UNITED NATIONS CONFERENCE ON TRADE AND DEVELOPMENT

Technical cooperation outcome

Solutions in traditional knowledge

How gravity water filters could help reduce single-use plastics in sub-Saharan Africa

UN trade & development

UNCTAD

Geneva, 2025

UNCTAD/TCS/DITC/INF/2025/5

Acknowledgements

This paper was prepared, under the overall guidance of Chantal Line Carpentier, Head of the Trade, Environment, Climate Change and Sustainable Development Branch of the UNCTAD Division on International Trade and Commodities, by a team comprising Henrique Pacini, Glen Wilson, Lalen Lleander and David Vivas Eugui.

UNCTAD gratefully acknowledges the research contributions of Doris van Halem and Guus Wiersma (Delft University of Technology) and comments from Marleen Ophorst (Nazava Water Filters), Micheal Roberts (IDE International), Tina Owen and Anna Bosworth (Winetowater), Tassia Gavioli (Stefani Cerâmicas), Elzette Henshilwood (SouthSouthNorth) and Maryna Peter (University of Applied Sciences and Arts Northwestern Switzerland).

This paper was produced under the Sustainable Manufacturing and Environmental Pollution (SMEP) Programme, funded by the Foreign, Commonwealth and Development Office (FCDO) of the United Kingdom of Great Britain and Northern Ireland and implemented in partnership with UNCTAD.

Photographs were kindly provided by Anna Bosworth (Wine to Water), Ben Langdon, David Graham (iDE) and Shaun Raviv (The Bhekisisa Centre for Health Journalism).

Desktop formatting was carried out by Lia Tostes and Rafe Dent.

Abbreviations

FCDO	Foreign, Commonwealth & Development Office of the United Kingdom
GWP	Global Warming Potential
LCA	life cycle assessment
SDG	Sustainable Development Goal
SMEP	Sustainable Manufacturing and Environmental Pollution Programme
SUP	single-use plastics
UNCTAD	United Nations Conference on Trade and Development

Table of contents

Executive summary

Executive summary

This study examines the challenge of improving water access to meet SDG 6 (Clean Water and Sanitation), while also reducing dependence on plastic-based water delivery systems, such as those using polyethylene terephthalate (PET) bottles and low-density polyethylene (LDPE) sachets. By considering the traditional technology of ceramic gravity filters, this paper estimates plastics displacement effects that could occur if gravity filter technologies increase their participation in selected African markets. The dual objective of meeting SDG 6 while reducing the plastics-intensity of the economy requires intersectoral action aligning efforts in the water, plastics and waste management sectors.

In the four evaluated countries combined (Ethiopia, Kenya, Uganda and Ghana), an estimated 60 million plastic bottles and sachets are used every day. This results in an annual total plastic footprint for drinking water of 105,000 tonnes, which is equivalent to an annual carbon footprint of 230,000 tonnes of CO_2. Full displacement of these SUPs would require an estimated 1.5 million ceramic water filters and could reduce the carbon footprint of water delivery by 99 per cent. This transition would, however, require a shift in consumer behaviour away from conveniently distributed and cooled plastic-packaged water. The banning of SUPs may accelerate this transition; however, without accessible and affordable alternatives, this can delay the achievement of SDG 6 in some regions.

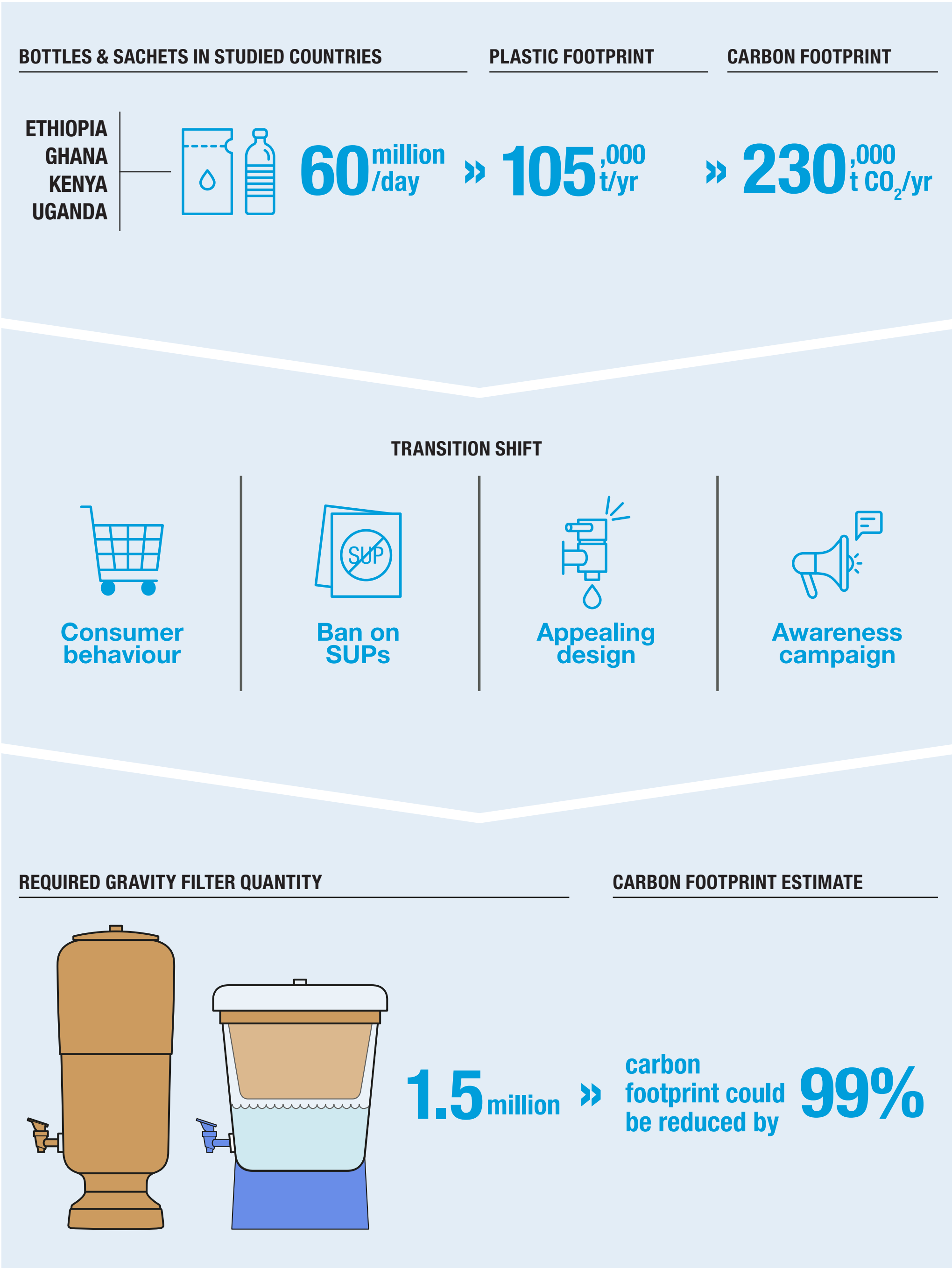
Therefore, we recommend:

- **appropriate water treatment technologies**, such as ceramic gravity filters, should be brought to the mainstream market in sub-Saharan Africa to design waste out of the water supply system by replacing SUP bottles and sachets;
- **commercial supply chains** for these products should be strengthened, with an emphasis on local production and circularity; and
- **behaviour change and marketing campaigns** should be conducted to reduce SUP adoption and promote water filters in their place.

