PERSPECTIVES PAPER

Global Water Partnership
Caribbean

A Toilet Paper

This Perspectives Paper was prepared by the Global Water Partnership - Caribbean Technical Committee Chair, Dr Adrian Cashman. It is intended to stimulate discussion within the GWP-C network and the larger water and development community.

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About Global Water Partnership-Caribbean

The Global Water Partnership-Caribbean (GWP-C) vision is for a water-secure Caribbean.

Our mission is to support Caribbean countries in the sustainable management of their water resources at the community, national and regional level.

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Any organisation with an interest in water sustainability in the region can become a GWP-C Partner. GWP-C currently has over 100 partners in more than 20 Caribbean countries. These include water management agencies, water user associations, private water management agencies, government institutions, academic and research institutions, private sector companies, non-governmental organisations, community-based organisations, civil society organisations, youth organisations, regional agencies, consultancy firms, among others.

This Perspectives Paper was authored by GWP-C Technical Committee (TEC) Chair, Dr Adrian Cashman.

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Purpose of the Paper

In 2002, two psychologists conducted an experiment in which they asked people, among other things, to rate their understanding of everyday objects such as the toilet on a scale of 1 to 7, and then elaborate on what they knew. Surprisingly, very few people could do it (Rozenblit & Keil, 2002). If we realise that we don't know as much as we think we know, even about everyday objects and how they work, it may just make us that bit more curious (Harford, 2020). In essence, that is what this paper is about – stimulating the reader's curiosity. There is a remarkably vast and varied literature on all things lavatorial, which would be impossible to cover in such a short space. We have no intention of trying but hope to touch on a sufficiently diverse range of topics to pique your interest in sanitation, history and health.

Our unifying thread is that toilets and sanitation practices form part of a system. To realise a change or development in one area requires change and innovation across supporting components; the household flush toilet would not have taken off if there hadn't been a water supply.

A further assumption is that toilets, and by extension sanitation practices, are at the intersection of technology, culture, economics, health and history. How sanitation is practised in particular places at particular times can tell us a great deal about society and the human condition. And it can be approached from many different perspectives. While sanitary engineers might think that they have a monopoly on the subject, a cursory Google search turns up numerous avenues of exploration. The most obvious might be the archaeology and history of sanitation across different cultures and continents, but we could also find ourselves gaining insights from French novelist Victor Hugo's classic 1862 novel, *Les Misérables*, through to research in linguistics and disability studies (LaCom, 2007). More recently, the COVID-19 pandemic has accelerated interest in the surveillance of sewage as a means of monitoring public health and informing targeted responses.

In this paper, we consider the growing interest and importance of toilets and sanitation, and global initiatives aimed at raising awareness. With that as a backdrop, we provide an abbreviated history of toilets covering observed practices across a selection of countries and civilisations. The point is not to replicate the countless books and articles that deal with the history of sanitation and toilets, but rather to illustrate the diversity of practices. Along the way, we will touch on human coprolites and apes, farmers' almanacs and compost, and the technological nexus that has enabled some present-day sanitation practices. Finally, we ask where all this is taking us – what is the future of sanitation in a rapidly warming world, and what is the future of the sit-down flush toilet?

Introduction

Sustainable Development Goal 6 seeks to "ensure availability and sustainable management of water and sanitation for all". The goal has eight targets to be achieved by 2030, with progress measured by eleven indicators. The two targets relevant to our discussion of toilets are Targets 6.2 and 6.3.

Target 6.2 focuses on ending open defecation and providing access to sanitation and hygiene by 2030. Its only indicator, 6.2.1, has two parts: "the proportion of population using (a) safely managed sanitation services and (b) a hand-washing facility with soap and water". A safely managed sanitation service is: "use of improved facilities that are not shared with other households and where excreta are safely disposed of in situ or transported and treated offsite" – in other words, separating excreta from human contact.

Target 6.3 focuses on improving water quality, wastewater treatment, and safe reuse by 2030; specifically, it requires halving the proportion of untreated wastewater and substantially increasing recycling and safe reuse. Indicator 6.3.1, the one relevant to this paper, addresses the proportion of domestic and industrial wastewater flows safely treated.

For both targets to be achieved, facilities are needed to provide the means of collecting and transporting waste away from the point of use, and systems must be in place to ensure that these are properly managed. In other words, technology, economics, social acceptability, and governance arrangements need to come together. The dysfunction of any one of these aspects jeopardises the others.

Sanitation is immensely important to both individual and societal well-being. According to the World Health Organisation (WHO), diarrhoeal disease, commonly associated with poor sanitation, was responsible for the deaths of 297,000 children under 5 years old in 2019 (WHO, 2022). The total of diseases attributable to diarrhoea in all age groups equates to 73 million disability-adjusted life years (DALYs)[1]. Taking into account the additional health burden associated with malnutrition caused by diarrhoea and other 'neglected' tropical water-, sanitation- and hygiene-related diseases, over 1 billion people are, and constitute a further, health burden of 19 million DALYs (WHO, 2019). Improving access to water and sanitation is one of the most cost-effective ways of addressing ill-health, malnutrition, and loss of productivity. Evidence suggests that every 1 US$ invested in sanitation yields some 5.50 US$ in benefits – lower health costs, greater productivity, and fewer premature deaths (Hutton, 2012).

