	MMP emissions (kg CO_2-Equiv./year)
Single Use Pads	2,104,938,000	21,049 (10 g/ pad)	61,043,202
Single Use Tampons	1,170,818,022	5,854 (5 g/ tampon)	21,074,724
Reusable Cups	111,438	0.2 (15 g cup)	46,804
Reusable Underwear	3,979,929	1,210 (60 g average)	437,792
Total annual		**28,114**	**82,602,523**

*Assuming use of one preferential product.

3.1.1. Product use per lifetime and associated waste

The estimated annual product use was multiplied by the number of years an average person menstruates (around 37.5 years) to calculate the number of products one person would use in their lifetime. Disposable menstrual products required can be anywhere between 7,169 units for tampons (36 kg of waste) and 7,425 for pads (74 kg of waste).

Reusable products provide the opportunity for individuals to drastically reduce their product consumption. Menstrual cups require the lowest amount of MMP within the products studied, with 4 units needed for the entire duration of menstrual life (0.1 kg of waste). Menstrual underwear was a slightly higher figure at around 94 pairs (6 kg of waste).

The waste estimation data was further applied in an attempt to understand if reusable products pose an opportunity for significant waste reduction overall. An assumption was made that the number of users that used tampons could move towards using cups, and those using pads could move towards reusable underwear. This correlation was identified in their report by (Zero Waste Scotland, 2019). The theoretical shift towards reusable products did not take into account affordability or variations in cycle. The findings are detailed in Table 5 and show that the transition from tampon use to cups could reduce waste by around 5, 845 tonnes annually, and that reusable underwear has the potential to reduce waste from pads by around 17,062 tonnes annually for a total of 22,092 tonnes, equating to a potential reduction of around 79%. It is important to note that menstrual underwear would generate significantly more waste than cups and tampons, but could still pose a better alternative than pads in terms of waste volumes. In addition, disposable pads often contain a combination of plastics and cellulose to function as absorbent products. The implication of using plastic in these products is that when products are incinerated or sent to landfill, energy in the form of gas recovered is often highly contaminated with pollutants (Huang, 1995). Human toxicity, acidification an ecotoxicity is also a significant issue with disposable products (Hait and Powers, 2019).

3.2. The comparative economic cost of disposable and reusable products

Document analysis of retailer websites indicated the extent to which the economic cost varies depending on the product. Despite disposable pads being more expensive annually than tampons, there appears to be a preference for these products (Table 2). Overall, menstrual underwear appears to cost the most, possibly due to being a recent product development and the amount of material required (Table 6). Menstrual cups bode well economically and environmentally, with one unit costing slightly more than an annual supply of tampons and lasting for up to 10 years, as per Hait and Powers (2019). Access to and cost of water for cleaning reusable products were not considered in the analysis. In the UK context water usage was estimated to 180 L/y per person for reusable underwear, and 24 L for cups (Tellier et al., 2020).

People who menstruate must regularly purchase MMP throughout their lives, which are often costly (Table 5), can be difficult to access in certain contexts and even harder to dispose of (Vora, 2020). Period poverty is a global issue, lack of resources and the taboo around menstrual health in the UK means that 49% of people who menstruate can find themselves missing out on education and around 10% of people who menstruate have been unable to afford MMP, 15% struggle to afford MMP and 12% have to improvise instead of using MMP due to affordability issues (PLAN INTERNATIONAL UK, 2017). The need to wash reusable MMPs poses a further challenge for its uptake in certain contexts such as humanitarian settings where water may be scarce, as it is estimated that around 15 L of water are needed per cycle to wash reusable cloth MMP, and around 1–2 L per cycle for cups (Tellier et al., 2020).

3.3. Waste management strategy evaluation

3.3.1. End routes for disposable products in the UK

Based upon methods described previously, an output model was generated to indicate the approximate amount of waste that is incinerated, sent to landfill and flushed. The disposal method available to the product user immediately after product use will influence whether or not the waste is properly managed with the ability for energy recovery. This model estimates that over half of the MMP waste generated is collected by bins in public spaces, as a person is likely to spend the majority of their time outside of home (Turn and Flow personal communication). An estimated 19% of waste is sent to landfill, in line with local authority data by DEFRA (2019) and a further 25% is assumed to be flushed either at home or in public based upon data by Friedler et al. (1996). Approximately 12.5% of this waste may be recovered from wastewater treatment plants and sent to landfill where energy recovery is possible. It is then likely that around 12.5% of the waste flushed away is not captured, meaning that around 3,363 tonnes of MMPs can end up in oceans, rivers and coastlines (Ó Briain et al., 2020). Previous studies have raised awareness of the environmental impact of flushing disposable MMPs, with tampons and pads reported to account for ca. 23% and 3.8% of all refuse items flushed (Friedler et al., 1996). Landfill and incineration are the main waste streams for municipal solid waste (MSW) in the UK, with energy recovery for 31.5% of the landfill sites (DEFRA, 2019).