Most importantly, action needs to be taken to provide potable water delivery systems with a low-plastic footprint. This requires a redesign of current water delivery systems and markets in sub-Saharan Africa giving priority to alternatives to packaged water that overcome the current trade-offs between SDG 6 (Clean Water and Sanitation) and the SDGs concerning environmental pollution, including SDG 11 Sustainable Cities and Communities; SDG 12 Sustainable Production and Consumption and SDG 14 Life Below Water. Investing in product availability and consumer acceptance of traditional gravity-driven household ceramic water filters for potable water delivery will instantly pay off in terms of lower carbon and plastic footprint today, by 2030 and beyond.

In Ethiopia, Kenya, Uganda and Ghana, an estimated **60 million plastic bottles and sachets are used every day** for drinking water

Figure 1
Summary of study findings, projections, and recommendations



Source: SMEP Programme, conceptual illustration developed for this report.

Chapter I

Introduction

© David Graham (iDE)

Introduction

Universal access to safely managed drinking water sources under Sustainable Development Goal (SDG) 6, target 6.1, which aims to ensure universal access to safe and affordable drinking water, continues to demand the attention of the United Nations and its member states. However, the construction of new water delivery infrastructure is failing to keep pace with rapid population growth, while regional impacts of climate change are making progress even more difficult (McDonald et al., 2011). In areas lacking reliable piped, trucked, or other forms of delivered water, the demand for bottled water has surged, creating significant environmental challenges. This reliance on bottled water to achieve SDG 6 complicates the attainment of other goals, such as SDG 12 (Responsible Consumption and Production) and SDG 14 (Life Below Water), both of which are negatively impacted by plastic pollution.

Building on observations and insights from the FCDO-UNCTAD SMEP Programme and its field projects in sub-Saharan Africa and South Asia[1], this paper offers a comprehensive overview of single-use plastics (SUPs) turnover for drinking water, including bottles and sachets in Ethiopia, Ghana, Kenya and Uganda. Furthermore, it compares the plastic and carbon footprint of SUPs against the traditional practice of gravity-driven household ceramic water filters, which is a point-of-use system for potable water delivery, presented here as a low-footprint market design alternative to packaged water. This paper then explores the plastic displacement potential that gravity filters could have over SUPs for drinking water, if water filters would experience market growth and become mainstream over SUPs towards achieving SDG target 6.1 by 2030.

The paper concludes that in the four evaluated countries combined, an estimated 60 million plastic bottles and sachets are used per day. This results in an annual total SUPs footprint for drinking water of 105,000 tonnes of plastic which roughly amounts to an annual carbon footprint of 230,000 tonnes of CO_2 equivalent. Full displacement of these SUPs would require an estimated 1.5 million ceramic water filters and could reduce the carbon footprint by two orders of magnitude. This transition would, however, require a shift in consumer behaviour away from conveniently available and cooled packaged water. The banning of some SUPs might accelerate this transition; however, without accessible alternatives, this might in some regions also delay achieving SDG target 6.1. Therefore, we recommend bringing water technologies with low- plastic footprints such as ceramic gravity filters to the mainstream in sub-Saharan Africa and to invest in customers' acceptance through the development of appealing filter products and marketing campaigns for different target groups.

Efforts to achieve SDG 6 in the studied countries face downstream **challenges due to plastic waste from single-use water packaging**

SUSTAINABLE DEVELOPMENT GOALS

6 CLEAN WATER AND SANITATION

[1] For more information on the Sustainable Manufacturing and Environmental Pollution (SMEP) programme and its initiatives, visit the official SMEP website.

Chapter II

Safe water access via single-use plastics

© Ben Langdon

Safe water access via single-use plastic

Through its unique mix of natural capital, the ocean has shaped the course of human history and determined the key trajectories of civilization. From ensuring sustainable livelihoods through fisheries to facilitating trade routes, humanity has long relied on oceans to meet its most pressing economic needs.

Every minute, one million plastic water bottles are sold worldwide, a number expected to double by 2030 (Ramirez, 2023)

Estimates suggest that approximately 50 per cent of all plastic produced is utilized only once before being discarded (Plastic Oceans, 2021), commonly referred to as single-use plastics (SUPs). Plastic bottles were introduced in 1973 and have since become an integral part of society across the globe (Parker, 2019). Every minute, one million bottles of water are sold worldwide, and this number is expected to double by 2030 (Ramirez, 2023). Plastic bottles are typically made from polyethylene terephthalate (PET), derived from petroleum, with the 500 ml variant being the most common (Gitnux, 2024) and when unmanaged at end of life remain in the environment for an extended period.

An emerging substitute for bottled water is water packaged in sachets, which are often simpler and cheaper to produce. Sachets, just like common bottles, are sold in a 500 ml plastic bag typically composed of low-density polyethylene (LDPE). The first sachets date back to the 1990s (UNEP, 2024) and initially featured manually tied corners. However, import of affordable machinery facilitated the heat-sealing of sachets, streamlining the production process (Stoler, 2017). Sachets have become mainstream SUPs for drinking water across West Africa and have exacerbated the problem of plastic pollution (Stoler, 2017).

In the absence of reliable and widespread water treatment and distribution systems via pipelines and related infrastructure, SUPs are an effective way of providing people with safe drinking water. Bottles and sachets are conveniently sold at every street corner (Figure 1), often pleasantly cooled, inexpensive and packaged in affordable sizes. From a retail perspective, drinking water supply via SUPs is an attractive business model for both large companies and small vendors given its quick turnover potential. The access to water via SUPs varies per country but it is estimated that in Kenya, 5.6 per cent of the population uses bottled water as their primary source (Kenya National Bureau of Statistics, 2023). In Ghana, 1.4 per cent of the population relies on bottled water and an additional 33.6 per cent on sachet water as their primary source (Ghana Statistical Services, 2024), a practice particularly popular in West Africa, while rare in other regions. In Uganda (0.12 per cent) and Ethiopia (0.10 per cent), water access via bottled water is not as dominant (Central Statistical Agency, 2017; Uganda Bureau of Statistics, 2020), however, access to safely managed drinking water is also lower in these countries (UN Water, 2024a; UN Water, 2024b).