In addition to these health benefits, addressing sanitation needs can lead to the potential recovery of water and nutrients, the expansion of renewable energy, and the potential mitigation of water scarcity through the reuse of treated wastewater, particularly in areas that will be affected by climate change – after all, wastewater is, on average, 99% water! These potential uses for 'wastewater' will increasingly impact how wastewater system components are designed and operated. It might even be argued that we are returning to ways in which societies previously viewed human waste – not as a waste but as a resource.

[1] The overall burden of disease is assessed using the disability-adjusted life year (DALY), a time-based measure that combines years of life lost due to premature mortality (YLLs) and years of life lost due to time lived in states of less than full health, or years of healthy life lost due to disability (YLDs). One DALY represents the loss of the equivalent of one year of full health. Using DALYs, the burden of diseases that cause premature death but little disability (such as drowning or measles) can be compared to that of diseases that do not cause death but do cause disability (such as cataract causing blindness). Source: World Health Organization https://www.who.int/data/gho/indicator-metadata-registry/imr-details/158

Agriculture and the Urban Revolution

Modern human dispersal out of Africa, which led to the spread of *homo sapiens* across the globe, is thought to have taken place about 75,000 years Before Present (BP) (Armitage, et al., 2011). although there is still much speculation around the date. Irrespective of exactly when, the human population is thought to have numbered between 1,000 and 10,000 people. These people lived in small groups of hunter-gatherers at extremely low population densities, moving around as nomadic extended family bands. Under these conditions, the disposal of human waste would not have been an issue.

The major change that eventually led to development of sedentary societies, and the need for systems of waste disposal, occurred during the Holocene period, around 12,000 years BP, when a transition to warmer temperatures and a relatively stable climate made environmental conditions favourable for agriculture (Zahid, Robinson, & Kelly, 2015).

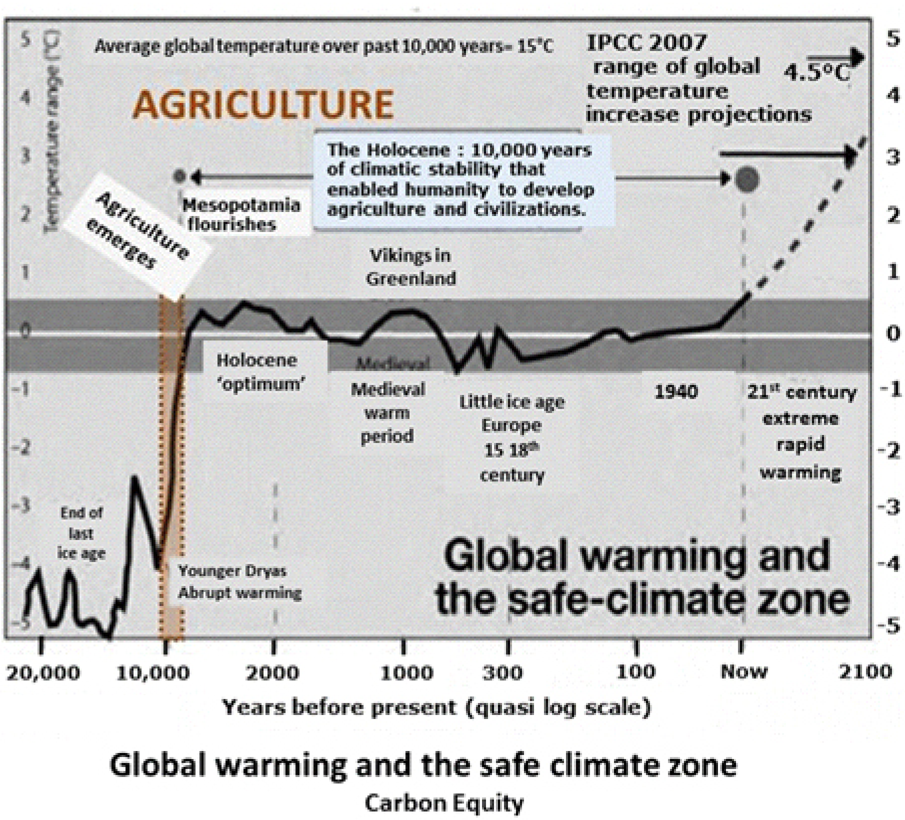

Figure 1: Global temperatures and the rise of civilisations
Source: http://www.climate-change-knowledge.org/civilization

The origins of agriculture and the move to a more sedentary way of life are still not fully understood although they are thought to have occurred independently in different parts of the world at around the same time: Central America, South America, Asia, Africa and the Levant. There was no single factor which would have triggered the transition, but the domestication of crops and animals allowed for a more reliable food supply and, with it, a move towards more permanent settlements. And agriculture provided the basis for the growth of urban centres. At around 10,000 BP, the human population was probably between 5 and 15 million people, although whether agriculture led to accelerated growth of the population is contested. Archaeological evidence for the growth of permanent settlements, suggesting a transition from a village-centred agrarian society to an urban-rural centred society, exists in various parts of the world. The earliest evidence is from the Levant at around 6,000–5,000BP (May, 2013). At around this time, it would seem that irrigated agriculture spread in what has been called the "hydraulic revolution", in places such as the Nile Valley, Mesopotamia, the Yangtze Delta and the Indus Valley.