The model reported in Fig. 1 illustrates the potential for around 87.5% of waste to be used for energy recovery whilst currently only 66% is treated through that route. Using reference data by Aracil et al. (2018) it can be estimated that the current energy recovery provides around 11, 027 MWh of electricity, 10,546 MWh from incineration and 481 MWh from landfill (Table 7). MMP emissions, for all type of disposal routes and environmental losses, add to approximately 12,800 tCO_2 eq/year (Table 7). These emissions could be mitigated if current waste was managed and treated differently. According to Jeswani et al. (2013) incineration with energy recovery provides the opportunity to reduce 34% of CO_2 equivalent of emissions when compared to incineration without energy recovery. Aracil et al. (2018) suggested that greenhouse emissions for incineration processes are the highest when compared to

Table 5
Avoidable waste and emissions following a theoretical switch to reusable products.

Theoretical Switch to Reusable Products	Number of users/ Number of units	Waste after the switch (t/year)	Potential Waste avoidable (t/year)	Emissions after the switch (tCO_2-Equiv./year)	Potential avoidable emissions (tCO_2-Equiv./year)
Pads to Underwear	10,631,000/26,577,500	3,987	17,062	2,924	58,120
Tampon to Cups	6,124,000/612,400	9	5,845	257	20,818
Total annual	–	3,996	22,907	3,180	78,937

Table 6
Calculation of the annual cost of MMP.

Product	Price per Pack (RRP[a]) and per unit (£)	Annual Product Use (APU)	Lifetime Product Use	Annual Cost (£)	Lifetime cost (37.5 y) (£)	Reference
Single Use Pads	1.99/0.14	196 Units	8499 Units	27.86	1,045	Boots (2020a)
Single Use Tampons	1.99/0.10	191 Units	8221 Units	19.00	713	Boots (2020b)
Reusable Cups	21.99	0.1 Units	4.3 Units	2.20	83	Boots (2020c)
Reusable Underwear	140.00/20.00	3.5 Units	75 Units	70.00	2,625	Modibodi (2020)

[a] Recommended retailed price.

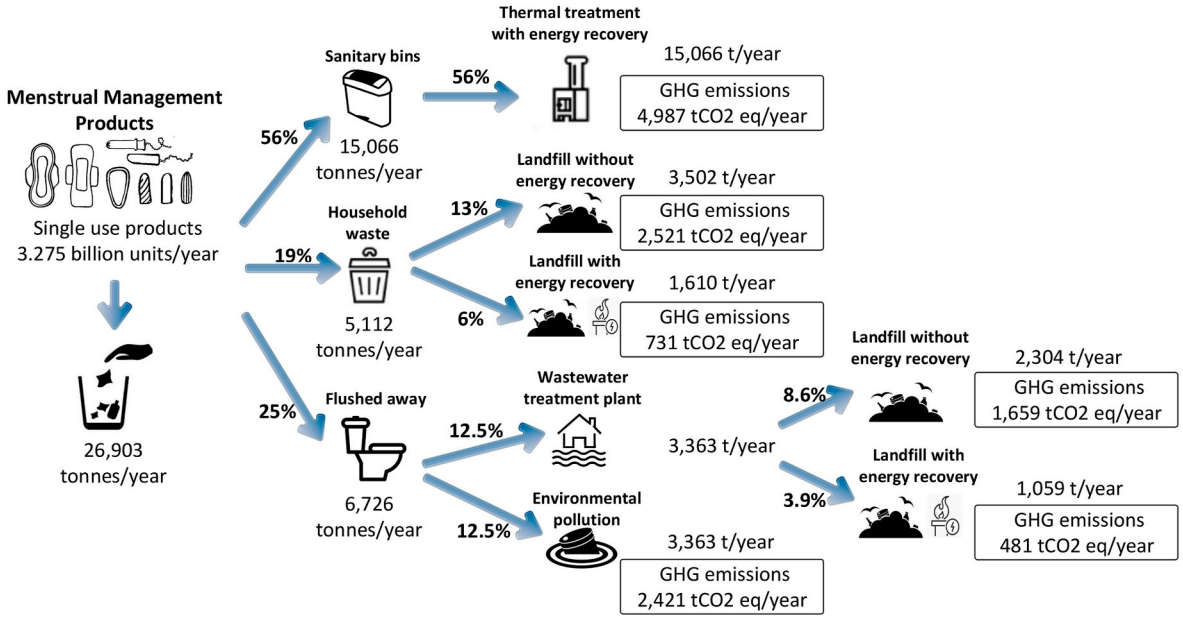

Fig. 1. Current MMP waste disposal model, estimated quantities and emissions.