Even though SUPs only provide a fraction of people in sub-Saharan African countries with safe drinking water, the environmental burden is enormous (UNEP, 2023). Only an approximate 9 per cent of global plastics are recycled, with the remainder being landfilled, incinerated or leaking into the environment (Ritchie, Samborska, Roser, 2023). In Ethiopia, 9 per cent of plastics are recycled, 12 per cent incinerated and 79 per cent accumulate in open dump sites (Ethiopia EPA, 2024). In Kenya, an estimated 92 per cent of plastic waste is mismanaged and only 7 per cent is recycled (USAID, 2024). In Uganda, 42 per cent of plastics are improperly disposed of (Uganda EPA, 2023). The situation in Ghana is also concerning, with only 9.5 per cent of plastics being recycled (Auditor-General, 2024). This persistent plastic presence in the environment poses harmful impacts on wildlife, ecosystems, and human health (Agbasi et al., 2024; CIEL, 2023), making plastic pollution an urgent global challenge that demands immediate attention. On the African continent, it is estimated that Egypt, Nigeria, South Africa, Algeria and Morocco are among the top 20 countries contributing to plastic waste entering our oceans (Jambeck et al., 2018).

This highlights the current trade-off between achieving SDG 6 (Clean Water and Sanitation) and other goals, such as SDG 11 (Sustainable Cities and Communities) and SDG 14 (Life Below Water), given the extensive use of single-use plastics (SUPs) in delivering drinking water. A comprehensive understanding of how SUPs are used and their environmental impact is essential for creating effective strategies to reduce plastic waste, promote sustainable alternatives, and mitigate the negative effects of plastic pollution on our planet.

In Kenya, an estimated 92% of plastic waste is mismanaged and only 7% is recycled

(USAID, 2024)

Chapter III

Gravity filters: a traditional alternative

© Wine to Water

Gravity filters: a traditional alternative

Humans have been obtaining potable water for millennia using gravity filtration techniques, producing clear water from muddy waters through various filtration methods, such as through sand, stones, paper, textiles, ceramics or other porous medium (Mays, 2013). This study specifically investigates the traditional practice of gravity-driven household ceramic water filters as a low-footprint market design for potable water delivery, which can function as an alternative to packaged water.

Gravity filters are the oldest type of water filters and were used for centuries in China, India, Egypt, Greece and Rome (Smith, 2017). The working principle of ceramic water filters is elegant in its simplicity: water travels through a porous medium, made of sand, cloth or ceramic, capturing particles and harmful micro-organisms, making water safe to drink. Today, gravity ceramic water filters are found in households across the globe, and they come in different shapes and sizes. For example, in Cambodia and Nicaragua, local production facilities distribute pot-shaped filters to rural communities whereas in Brazil and Mexico, the table-top candle filter is commonly found in urban households (Huaman, 2022).

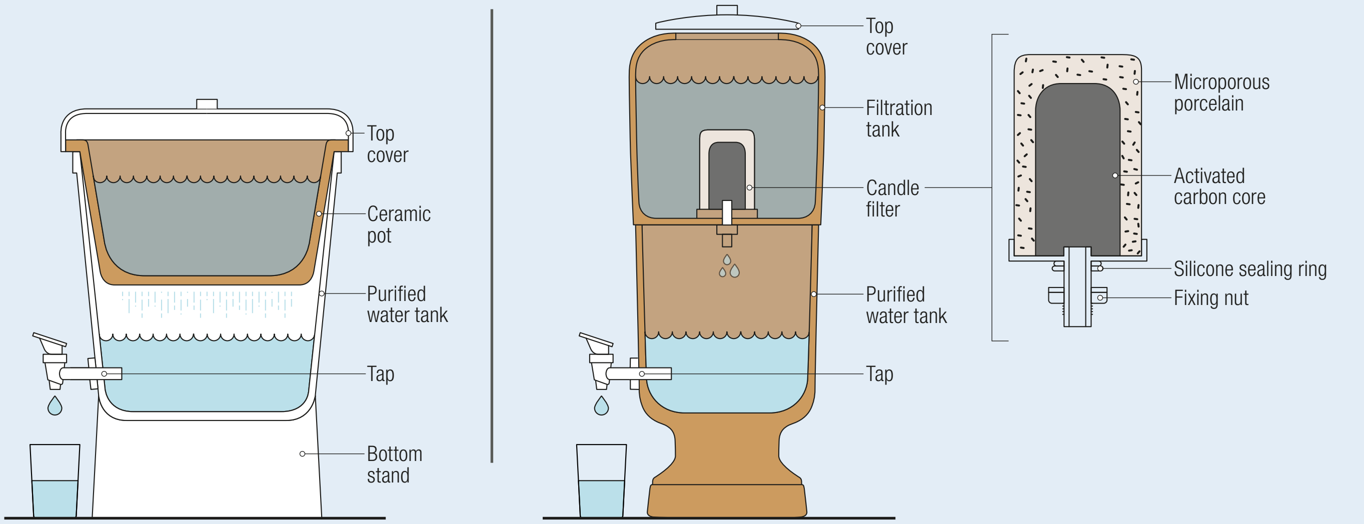
Filters in candle shape are manufactured in industrial settings, typically in Asia, and imported to the African continent. The pot-shaped filters are manufactured at local production sites in Africa with local materials and a kiln (Figure 2). Either way, the production process consists of pressing and firing a mixture of clay, water and an organic combustible material (e.g. sawdust or rice husks). After firing, the ceramic element is often impregnated with a silver solution to prevent biofilm growth and, in some cases, activated carbon is added to the final design for colour and taste improvement. Depending on the raw water quality, ceramic water filters can typically produce up to 7,000 liters of water over their lifetime (Nazava, 2024) and the plastic, ceramic or metal containers of these units can be reused over several filter replacements.

Ceramic water filters can produce up to **7,000 liters of safe drinking water over their lifetime**

The effectiveness of ceramic water filters to produce safe drinking water depends on their ability to remove faecal indicator organisms. Studies have shown that ceramic household filters can remove larger microorganisms, including bacteria and protozoa but will only partially remove viruses (Van Halem et al., 2007; Van der Laan et al., 2013). This is supported by Round II of the international scheme to evaluate household water treatment technologies of the World Health Organization (WHO) (WHO, 2019), providing a single star performance based on effective bacteria and protozoa removal (> 2 log) for three ceramic gravity filter designs. It should be noted though, that ceramic filters provide protection against waterborne infectious diseases but not against health issues caused by dissolved contaminants such as pesticides, fluoride or arsenic. Nevertheless, research shows significant positive health impact of this reliable, affordable water filter technology (Hunter, 2009; WSP, 2007).