The production of food surpluses and storage, and settlements had a profound effect on the organisation of human society. It allowed the rise of large, dense sedentary and stratified societies as stored food surpluses can feed non-food producing specialists, such as scribes and artisans (Diamond, 1997). Urban centres became trading and manufacturing hubs, focal points for administration and education, as well as centres of culture and creativity. They also gave rise to division of labour and the development of different social and economic classes. Another feature tended to be shared communication, such as language, writing and counting systems, and ideas – all of which support the infrastructure needed for technology, trade, cultural exchanges and government. The hydraulic revolution took this a step further: in an economy reliant on irrigation, labour had to be mobilised to construct, operate and maintain the management of water infrastructure. This technological and social organisation revolution, it has been suggested, enabled the evolution of state-like organisations (Wittfogel, 2011).

Box 1: Why don't chimpanzees use toilet paper?

Most animals don't wipe after defection, generally because they have not developed the ability. This also suggests that there has been no evolutionary pressure to do so. Although some mammals clean themselves by licking, it is not a route that hominids have gone down.

So why do humans wipe between their buttocks after a "number two"? One of the characteristics that distinguishes humans (*homo sapiens*) from other primates is our upright stance and bipedal motion – we walk upright. As with many evolutionary adaptations, the development implies compromises, although the benefits outweigh the downsides. The upright posture means that our anus is tightly sandwiched between two mounds of flesh that are our buttocks. As a result, faecal residue might stay around the anus, and accumulated residue along with moist conditions could cause infections to occur. This would be a particular hazard for females, due to the proximity to the vagina and urethra.

There are further complications associated with diversity in human diets. Humans have a varied diet and cook food – a practice that also has had its own evolutionary impact on our physiology. As a result, human excrement has diverse forms: hard, soft, dry, runny, etc., which can contribute to health hazards. At some stage, hominids evolved behaviours to mitigate the hazards, through wiping or washing to remove faecal residue. Unlike many of us who use sit-down toilets, our ancestors would have squatted during defecation, as many still do in various parts of the world. This puts less strain on the human system – think about it – and allows smoother evacuation of the bowels, which also alleviates the need for wiping. We won't know when the wiping (or washing) behaviour began, but we do know that as hominids have developed, so cultural behaviours, taboos and norms associated with defecating also developed.

So wiping and washing behaviours are products of human physiology, diet and culture, and differentiate us from other members of the primate family.

Why is Human Waste a Problem?

An unwanted consequence of domesticating animals and having concentrated human populations in close proximity is that it provides ideal conditions for the spread of diseases. People in a sedentary society, especially where they are densely packed together, such as in cities, tend to live amid their own sewage. Such closeness shortens disease transmission pathways, contaminates drinking water and provides living conditions for disease-transmitting pests such as rats and mosquitos. Trade routes play a role too, in allowing infections to be transported between population centres, spreading diseases. Urban centres are thus ideal for maintaining crowd diseases (Diamond, 1997, p.206). The crowd diseases that we are familiar with today evolved from diseases present in animals with similar characteristics of large, dense populations – mainly social animals such as cattle, sheep, poultry, and pigs. Unfortunately, it was these same animals that were ideal for domestication, thereby providing a reservoir of diseases that could be transferred to humans via an intermediate vector. The proximity of domesticated animals to human settlements has provided the conditions that allow crowd diseases to cross the species barrier. Large quantities of animal and human excrement not only host diseases but also harbour intermediate disease vectors (Wolfe, Dunavan, & Diamond, 2012). However, it is only through the development of modern medicine that we have gained a better understanding of how diseases are transmitted and the health threat that excrement poses.

Box 2: Bristol Stool Chart | Source: Dynamic Nutrition Sdn Bhd, 2022

The **Bristol Stool Chart** is a medical aid designed to classify faeces. It was devised by doctors in the Bristol Royal Infirmary, England, and based on the bowel movement of nearly 2,000 people.

Of more immediate concern, especially for urban dwellers, is the sheer volume of shit that can build up. According to an article by Mindy Weisberger (2018), studies in the United States show that an average adult produces about 400–500 grams of faeces per day, of which 70% are solids. Over the course of a week, that's 2.8 kg per person. Sumer, one of the oldest cities of the ancient world, in modern-day Iraq, was home to some 40,000 people in 2800BCE – ignoring the very different human physiology and diet, that's an accumulation of over 100 tonnes of shit each week. So what did they do with it all? There is some evidence of cylindrical drainage pits in a few houses, but they were the exception, so a lot of it would have ended up on the streets, along with household and other waste (McMahon, 2016). Apart from making any excursion outside your house an unpleasant experience, the accumulation of such large amounts of waste would have created quite a stink.

Even before the modern understanding of germs and pathogens, a widespread belief has associated bad odours with sickness and disease, causing people to become ill. This was the result of attributing causality to the co-occurrence of disease and bad odours, because the smell was perceptible whereas the germs were not. This belief still persists. Studies for the US military found that everyone tested was averse to odours associated with faecal or human waste products (Dalton, 2003). Not only are these odours highly recognizable, but that they are universally repellent and believed by many to be a potential source of disease. It may be that the prevention of odours was one of the reasons behind the adoption of sanitation systems. Even so, the build-up of waste would also have been both unpleasant and hazardous.