Table 7
Current and potential energy recovery, greenhouse gas emissions and avoided emissions of disposable menstrual waste based on data by Aracil et al. (2018) and Lou and Nair, (2009).

Disposal route	Amount of waste (t/year)	GHG Emissions (tCO_2 eq/year)	Electricity per Tonne of Waste (MWh)	Avoidable emissions compared to current management (tCO_2 eq/year)	Additional electricity compared to current management (MWh)
Landfill	2,669	1,210	481		
Incineration with Energy Recovery	15,066	4,990	10,546		
Landfill with no energy recovery + pollution[a]	9,168	6,600	–		
Current estimated emissions and energy recovery		*12,800*	*11,027*		
If total waste recovered (87.5%) was sent to incineration	23,540	7,790	16,478	5,010	5,451
If total waste recovered (87.5%) was sent to gasification	23,540	7,560	29,325	5,240	18,298

[a] Pollution emissions calculated as for landfill without energy recovery.

gasification processes, and that landfill has the highest pollution load overall. Both studies demonstrate the negative implications of landfill, and waste to energy recovery systems such as incineration and gasification could provide the opportunity to reduce greenhouse gas emissions and pollution.

Substituting the current disposal and treatment methods with incineration would reduce the total emission by 5,000 tCO_2 eq/year and create additional energy (5,451 MWh). Using a more efficient process such as gasification (Aracil et al., 2018) would produce similar reduction in emissions (5,240 tCO_2 eq/year) but three times more energy (18,298 MWh).

3.3.2. *Management of reusable product waste*

Reusable products constitute a more sustainable solution than disposable products, although this is only possible if the waste is properly managed. For example, if all pad users switched to reusable underwear, there is still the potential waste of around 3,987tonnes/year (Table 5). The underwear sample used in this study features plastic, bamboo and a complex combination of textiles to absorb menstrual blood. In this case the absorbent core of the products was not yet recyclable, and would need to be sent to landfill or incineration. Even if a significant fraction of the original product mass is non-recyclable, there is still an opportunity for the remaining textiles to be used and recycled into useful products. Textile recycling is a complex process and

depends on the material composition of a product. The polyester parts of the underwear could be reused for fibre, fabric or monomer recycling methods (Sandin and Peters, 2018). While this is an ideal scenario, there is a distinct lack of infrastructure in the UK to effectively manage this.

The menstrual cup could significantly reduce waste from tampons being flushed, incinerated or sent to landfill, and would approximately generate 9 tonnes of waste per year rather than 5,854 tonnes for the UK (Tables 4 and 5). The menstrual cup is made from medical grade silicone rubber (Hait and Powers, 2019) and could possibly be sterilised and recycled in the long term, but at present is not widely recycled. It could be suggested that a chemical recycling approach could be an effective method of managing this type of waste, as the heat and pressure should sterilise any contaminants from menstrual blood. The outcomes of this process would more than likely be fuel and monomers that could be used as feedstock for new useful products (Devasahayam et al., 2019).

Mazgaj et al. (2006) conducted an environmental life cycle assessment (LCA) of pads and tampons with a focus on the impacts of raw materials, product processing, transport and disposal. The analysis indicated that pads have a higher negative environmental footprint in almost all aspects when compared to tampons, although tampons have high environmental impacts from chemicals required in the agriculture process. Hait and Powers (2019) also found that when compared to tampons, disposable pads had the highest impact in terms of eutrophication and climate change without biogenic impacts considered. Tampons had higher impacts with regards to resource depletion and climate change with biogenic impacts (Hait and Powers, 2019). Both studies indicated the overall negative environmental impacts of disposable pads and tampons were significantly higher than those of the menstrual cups. Very little is known about menstrual underwear. Adult incontinence underwear was shown to be significantly more resource efficient than disposable adult incontinence underwear, and it was proposed that a new type of reusable underwear without disposable inserts would make the products even more resource efficient (Muthu et al., 2013).