Depending on the country or region, pot-shaped or tabletop candle filters can be more common. The geographic spread of production varies, with Asia, the Americas and Europe concentrating most producers. From a global perspective, the African

Figure 2
Examples of household ceramic gravity filters found in households across the globe



Source: SMEP Programme, conceptual illustration developed for this report.

continent is lagging behind in number of producers (NMSC, 2023). The local production or assembly of water filters creates local jobs and increases supply chain resilience. Water filters are sold under HS Code 842121, which represented a trade volume of USD 11.8 billion in 2022 (OEC, 2024). This code covers a wide range of products, including products that need to be connected to a piped water source (pressure-driven and membrane filters). It is therefore hard to estimate the actual trade of gravity filters since their exports are bundled with other water filtration technologies. According to industry research statistics, the global market for ceramic filters was approximately USD 1.3 billion in 2021, suggesting gravity filters represent about 11 per cent of the total trade in water filtration products (NMSC, 2023; OEC, 2024). To get a better estimate of the current market of gravity-driven water filters specific to sub-Saharan Africa, existing surveys on filter use provide an estimate per country. In Ghana, an approximate 0.1-0.3 per cent of the population use a gravity water filter (Ghana Statistical Services, 2024), except for the Ashanti region where 1.2 per cent of the population indicated using a filter. It is important to note, however, that in these surveys, the term 'filters' are used as an umbrella that includes sand and membrane filters; the survey answers thus do not specifically refer to ceramic filters. In Kenya, filter use is also well below 1 per cent in most districts (Kenya National Bureau of Statistics, 2023) although higher percentages are reported in some regions (e.g. 5.5 per cent and 3.7 per cent for Nakuru and Tana River, respectively). Here the word 'filter' might also refer to filters other than ceramic gravity filters since filters for removal of geogenic fluoride are also found in Kenya. Filter use is on average 0.7 per cent in Uganda (Uganda Bureau of Statistics & ICF, 2018) and 1.2 per cent in Ethiopia (Central Statistical Agency Ethiopia and ICF International, 2012). In comparison, filter use in Cambodia is more widespread with percentages ranging from 4 to 54 per cent per region (National Institute of Statistics, Ministry of Health and The DHS Program, 2023).

Chapter IV

The footprint of SUPs for drinking water

© Ben Langdon

The footprint of SUPs for drinking water

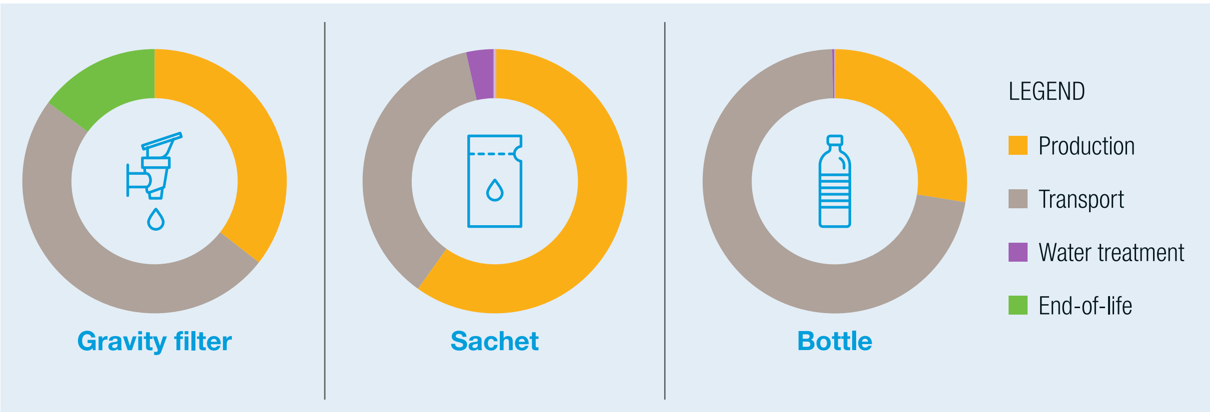
In order to estimate carbon emissions associated with water delivered through plastic bottles, sachets, and ceramic filters, a life cycle assessment was conducted considering production (including extraction of raw materials), (inter)national transport, water treatment and end-of-life disposal (Guinée et al., 2002). The percentage contribution of emissions in each phase is depicted in the pie chart in Figure 3.

For the gravity water filters, the Nazava filter (Nazava, 2024) in Kenya (candle filter) and Pure Home Water filter from Ghana were assessed and the average is reported (Pure Home Water, 2024). The ceramic element in the filters is considered to have a lifetime of 7,000 and 11,000 liters respectively, as reported by the vendors, and the receptacles were estimated to survive 2 additional filter replacements. For bottled water, the most common 500 ml PET bottle with HDPE cap was assessed. As 62 per cent of all plastic on the Ghanaian market is imported, the LDPE film for the sachets and plastic bottle are assumed to be imported from Asia (GPMA, 2024). National transport kilometres were calculated assuming water bottling in (district) capitals, while sachet fillings were assumed to occur in regional towns. Water treatment of both bottled and sachet water was assumed to consist of granular filtration, softening and reverse osmosis. End-of-life was calculated assuming incineration of plastics, which does not account for recycling, reuse and environmental pollution.

The modelling results compared the global warming potential (GWP) in terms of CO_2 equivalent per liter of drinking water. Results show that the ceramic gravity filter has between a 10 and 100 times smaller carbon footprint than sachets or bottled

Figure 3

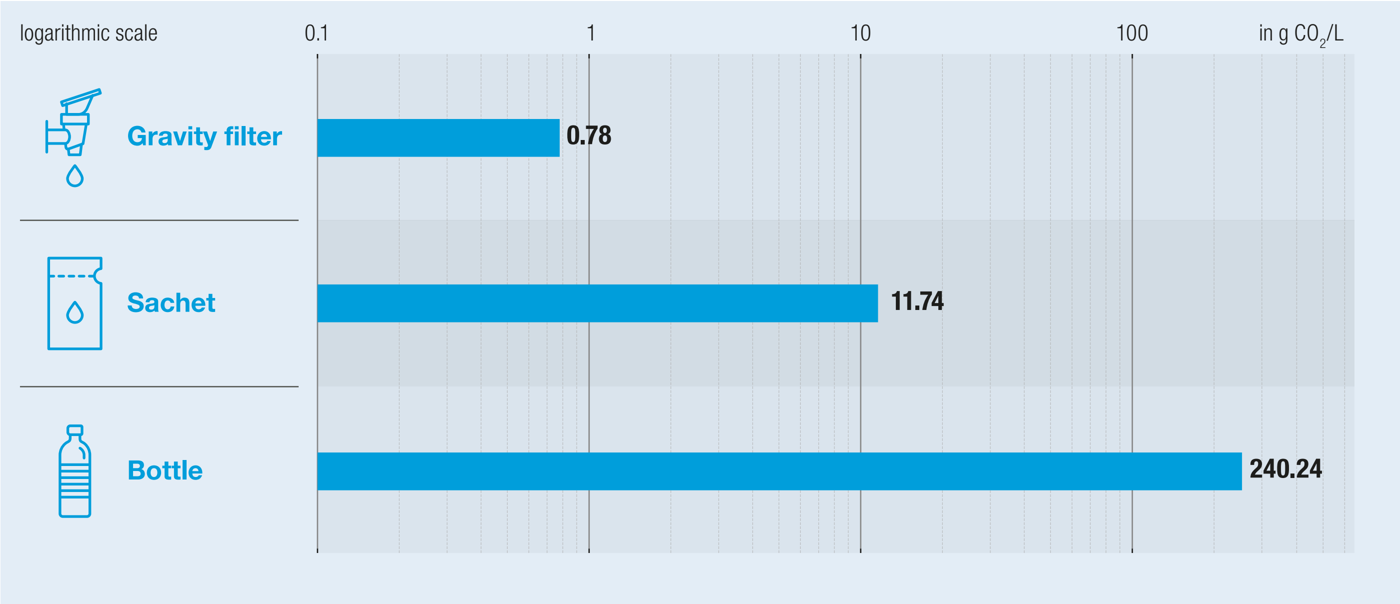
Carbon footprint emissions breakdown by phase: ceramic gravity filters, sachets and bottled water



Source: SMEP Programme, conceptual illustration developed for this report.