Passing in the Past – What Was Done About Human Waste

The emergence of urban areas and the range of economic activities that underpinned them also gave rise to social and wealth stratification. Archaeological investigations provide examples of high-status homes and buildings. While burial or open defecation may have been an acceptable practice among nomadic and rural communities, as people congregated together in closer proximity, those means of disposal would have become more problematic. And presumably, higher-status individuals and households would want to distance themselves from the unpleasant nature of excrement. So what were the sanitation practices in ancient times? Archaeological records from around the world provide numerous examples of how different civilizations and societies have dealt with sanitation – the treatment and disposal of human excreta and sewage. We discuss some briefly in the following sections.

India

The Indus Valley Civilization, also known as the Harappan Civilization, was located in modern-day Pakistan and flourished between 3300–1300BCE. The Harappan cities were noted for their urban planning, which, it has been suggested, indicated a high degree of municipal governance, which prioritised hygiene and religious ritual. The city remains of Mohenjo-Daro contain the Great Bath, which may have been a large, public bathing and social area. Excavations have revealed remains of what appear to be latrines connected to wastewater drainage and rubbish collection systems. Individual homes drew water from wells, while wastewater was seemingly directed to covered drains on the main streets; some houses appear to have been equipped with private bath-toilet areas. Even the smallest homes on the city outskirts are believed to have been connected to the system, further supporting the conclusion that cleanliness was a matter of great importance. According to Antoniou et al. (2016), these remains in the ancient cities of Harappa and Mohenjo-Daro in the Indus Valley are among the earliest known multiple lavatories flushed with water and attached to a sewage system. They date from the mid-third millennium BCE. The toilets at Mohenjo-Daro were apparently only used by the affluent classes. Most people would have squatted over old pots set into the ground or used open pits (Rizvi, 2011).

Mesopotamia

Mesopotamia, the land of the Tigris and the Euphrates rivers, in modern-day Iraq, was one of the earliest centres of agriculture and city-based civilizations. All the archaeological evidence suggests that ancient Mesopotamians from the fourth millennium BCE had the technology and the ability to build sewerage pipes to transport waste from buildings. However, how to interpret the archaeological evidence is another question. Some experts suggest that it indicates the existence of sewers and wastewater drainage systems, albeit associated with royal zones within cities. Others have pointed out that the gradients of these systems would not have been sufficient to transport waste (Margueron, 2013) and that these systems probably managed rainwater. Waste was probably disposed of in cesspits – for which there is extensive evidence.

Relatively few toilets have actually been identified and have tended to be in the bathrooms of houses which are larger than average size (George, 2015). Examples from two-storey houses show the toilet was located under the stairs. The toilets were connected to cesspits constructed from baked clay pipes and stacked on top of each other. Bitumen appears to have been used as a natural sealant on the floors of bathrooms and as caulking for pipes. As for the toilets themselves, both squat and seated versions were present. For the squat toilets, brick supports were provided to stand on and give some elevation off the floor. Examples of seat toilets indicate that they were built with baked bricks and coated with bitumen, with a slot through the middle. Margueron (2013) has questioned this interpretation, pointing out that a civilization is unlikely to have adopted two different solutions. So that although there may be some evidence of a sanitation system, this would not have been a flush-away system.

Minoan Civilization

The Minoans of Crete (3200–1100BCE) are credited with the first flushing human waste management system, which was achieved by pouring water into a conduit. Minoan expertise in hydraulics may have developed because of the climate and the very low availability of water, which may have spurred innovation. The Minoans developed a quite advanced water supply, drainage and wastewater management system to handle organic waste. Evidence of systems of stone drains and large sewers – large enough for people to walk through – have been found at many Minoan sites. Excavations on Crete have provided evidence of indoor toilet facilities, mostly inferred from the existence of sewer connections from buildings to outside central sewerage and drainage lines. Traces of stone or wooden seats, and in one case, the remains of a clay tube, were found just outside the door of the room in which the seats were found. It is thought that water was poured through a hole in the floor immediately outside the toilet door, while an under-floor channel linked the hole with a vertical clay pipe under the lavatory seat. The toilet consisted of a wooden seat with an earthenware ‘pan’ and a rooftop reservoir, as a source of water. The toilet could be flushed even during a rainless period, either by an attendant outside the lavatory, or by the user. It is generally believed that water was poured into toilets to flush them, hence the claim that these are the oldest flush toilets (Antoniou et al., 2016).

China

The Chinese character for "toilet" goes back some 2000 years. It was originally associated with a pigsty because toilets were built next to pigsties, in order to channel human waste there for the pigs (Wangyun, 2018). Around 500BCE better off people who lived in urban areas began to integrate toilets into homes and an interesting north-south divide emerged (Newitz, 2016).

Northern China often suffered from water shortages, so squat toilets were more common, as this allowed night soil to be stored. Night soil collectors would collect human waste from toilets and sell it to farmers in the countryside, who then would spread it on their crops. In southern China, sitting toilets were more common. Whether in northern or southern China, most people didn't have such facilities in their homes and just went about their business in the streets (Carr, 2017).

Box 3: Origin of the word "lavatory"

The oldest Latin word for toilet is thought to be *lavatrina,* which covers the concept of both bathing facility and toilet. By the 3rd century BCE the term *balineum* began to be used to indicate a separate, private bathing structure while *latrina* – a contraction of *lavatrina* – became associated with a public toilet. By the 1st century BCE, *forica* was being used to denote a large multi-seat lavatory with an open plan. (Koloski-Ostrow, 2015, p.40).