4. Reusable products to reduce waste and conclusions

An estimated 15 million people in the UK menstruate over the span of around 37.5 years, with the majority currently using disposable menstrual management products designed in a linear 'take, make and dispose' model. This study estimates the annual amount of waste from menstrual products each year to be around 28,114 tonnes, with disposable pads contributing the most in terms of mass and having the highest negative environmental impact overall. Menstrual cups pose an opportunity to significantly reduce waste from 37,326 tonnes per year to just 92 tonnes while also requiring less water than the reusable underwear alternative at most accounting for 2 L of water per cycle.

Data collected shows there is an opportunity to drastically reduce the amount of waste generated from MMP. The shift towards reusable underwear, pads and cups highlights an opportunity to remove the taboo from purchasing disposable products and can give users the opportunity to take ownership of their cycle, comfort and waste. The menstrual cup appears to produce the least amount of waste overall when compared to pads and tampons. Water scarcity is a key sustainability issue meaning that further research is needed about reusable products and required water use for their cleaning.

One key barrier identified towards the widespread use of reusable products is the initial high price point, which remains a constrain even if the whole life cost of reusable MMPs can be significantly lower than disposable alternatives with, for instance, menstrual cups saving the user ca. £20 per year after less than two years of use.

In terms of sustainable development, Vora (2020) found that reusable products alone were not useful to people who menstruate that are homeless or in accommodation of a temporary nature. To ensure that these products create meaningful change, along with being more environmentally friendly, there is a need for systemic change. People who menstruate that are at a socioeconomic disadvantage would possibly benefit more from support in the form of educational workshops and safe spaces with facilities where they privately change, wash reusable products and dry them with the removal of all unconscious biases (Patkar, 2020). Reduction of the stigma surrounding menstrual practices and MMP waste management would be significantly reduced (Moffat and Pickering, 2019), empowering anyone with menstruation needs to sustainably manage their waste. Vora (2020) discussed the benefits arising from organisations that provide this type of services to help empower people, while improving menstrual wellbeing and safe environmental practices.

Further to the economic aspects of shifting to reusable products, a greater understanding is needed of the behaviour of individuals, the capability of cultural values and systems to welcome changes (Michie et al., 2011), with practices such as the Com-B model that can identify what needs to change in order for a behaviour change intervention to be effective. The value of social practice theories implemented by workshops about menstruation that can aid reduction of unsustainable practices has been previously reinforced (Reckwitz, 2002), but remains poorly documented in literature. Design thinking has also been suggested in a toolkit for workshops by AHPMA (2020a,b, 2021); Aracil et al. (2018); Hait and Powers (2019); Hoolohan and Browne (2020) with key tools including: exploration of problems; identifying key change points by provoking thoughts about the unsustainable practice; making use of diversity; generating influence maps and putting ideas into action. Further consideration of resource efficiency and sustainable management of waste derived from reusable products is still needed, with positive environmental impacts of improving reusable underwear through better utilisation of recycled materials or use of more sustainable materials as a feedstock when manufacturing menstrual cups, pads or underwear to reduce the need for new plastic production (Sandin and Peters, 2018) or allow composting in domestic settings (Davidson, 2012). The use of plastics and unsustainable materials such as rayon means there will subsequently be a reliance on fossil fuels. Even in the development of reusable products, unsustainable materials such as silicone rubber, polyester and nylon could pose a threat to any progress made further down the line (Chen and Burns, 2006).

Furthermore, much of the discussion around waste relays the notion that users are solely responsible for waste generated by products they use, with a disregard of the responsibility of those producing products. Legislation to encourage producers to take responsibility for waste, and design for appropriate disposal rather than cost reduction and increased profit margins will undoubtfully drive sustainable management of MMP waste.

If all products were required by law to be made from natural materials such as cotton and plant starches, the negative implications of incineration and landfill could be reduced in line with the Circular Economy model (Ellen MacArthur Foundation, 2015). At present there is very little in place in terms of regulation and legislation about MMP. The AHPMA (2020b) have dedicated a code of practice for product safety of tampons following cases of Toxic Shock Syndrome (TSS) although this is voluntary and down to the discretion of the company producing tampons. Finally, social practice theory, a tool utilised to address changes in existing problematic systems (Reckwitz, 2002) in combination with design thinking (Hoolohan and Browne, 2020) and cradle to cradle thinking (McDonough and Braungart, 2009) should be used to produce more sustainable products and reduce unsustainable practices such as those associated with MMP.

Declaration of competing interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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