Figure 4

Carbon footprint per liter of drinking water: ceramic gravity filters, sachets and bottled water



Source: SMEP Programme, conceptual illustration developed for this report.

water, respectively (Figure 3). The evaluated ceramic gravity filters (candle and pot designs) which are sold in sub-Saharan Africa are generally contained in plastic receptacles (shells). The average carbon footprint of the plastic receptacles is 15 kg of CO_2 equivalent per filter, which corresponds to 0.8 g per liter of drinking water produced.

In practice the end-of-life of plastics varies widely. For example, the plastic components of the ceramic gravity filters (e.g. tap, container) are designed for reuse when ceramic elements are replaced, whereas SUPs are widely reported to leak into the environment, causing environmental pollution (Chen et al., 2021). Plastic bottles are mostly imported from Asia, but some factories use locally produced bottles, which reduces the carbon footprint by half (GPMA, 2024). Table 1 provides an overview of SUPs usage for Ethiopia, Ghana, Kenya and Uganda.[2] In the calculations the weight of a 500ml plastic bottle is considered to be 11 grams for the bottle (PET) and 2.55 grams for the cap (HDPE). The weight of a single sachet is 2 grams (LDPE). SUPs usage is calculated from the percentage of population using bottled or sachet water as their primary source according to the most recent national Demographic and Health Surveys (DHS).[3] The contribution of SUPs to the total annual plastic consumption per country was estimated based on literature and industry sources (Interplast, 2024; IUCN, 2023; NRSP, 2021; SMEP, 2022). The assumed daily water consumption used in the calculations is 2 liters per person, as advised by the World Health Organization.

2 Using data from the most recent Demographic and Health Surveys (DHS) for Ethiopia, Ghana, Kenya and Uganda, combined with the SDG 6 Data Portal for population numbers, as well as for the percentages of bottled and sachet water users (KNBS, 2023; Ghana Statistical Services, 2024; CSA, 2017; Uganda Bureau of Statistics, 2020; UN Population Division, 2024).

3 It should be noted that in these surveys, no differentiation is made between bottled water in SUPs or in refillable 20L vessels, so these were excluded from the analysis.

Table 1
Plastic footprint estimation of SUP usage for drinking water

Studied countries	Ethiopia	Ghana	Kenya	Uganda
Population using bottled and sachet water PERCENTAGE	0.10	1.40 bottled 33.6 sachet	5.60	0.12
Drinking water consumption via SUPs MILLION M³/YEAR	0.08	8.55	2.21	0.04
National plastic footprint related to drinking water via SUPs MILLION KG/YEAR	2.1	42	60	1.0
SUPs usage for drinking water per 100,000 inhabitants METRIC TONNES/YEAR	2.0	126	110	2.3
Contribution of SUPs to total plastic waste PERCENTAGE	0.5	3.8	6.0	0.2

Source: Authors' calculations, based on Demographic and Health Surveys (DHS) for Ethiopia, Ghana, Kenya and Uganda, combined with SDG 6 Data Portal population data and national statistics on bottled and sachet water use (KNBS, 2023; Ghana Statistical Services, 2024; CSA, 2017; Uganda Bureau of Statistics, 2020; UN Population Division, 2024).

Drinking the same amount of water in bottles instead of sachets raises **a person's plastic footprint from 2.9 kg to nearly 20 kg per year**

Plastic usage is widely reported to be higher in cities than in rural areas, however, in these calculationsnational averages were used. The estimation was limited to people reporting bottled water or sachet water as their primary source of drinking water, excluding reports of secondary use, thus underestimating the total impact.

Close to 11 million m3 of drinking water is annually consumed via packaged water in the four countries combined. Ghana has by far the highest percentage of people using SUPs as their primary source of drinking water. Particularly sachet water is widely consumed, both from certified and illegal vendors. Consequently, water quality in the sachets may vary, including risk of faecal contamination and plastic residues (Agbasi et al., 2024; Amuah et al., 2021; Angnunavuri et al., 2022; Boadi et al., 2023). In Kenya, the volume of drinking water via SUPs is much smaller than for Ghana, but the same annual plastic load is generated due to the use of bottles instead of sachets and bottles containing more plastic per liter than sachets. To illustrate, a person who consumes drinking water via sachets will have an approximate plastic footprint of 2.9 kg LDPE per year, while drinking the same volume of water through bottled water would add up to a footprint of nearly 20 kg plastic per year (16 kg PET and 3.7 kg HDPE).[4] In Uganda and Ethiopia, a relatively small percentage of people use bottled water as their primary source (0.10-0.12 per cent), resulting in plastic footprints of 2.0-2.3 tonnes/year per 100,000 inhabitants. This is over 50 times smaller than the 110 and 126 tonnes/year per 100,000 inhabitants of Kenya and Ghana, respectively. The use of SUPs for drinking water compared to the total annual plastic waste production in these countries shows that in Kenya, SUPs have the highest share, being 6 per cent, followed by Ghana (3.8 per cent), while Uganda and Ethiopia have a much lower contribution of SUPs (<0.5 per cent) compared to the annual total plastic waste production.

[4] It should be noted that an unknown proportion of this plastic footprint will consist of 20L refillable containers.

Chapter V

Scope for plastic displacement by filters

Scope for plastic displacement by filters

Water delivered via single-use packaging offers undeniable portability, convenience and storage, therefore becoming attractive to consumers. However, a growing body of research shows that packaged water is not necessarily a niche of quality premiums or a social need, but instead a reflection of infrastructure deficiencies, coupled with sophisticated marketing and branding by beverage companies (Hawkins, 2017; Valavanidis, 2020; Qian, 2018).