Classical Greece

In Classical Greece, archaeological evidence is supplemented by the written record, and therefore provides a more nuanced picture. The comedies of Aristophanes are the main ancient sources about the terminology of the sanitary structures in ancient Greece. The excavated evidence shows that the Greeks had reverted to using cesspits as well as clay containers, which are also referred to in written sources (Antoniou et al., 2016). Small sewage ducts made of clay or lead have been found leading to cesspits outside buildings. Clay vessels with an anatomical shape and no base have also been unearthed, which suggests that they were used either over cesspits or over some other receptacle collecting the sewage. Typical features of an ancient Greek lavatory included a water channel, a duct below floor level, a bench-type seat with keyhole openings, and a sewage duct by an outer wall running along the street or beside buildings. In addition, the lavatory area contained receptacles for cleaning sponges, used as the equivalent of toilet paper. Generally, in private residences, lavatories had more than one position, although the customs around their use are unclear. During the Classical Greek period, we also see the emergence of public toilets, with similar features and design, which could be used by many people at the same time. This practice went on into the Roman Era (Antoniou et al., 2016).

The Roman Era

Much has been written about Roman-era sanitation due to a diverse wealth of physical and written evidence across a wide range of geographical settings. It has been suggested that public latrines were introduced into the Roman world from around the second century BCE from the Greek Hellenistic world. The process may have been a result of trade and Rome's wars of expansion involving both contact between merchants and travellers and returning army veterans (Koloski-Ostrow, 2015). The Greek public latrines would have been viewed as an improvement on Romans' basic facilities, which would have spurred the adoption and introduction of public latrines. The provision of public latrines, along with bathing as a social practice became a feature of Roman culture and identity and was disseminated across the Roman world. It seems that, initially, public latrines were associated with marketplaces as a way of trying to ensure that defecation, urinating and the general fouling of an area were limited to specific places. Over time, the public settings expanded, and latrines were increasingly associated with other public facilities such as fora, theatres and bathing facilities (Koloski-Ostrow, 2015). Although increasingly included as part of these structures, they were still hidden away, probably for aesthetic reasons – smell, flies and mosquitos.

Excavations have indicated that early public latrines were modest affairs in terms of materials and decoration. With Rome's increasing wealth during the Republican and Imperial eras, public latrines became increasing lavish, with more design features reflecting changes in taste and ideas, and a more prominent feature of the planning of public spaces and facilities. Alongside city authorities, elites invested part of their wealth in extravagant projects, including public buildings, baths and latrines. Increasingly, these became a feature of open communal living, associated with expanding urban populations – the Roman distinction between the public and the private was quite different from modern-day understandings (Koloski-Ostrow, 2015). While the wealthy and political elites lived in individual homes and villas, the majority of urban populations lived in multi-storey building complexes with limited access to water, washing, and waste disposal. Roman towns would have been foul, stinking, fly-infested places, in which all kinds of waste accumulated, contributing to poor health and high mortality rates. The provision of public facilities such as latrines, fountains and baths were not built because of pressure to improve conditions but were intended to increase prestige and foster political patronage (Koloski-Ostrow, 2015). In Rome itself, and other towns, increased provision of public facilities was facilitated by ensuring copious supplies of water. Indeed, without the emphasis on improving water supplies, the provision of public facilities could not have expanded to the extent that it did. Furthermore, as water supplies increased, so wealthy citizens used them to incorporate more water-using amenities in their properties: toilets, gardens, fountains, baths, ponds and other washing facilities (Stamper, 2021).

Figure 2: Roman toilets | Source: Stamper, 2021

The archaeological evidence for standard toilet features is strong. Across the Roman world, irrespective of the number of seats in a facility, the spacing was 300mm or thereabouts, the same as for public theatres.

The toilet seat itself consisted of a keyhole opening for defecating and a slot for wiping the backside. The shallow trench at the foot was for washing off the sponge stick used to wipe the backside. Beneath the toilet seat was the sewer channel for waste flushed with water. These public, multi-seater toilets were located near, or over, a sewer, which allowed the waste to be washed away in channels lined with concrete. The source of water for flushing could have come from overflow from public baths or fountains. The facilities had a reasonable degree of ventilation to prevent the build-up of odours but were poorly lit.

Recent thinking suggests that the public sewers were not built to take away waste but functioned as drains to handle excess rainfall, overflows from baths and fountains, and to minimise flooding. The flow from fountains and baths would not have been enough to clear the waste deposited in them; in fact, both literary and physical evidence indicates that waste deposits built up and had to be cleaned out periodically. The main task of sewers was to transport waste away from where it was a nuisance, or impeded economic activity and industry, to somewhere else. According to Koloski-Ostrow (2015), the focus of Roman hygiene was on the removal of visible waste rather than its safe disposal. The archaeological evidence suggests that the use of cess pits and urine pots by households was widespread but that connection to public sewers was limited. There are good reasons for this. First, human and animal waste was widely used in agricuture and therefore had value. Urine was used in a variety of processes, from tanning to toothpaste, and was at one stage taxed by the Emperor Vespasian (Nair & Sriprasad, 2010). Second, connecting toilets to a public sewer brought with it hazards, such as the buildup of flammable gases, and backflow of sewage during flooding. The evidence for sewers is not as extensive as it would be if they had been considered an integral part of waste management. It is doubtful whether Roman engineers understood much about the principles of sanitary engineering e.g. self-cleaning flows and velocities – which stands in contrast to their water supply expertise. As Koloski-Ostrow (2015) puts it, sewers appear to have been a last resort to the problems of waste removal in Roman towns and urban areas.