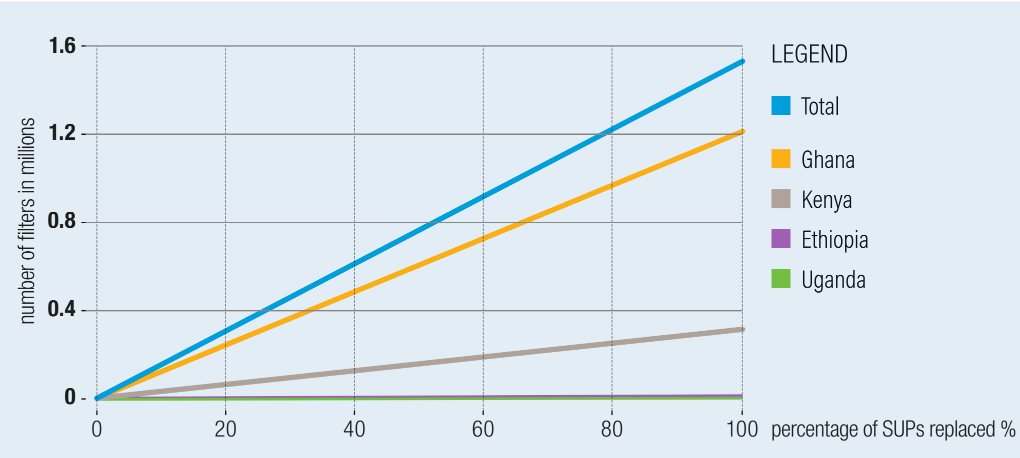
In the four evaluated countries combined, an estimated 60 million plastic bottles and sachets are used every day. This results in an annual total SUPs footprint for drinking water of 105,000 tonnes of plastic, which roughly amounts to an annual carbon footprint of 230,000 tonnes of CO_2 equivalent. Figure 5 presents the estimated number of filters that would be required to displace water access via SUPs. Calculations are based on SUPs usage per country in latest DHS and population information from UN Data Portal (KNBS, 2023; Ghana Statistical Services, 2024; CSA, 2017; Uganda Bureau of Statistics, 2020; UN Population Division, 2024). For ceramic water filters a conservative lifetime of 7,000 liters is assumed. Therefore, a 100 per cent displacement of SUPs would require an approximate 1.5 million filters, 1.2 million being required in Ghana alone. This corresponds to the production of nearly 11 million m3 of drinking water, which is currently supplied annually through water packaged in plastics.

Replacing single-use plastics (SUPs) for water, such as bottles and sachets, will demand significant changes in both consumer behavior and the supply of alternative potable water options. Currently, water in plastic packaging is widely accessible and conveniently available on almost every street corner,

Over 11 million m³ of drinking water are consumed yearly via plastic packaging in the four countries

Figure 5

Carbon footprint per liter of drinking water: ceramic gravity filters, sachets and bottled water



Source: Authors' calculations, based on DHS data and national statistics (KNBS, 2023; Ghana Statistical Services, 2024; CSA, 2017; Uganda Bureau of Statistics, 2020) and population data from the UN Population Division (2024).

Currently, **38.4% of Ethiopians, 20% of Kenyans, 19% of Ugandans, and 12.1% of Ghanaians** lack access to safely managed drinking water sources (UN Water, 2024a–d)

especially in warm climates where it offers a cold, refreshing drink. This bottled and sachet water is also generally perceived as high quality and safe to drink.

Transitioning to home water filters would mean consumers need to carry water in reusable bottles, which may not stay as clean or as cold. Additionally, while household ceramic gravity filters are an option, they do not always meet the high purification standards achieved by bottled water companies using reverse osmosis. Moreover, sachet water is sometimes packaged by uncertified vendors, resulting in variable quality and occasional contamination with harmful bacteria, like E. coli (Oludairo and Aiyedun, 2015; Boadi et al., 2023).

Another concern is the growing evidence of micro and nano plastics, along with other plastic-related contaminants, leaching into bottled and sachet water (Chen et al., 2023). Each water delivery option has its own risks to water quality, yet the convenience of SUPs may continue to be a barrier to reducing plastic use, even as awareness of these risks grows.

Many sub-Saharan African countries recognize the negative impact of plastic pollution on the environment and in response, laws controlling the usage and disposal of plastics, such as carrier bags and beverage containers, are being implemented (Greenpeace, 2020; FlipFlopi, 2023). Increased responsibility is being enforced on producers, such as through Ghana's plastic bottle tax (Francis, 2021). Other strategies to mitigate environmental pollution by SUPs include improved waste management, such as advancing and modernizing conditions for waste pickers (SMEP, 2024), installing plastic collectors, such as floating surface-level booms in water bodies (SMEP, 2024) and recycling specific plastics (e.g. HDPE caps). Such clean-up initiatives are important, but prevention of SUPs entering the market will be the most effective to limit plastic pollution. Alternatives to water in SUPs are the refillable 20L PET bottles or jerrycans (1001 fountaines, 2024), which has been calculated here to reduce the plastic footprint per liter of drinking water by 90% compared to SUPs and would cause less diffuse pollution. Alternatively, a switch towards biodegradable plastics, such as PHA (Bio Based Press, 2016), could partially reduce the plastic load of water delivery. However, local production of these plastic alternatives has not yet reached the scale, quality and cost-effectiveness of LDPE or PET, and significant questions have been raised on their environmental merits when compared to conventional plastics (Scientists Coallition, 2023).

Reducing the plastic and emissions intensity of water delivery systems is essential; however, the broader challenge remains the limited access to safe drinking water, an ongoing issue in many regions. Addressing plastic pollution alongside safe water access requires a concerted effort to reduce reliance on SUPs and to redesign water delivery system sustainably by 2030.

Currently, 12.1 per cent of Ghanaians do not have access to safely managed drinking water sources – a percentage that is even higher for Kenya (20 per cent), Uganda (19 per cent) and Ethiopia (38.4 per cent) (UN Water, 2024a; UN Water, 2024b; UN Water, 2024c; UN Water, 2024d). Today, an estimated 52 million m3 of additional safe and affordable drinking water would be required per year to meet SDG 6.1 in these four countries. This number might grow to 62 million m3/year by 2030 when considering population growth projections (UN Population Division, 2024). In the scenario that sachet water would become the popular choice for drinking water in all four investigated countries – as currently seen in Ghana – bridging the water gap could annually result in an approximate 250,000 tonnes of additional waste plastic by 2030.

Chapter VI

Conclusion

Conclusion

To meet both Sustainable Development Goal 6 and to encourage a shift from single-use plastics (SUPs) to sustainable water alternatives, an urgent transition to low-plastic water delivery systems is essential. This paper concludes that in the four evaluated countries combined, an estimated 60 million plastic bottles and sachets are used per day. This results in an annual total SUPs footprint for drinking water of 105,000 tonnes of plastic, which roughly amounts to an annual carbon footprint of 230,000 tonnes of CO_2 equivalent.

Full displacement of these SUPs would require an estimated 1.5 million ceramic water filters and could reduce the carbon footprint by 99 per cent. By 2030, ceramic water filter needs would rise to approximately 9 million units for Ethiopia, Kenya, Uganda, and Ghana only to meet safe drinking water targets, with Ethiopia alone requiring around 6 million of these.

This transition would, however, require a shift in consumer behaviour away from conveniently available and cooled packaged water. The banning of some SUPs might accelerate this transition; however, without accessible alternatives, this might in some regions also delay achieving SDG 6.1. Currently, the number of ceramic filter providers in these countries is limited compared to other nations, such as Brazil and Cambodia. Although ceramic filters cannot entirely solve the safe water access gap due to broader infrastructure and resource challenges, this study shows substantial potential for market expansion.