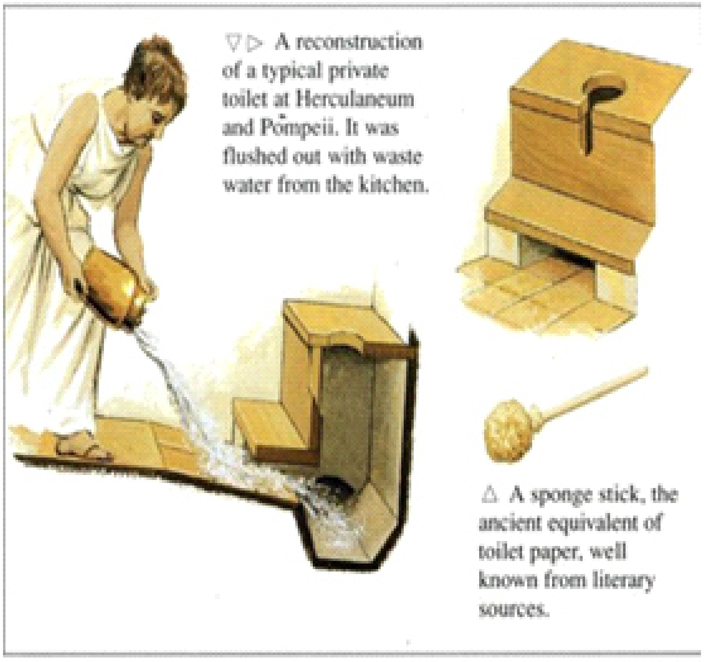

Figure 3: Flush toilets – Roman style

Roman sanitation practices demonstrate some interesting points. The first is that the technology available had a determining impact on the way in which water was supplied and regulated. Although the Romans had valves that could regulate flows, it seems that maintaining a flow of water was important. Furthermore, written evidence does not suggest that water shortages were an issue; the estimated average volume of water used per person in Rome was between 750–1000 litres per day. This also meant that excess water supplied had to be removed – hence the sewers operating as drains – and labour was needed to perform various tasks such as the cleaning of sewers. Warfare, and the taking of defeated opponents as slaves, provided such a pool of labour but as this source declined, the use of free labourers was considered more cost effective. This, coupled with the fact that human and animal waste was a valuable product, provided little incentive to drive technological change. The legal and administrative arrangements governing the management of waste and sewers was somewhat ad hoc, with responsibilities changing frequently. So while the impression persists that the Romans were excellent hydraulic engineers with a well-developed system of water supply governance, their stewardship of waste management did not meet the same threshold. Lastly, we see that the customs around water management became part of Roman culture and how they would define themselves.

The Rise of Technology – Putting the Pieces Together

Essentially, there was very little improvement in Europe in the approaches to and provision of sanitation from the middle of the first millennium CE until what has been called the Age of Enlightenment, starting around 1700 CE (Tulchinsky & Varavikova, 2014).

At a basic level, toilets facilitate urinating and defecation and provide a way of separating people from their waste through some form of transfer, from one place to another. The smooth functioning of a toilet requires the bringing together of a host of interconnected components, both technical and organisational. Each component is reliant on other components, and a breakdown in the harmony between them can have public health consequences. We can think about toilets, particularly flush toilets, and their functioning, by considering what is required for them to function satisfactorily as a system:

- With some notable exceptions, flush toilets need a supply of water to remove and transport the waste products away;
- The toilet itself must be engineered to store and control the flushing of water;
- The toilet should be accessible, convenient and comfortable to use;
- The toilet should not be unpleasant or unsafe to use, e.g. it controls odours;
- The provision of installation and maintenance services is necessary;
- The infrastructure to transport and dispose of waste is also essential;
- The different components should meet a set of generally accepted standards of service;
- The person or body benefiting should be in a position to afford the above; lastly
- A person or body may wish to exercise choice over some of the above aspects.

In other words, the toilet as a fixture lies at the intersection of engineering, technology, economics, culture, organisation and institutions. And, as might be expected, there are different ways in which each of these requirements can be met (or not). We can gain some appreciation of how the different components have emerged by considering the evolution of sanitation in England, and in particular London, through the development of the flush toilet.

Water Supply

Up until the 16th century CE, Londoners got their drinking water from wells, springs and rainwater. Some obtained water from the Great Conduit, run by city authorities, which consisted of a lead pipe from a spring to a large cistern. “Keepers of the Conduit” controlled access and gathered fees from those who could pay, who were granted permission for a household connection. Over time, the Great Conduit was extended, and other sources incorporated. In 1582, with the support of the City of London, a pumped water supply was installed, powered by undershot waterwheels in the arches of London Bridge. This was known as the London Bridge Waterworks and in 1592 was joined by another pumping station, also backed by the City of London. Supply from the London Bridge Waterworks was intermittent and so water was distributed across the city on a weekly schedule (Tomory, 2015).

In 1613, a water supply scheme, New River, was commissioned, which brought water to London via a 68-km waterway. The New River scheme was promoted by an entrepreneur, who obtained a patent and water rights, as well as investment, from the king. In 1619, the New River Company, incorporated by letters patent took over and was one of the first joint-stock companies in England, and remained in existence for nearly 300 years as a private company. The New River Company supplied water via a network of wooden pipes, and as with the Great Conduit, an additional fee was levied for a supply via lead pipes into homes that could afford it. Water was available for a few hours a day. The Great Fire of London, in 1666, destroyed much of the wooden and lead water piping (Tomory, 2015).

From the mid-17th century onwards, an increasing number of new, private waterworks were set up, supplying the expanding urban area. Some were established by an act of parliament while others were issued with letters patented by the Crown. Although the Acts of Parliament which created the water companies encouraged them to compete for customers, the companies quickly realised that this would not be profitable. As a result, from the 1800s, the various companies agreed amongst each other to set boundaries within which each would operate. In 1852, Parliament passed the Metropolis Water Act, which sought to regulate the provision of water supplies and set standards such as the requirement that water be “effectually filtered”. The revised Metropolis Water Act of 1902 nationalised the private water companies by compulsory purchase and established the Metropolitan Water Board, which became responsible for London’s water supply (“London water supply infrastructure”, 2022).

Thus, over a period of more than 500 years, the provision of water supplies was expanded from a situation where only a privileged few had household connections, to almost universal household coverage. At the same time, supplies were transformed from intermittent and irregular to continuous supplies, and from water of doubtful to wholesome quality. This was brought about by technological advances, the ability to finance and operate schemes, organisational developments, and regulation.

The Water Closet

Credit for developing the first flush toilet is commonly attributed to Sir John Harrington in 1592, who was the godson of Queen Elizabeth I. Two were built, one of which was installed in Richmond Palace, outside London, and required 34 litres per flush. That said, Harrington claimed that 20 people could use it between flushes. However, all this did was confirm that a toilet without a sewer was just a fancy chamber pot! With the advent of the Industrial Revolution and advances in manufacturing, a series of incremental advances paved the way for the development of the flush toilet. The advances were based around improvements to existing chamber pots, otherwise known as commodes, and aimed to make the removal of the urine and faeces more ‘convenient’. In other words, design and innovation followed on from an existing form (Museumfacts, 2022).

In 1775, a watchmaker called Alexander Cummings developed an S-shaped pipe which could go under a toilet basin and could contain foul odours. Two years later, Samuel Prosser invented and patented a plunger closet, which unfortunately was not able to fully clear waste deposits. In 1778, Joseph Bramah patented (though he did not develop) a hinged flap valve to seal the bottom of the basin bowl. In 1790, a ballcock to regulate the filling of cisterns was devised by a Mexican priest, José Antonio de Alzate y Ramírez. In 1853, the symphonic flush was thought up by Joseph Adamson, and improved upon by George Jennings. Various improvements in design followed but the basic features of a cistern containing water for flushing, a toilet bowl on which to sit and distribute the flush, and a waste pipe to convey the waste away had been established by the early 19th century (Museumfacts, 2022).

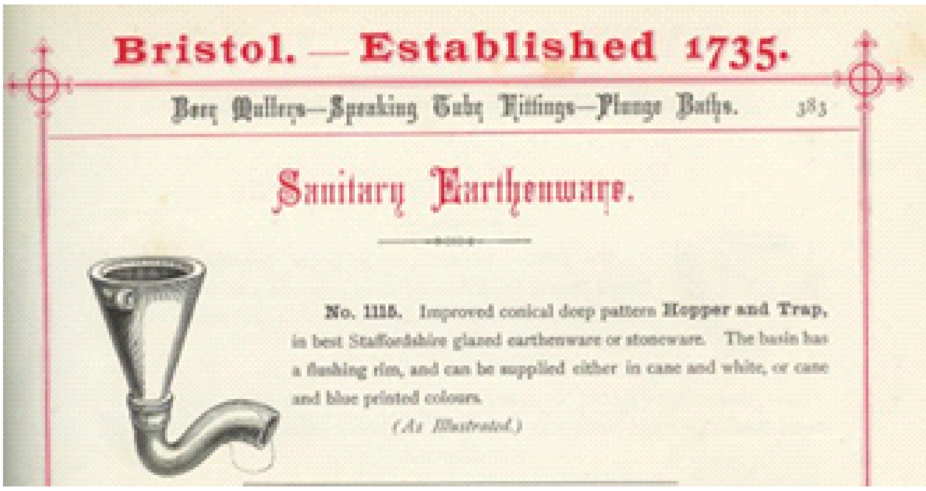

Figure 4: Advertisement for a toilet

In 1848, the British government decreed that all new houses should have either a water closet or an ash-pit privy – a form of composting toilet. However, the arrangements for the removal of solid and liquid waste remained inadequate. One effect of the decree was to increase groundwater pollution, as properties still relied on cess pits, or the services of night soil operators, or the open sewers, which drained into streams and rivers, such as the Thames (Tomory 2015, 2017).

Box 4: Using "the crapper"

The expression "crap" predates Thomas Crapper but the use of *"the crapper"* as a synonym for toilet is thought to date to 1917/18 when American servicemen in Europe saw the name on the toilet bowl and took the expression back to the States.