Having said this, ceramic water filters also face downsides, as consumers complain about their low flow rates and scientists have shown that ceramic water filters cannot removal all contaminants (for example, viruses, dissolved chemicals). However, when targeting application of filters for urban populations with access to piped tap water, the ceramic water filter functions as a polishing step to remove potential recontamination during transport. This is a different function from the primary disinfection treatment step for which ceramic filters are used in rural communities

As such, a new generation of ceramic water filter products could be developed, specifically for this function, considering the different motivations of rural and urban populations, addressing perceptions of water safety and the willingness to pay for filter solutions to maximize impact. For filters to become a mainstream solution, increased investment is needed, particularly in local manufacturing and supply chain development, including trade facilitation, alongside behaviour change campaigns focused on shifting consumer preferences. Effective measures to reduce SUPs would also involve regulation, control measures and robust enforcement. While current filter programs often target rural populations, urban areas represent the highest potential for plastic reduction due to higher SUP usage. Therefore, we recommend bringing water technologies with low- plastic footprints such as ceramic gravity filters to the mainstream market in urban sub-Saharan Africa and to invest in customers' acceptance through the development of appealing filter products and marketing campaigns for different target groups.

By 2030, Ethiopia, Kenya, Uganda, and Ghana will need around **9 million ceramic water filters to meet safe drinking water targets**

References

1001 fountaines (2024). Bringing lifelong access to safe drinking water. Available at https://www.1001fontaines.com/en/.

Agbasi, J. C., Ezugwu, A. L., Omeka, M. E., Ucheana, I. A., Aralu, C. C., Abugu, H. O., & Egbueri, J. C. (2024). More about making profits or providing safe drinking water? A state-of-the-art review on sachet water contamination in Nigeria. *Journal of Environmental Science and Health*, Part C, 1–43.

Amuah, E. E. Y., Bekoe, E. M. O., Kazapoe, R. W., Dankwa, P., Nandomah, S., Douti, N. B., Abanyie, S.K., Okyere, I. K. (2021). Sachet water quality and Vendors' practices in Damongo, northern Ghana during the emergence of SARS-CoV-2 using multivariate statistics, water quality and pollution indices, and panel assessment. *Environmental Challenges*, 4, 100164.

Angnunavuri, P. N., Attiogbe, F., Dansie, A., & Mensah, B. (2022). Evaluation of plastic packaged water quality using health risk indices: a case study of sachet and bottled water in Accra, Ghana. *Science of the Total Environment*, 832, 155073.

Auditor-General of Ghana (2024) Performance audit report on the disposal of plastic waste in Ghana. Available at: https://audit.gov.gh/files/audit_reports/Performance_Audit_report_of_the_Auditor-General_on_the_disposal_of_plastic_waste_in_Ghana.pdf.

Bio Based Press (2016). PHA: promising, versatile, biodegradable. Available at: https://www.biobasedpress.eu/2016/08/pha-promising-versatile-biodegradable/.

Boadi, N. O., Saah, S. A., Badu, M., Baa-Poku, F., Odame, F., & Sakyi, P. O. (2023). Assessment of sachet water quality in Kumasi, Ghana. *Discover Water*, 3(1), 24.

Center for International Environmental Law (2023). The Toxic Impacts of Plastic Across its Lifecycle - Center for International Environmental Law. Available at: https://www.ciel.org/the-toxic-impacts-of-plastic-across-its-lifecycle/.

Central Statistical Agency (2017). *Ethiopia demographic and health survey 2016*.

Central Statistical Agency Ethiopia and ICF International (2012). *Ethiopia demographic and health survey 2011*.

Chen, Y., Awasthi, A. K., Wei, F., Tan, Q., & Li, J. (2021). Single-use plastics: production, usage, disposal, and adverse impacts. *Science of the Total Environment*, 752, 141772.

Chen, Y., Xu, H., Luo, Y., Ding, Y., Huang, J., Wu, H., Han, J., Du, L., Kang, A., Jia, M., Xiong, W., Yang, Z. (2023). Plastic bottles for chilled carbonated beverages as a source of microplastics and nanoplastics. *Water Research*, 242, 120243.

Ethiopia EPA (2024). *National Plastic Waste Management Strategy and Roadmap 2024–2034*. FDRE Environmental Protection Authority. Available at: https://www.epa.gov.et/images/2024/National%20Plastic%20Strategy%20and%20Action%20Plan.pdf.

FlipFlopi (2023). *State of Affairs: Policies, Regulations and Laws that address the harmful effects of single-use plastics in the East African Community*. Available at: https://unctad.org/system/files/non-official-document/ditc-ted-12042023-Single_Use_Plastics_Report_2023-3.pdf.

Francis, T. B. (2021). New tax on plastic packaging in Ghana – Will this solve the problem of plastic waste? Available at: https://thebftonline.com/2021/11/16/new-tax-on-plastic-packaging-will-this-solve-the-problem-of-plastic-waste/.

Ghana Statistical Services (2024). *Ghana demographic and health survey 2022*.

Gitnux (2024). Statistics about the average water bottle size. No longer available online.

GPMA (2024). Ban importation of flexible plastic bags from China – GPMA to govt. Available at: https://gpma.org.gh/index.php/news/ban-importation-of-flexible-plastic-bags-from-china-gpma-to-govt.

Greenpeace (2020). *34 plastic bans in Africa: A reality check*. Greenpeace Africa. Available at: https://www.greenpeace.org/africa/en/blogs/11156/34-plastic-bans-in-africa/.

Guinée, J. B. et al. (2002). *Handbook on life cycle assessment: operational guide to the ISO standards* (Vol. 7). Springer Science & Business Media.

Hawkins, G. (2017). The impacts of bottled water: an analysis of bottled water markets and their interactions with tap water provision. *Wiley Interdisciplinary Reviews: Water*, 4(3). https://doi.org/10.1002/wat2.1203.

Huaman Milian, L. M. (2022). *Eficiencia de tres filtros cerámicos en el control de los principales patógenos acuáticos en el agua de consumo humano*. Universidad Privada del Norte. Available at: https://repositorio.upn.edu.pe/bitstream/handle/11537/31038/Huaman%20Milian%20Luz%20Merly.pdf?sequence=1&isAllowed=y.

Hunter, P. R. (2009). Household water treatment in developing countries: comparing different intervention types using meta-regression. *Environmental Science & Technology*, 43(23), 8991–8997.

Interplast Pack Africa (2024). *Plastic packaging & printing news*.

IUCN (2023, December 18). Combatting plastic pollution in Ghana. Available at: https://www.iucn.nl/en/news/combatting-plastic-pollution-in-ghana/.

Jambeck, J. et al. (2018). Challenges and emerging solutions to the land-based plastic waste issue in Africa. *Marine Policy*, 96, 256–263.

Job, F. C. (2012). End user perception and willingness-to-pay for gravity driven membrane disinfection in Nakuru, Kenya.

Kenya National Bureau of Statistics (2023). *Kenya demographic and health survey 2022. Volume 1*.

McDonald, R. I., Douglas, I., Revenga, C., Hale, R., Grimm, N., Groenvall, J., Fekete, B. (2011). Global urban growth and the geography of water availability, quality and delivery. *AMBIO*, 40, 437–446. Available at: https://link.springer.com/article/10.1007/s13280-011-0152-6.

Mays, L. W. (2012). A brief history of water filtration/sedimentation. *Water Supply*, 13(3). Available at: https://iwaponline.com/ws/article-abstract/13/3/735/27135/A-brief-history-of-water-filtration-sedimentation.

National Institute of Statistics, Ministry of Health and The DHS Program (2023). *Cambodia demographic and health survey 2021–22*.

Natural Resources Stewardship Programme (2021). Plastic consumption and recycling in Addis Ababa, Ethiopia.

Nazava (2024). Meet the revolutionary Nazava water filter: No more expensive bottles or boiling. Available at: https://nazava.co.ke/#:~:text=Last%20For%207000%20Liters%20Before,Replacements%20Readily%20Available.

NMSC (2023). *Ceramic filters market by product type: Global opportunity analysis and industry forecast 2022–2030*. Available at: https://www.nextmsc.com/report/ceramic-filters-market.

OEC (2024). HS code for water filtering or purifying machinery or apparatus. Available at: https://oec.world/en/profile/hs/water-purification-and-filtration-equipment.

Oludairo, O., & Aiyedum, J. O. (2015). Contamination of commercially packaged sachet water and the public health implications: An overview. Available at: https://www.researchgate.net/profile/Oladapo-Oludairo/publication/313331820_TRANSBOUNDARY_DISEASES_AND_WILDLIFE_MANAGEMENT_AN_OVERVIEW/links/595a411e458515a5406fc106/TRANSBOUNDARY-DISEASES-AND-WILDLIFE-MANAGEMENT-AN-OVERVIEW.pdf.

Parker, L. (2019). How the plastic bottle went from miracle container to hated garbage. *National Geographic*. Available at: https://www.nationalgeographic.com/environment/article/plastic-bottles#:~:text=Polyethylene%20terephthalate%20has%20been%20around,safe%2C%20cheap%E2%80%94and%20recyclable.

Plastic Oceans (2021). *Science*. Available at: https://www.plasticoceans.org.au/science#:~:text=Key%20Facts%20about%20Plastic%20pollution&text=We%20are%20producing%20over%20380,(Plastic%20Oceans%2C%202021).

Pure Home Water. *Producers of the AfriClay Filter. Safe water for every household*. Available at: https://purehomewater.org/. Accessed on 31 May 2024.

Qian, N. (2018). Bottled water or tap water? A comparative study of drinking water choices on university campuses. *Water*, 10(1), 59. Available at: https://www.mdpi.com/2073-4441/10/1/59.

Ramirez, R. (2023, March 16). The plastic water bottle industry is booming. Here's why that's a huge problem. *CNN*. Available at: https://www.cnn.com/2023/03/16/world/plastic-water-bottles-un-report-climate.

Ritchie, H., Samborska, V., Roser, M. (2023). Plastic pollution. *Our World in Dat*a. Available at: https://ourworldindata.org/plastic-pollution.

Scientists Coalition (2023). *Fact sheet: Plastics alternatives and substitutes*. Available at: https://ikhapp.org/materials-thematic-area/plastic-alternatives-and-substitutes/.

SMEP (2022). Challenges and opportunities for substitutes to single-use plastic: Insights from Kenya. Available at: https://unctad.org/system/files/non-official-document/tcsditcinf2022d3_fs2_en.pdf. Accessed on 11 June 2024.

SMEP (2024). *RiverRecycle OY*. Available at: https://smepprogramme.org/project/riverrecycle-oy/.

SMEP (2024). *The GIVO-Warwick Project*. Available at: https://smepprogramme.org/project/the-givo-warwick-project/.

Smith, L. (2017). Historical perspectives on water purification. In: *Chemistry and Water: The Science Behind Sustaining the World's Most Crucial Resource*. Available at: https://www.sciencedirect.com/science/article/abs/pii/B978012809330600012X.

Stoler, J. (2017). From curiosity to commodity: a review of the evolution of sachet drinking water in West Africa. *WIREs Water*, 4(3).

Uganda Bureau of Statistics & ICF (2018). *Uganda demographic and health survey 2016*.

Uganda Bureau of Statistics (2020). *Uganda national panel survey 2018–2019*. The World Bank. Available at: https://microdata.worldbank.org/index.php/catalog/3795.

Uganda EPA (2023). *National Strategy for Management of Plastic Pollution 2023–2028*. No longer available online.

UN Water (2024a). *SDG 6 snapshot in Ethiopia*. Available at: https://www.sdg6data.org/en/country-or-area/Ethiopia.

UN Water (2024b). *SDG 6 snapshot in Uganda*. Available at: https://www.sdg6data.org/en/country-or-area/Uganda.

UN Water (2024c). *SDG 6 snapshot in Ghana*. Available at: https://www.sdg6data.org/en/country-or-area/Ghana.

UN Water (2024d). *SDG 6 snapshot in Kenya*. Available at: https://www.sdg6data.org/en/country-or-area/Kenya.

UNEP (2024). The rarely told story of the widely used water sachets. Available at: https://www.unep.org/news-and-stories/story/rarely-told-story-widely-used-water-sachets.

United Nations Population Division (2024). Data: *Visualization data tool*. Available at: https://population.un.org/dataportal/data/indicators/49/locations/288/start/2020/end/2030/table/pivotbylocation?df=ec89b4bd-b823-404a-ab10-fb66370af670. Accessed on 26 May 2024.

USAID (2024). *Unlocking the plastics value chain in Kenya*. No longer available online.

Valavanidis, A. (2020). Tap drinking water versus bottled water: risk perceptions on safety and taste increased use of bottled drinking water that fit the modern way of life. Available at: https://www.researchgate.net/profile/Athanasios-Valavanidis/publication/344044374_Tap_Drinking_Water_versus_Bottled_Water_Risk_perceptions_on_safety_and_taste_increased_use_of_bottled_drinking_water_that_fit_with_the_modern_way_of_life/links/5f4f8b9292851c250b8914f7/Tap-Drinking-Water-versus-Bottled-Water-Risk-perceptions-on-safety-and-taste-increased-use-of-bottled-drinking-water-that-fit-with-the-modern-way-of-life.pdf.

Van der Laan, H. et al. (2013). Bacteria and virus removal effectiveness of ceramic pot filters with different silver applications in a long-term experiment. *Water Research*, 51, 47–54.

Van Halem, D., Heijman, S.G.J., van Dijk, J.C., & Amy, G.L. (2007). Ceramic silver-impregnated pot filters for household drinking water treatment in developing countries: material characterization and performance study. *Water Science & Technology: Water Supply*, 7(5–6), 9–17.

World Health Organization (2019). *Results of Round II of the WHO International Scheme to Evaluate Household Water Treatment Technologies*. ISBN 978-92-4-151603-7.

WSP (2007). *Use of ceramic water filters in Cambodia*. Available at: http://documents1.worldbank.org/curated/en/211941468216599631/pdf/410240KH0ceramic0filters01PUBLIC1.pdf?_gl=1*sdwld6*_gcl_au*MTYzODE0NTEzMS4xNzI0NDM3ODYx.