At the Great Exhibition held in London in 1851, the aforementioned George Jennings pursued the organisers to allow him to install his Monkey Closet in the retiring rooms there – effectively the first public flush toilets ('George Jennings", 2023). "Spending a penny", which was the price to use the facilities, came with a clean seat, towel, comb and shine. The financial success of the venture led to the provision of public conveniences, initially only catering for men[1].

[1] The popularity of the term "spending a penny" most likely dates from the 1890s when public lavatories fitted with penny coin-operated locks were first established by British local authorities.

In 1861, Thomas Crapper, who had three patents[1] related to the improvements of toilets, was commissioned to install lavatories in Westminster Abbey, Buckingham Palace and Windsor Castle. Crapper's flushing toilets were elegant, reliable and water-efficient – three qualities that helped them spread. This use by the monarchy helped to dispel the notion that indoor toilets were unhygienic, and contributed to the improvements in sanitation. His other innovation, from 1870, was to open a showroom to display his company's wares (Historic England, 2022; Sullivan, 2021). From 1885, Thomas Twyford revolutionised the water closet when his company built a trapless, one-piece ceramic toilet. A ceramic toilet was unique, as up to that point, toilets had been made from metal and wood.

The uptake of flush toilets, we might conclude, was a result of advances in technology and manufacturing, regulatory requirements and marketing. The incorporation of toilets into homes influenced the design and layout of homes. Whereas in the past, doing one's 'toilet' was something that could be carried out in the bedroom – or for the wealthy, in the dressing room – now separate provision had to be made for the toilet's installation and use.

The Bidet

In many parts of Europe, a bidet is still an integral part of bathroom furniture. In essence, it is a low-level washbasin, which is used for washing legs, genitalia, inner buttocks and anus. It is not known who invented the bidet, but historians agree that they appeared first in France in the 17th century CE as a bedroom hygiene tool ("Bidet, 2023). From these beginnings, the bidet has gradually become a bathroom fixture in many countries. In the beginning, its use was confined to the aristocracy, before becoming more widespread in more recent times. In France, bidets were regarded as a 'civilized way' of preparing for sex, or rinsing off afterwards. Today, some bidets have taps that pour warm water into a basin; some have a basin that can be plugged and filled with water; others have a nozzle that is pointed upwards for washing the nether regions. And the design has morphed alongside that of the toilet, with the bidet's functions being incorporated into the toilet, as will be seen later.

Toilet Paper

Adoption of the flush toilet brought with it associated challenges: how were people using toilets to clean themselves after defecating? (Blakemore, 2020) For the Greeks "three stones are enough to wipe". The Romans used sponges on a stick to clean themselves; the sponge was then washed off in a container filled with salt water or vinegar water. Evidence suggests that this was the opposite of hygienic and contributed to the spread of infections, such as roundworm (Preskar, 2022). Analysis of the contents of cesspits across the Roman world suggests that they would have suffered from a variety of intestinal infections.

By the early 14th century CE, the Chinese were manufacturing toilet paper at the rate of 10 million packages of 1,000 to 10,000 sheets annually. In the 1390s, thousands of perfumed paper sheets were produced for the Hongwu Emperor's imperial family. However, even though paper making spread out from China, paper was an expensive commodity.

The first commercially packaged factory-made toilet paper was probably created in the United States in 1857 (Toilet Paper History, 2023); it was called "therapeutic paper" and was medicated with aloe, with the name of

[1] His advertising laid false claim to some patents he did not have and some inventions (such as the syphonic flush) that were not his. One of his innovations was the modification of the S-bend to the modern U-bend.

the manufacturer on every sheet. Although 500 sheets cost 50 cents, the venture was apparently not a commercial success. The United States led the way in developing toilet paper, although perforated toilet paper on a roll appears to have been invented at the same time on both sides of the Atlantic in 1879. In 1885, Oliver Hewlett Hicks patented packages of toilet paper and the manufacturing process.

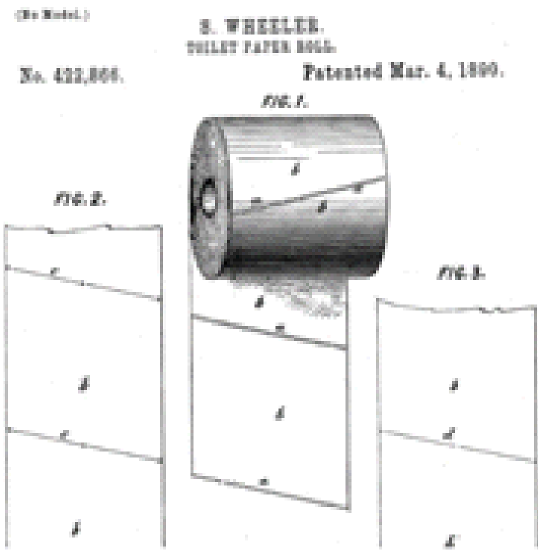

Figure 5: Perforated toilet paper

In the United States, it is said that during the 19th century CE, sheets from mail order catalogues were torn off and used. When the catalogues began using glossy paper, rural America switched to using the Farmer's Almanac, which was often nailed to the wall, leading the company to pre-drill the legendary "hole" into their publication in 1919.

No one company had a monopoly on the production of toilet paper. Toilet paper manufacturers therefore needed to find ways to market and promote their products to increase sales, which led to the adoption of new approaches to marketing. In 1928, the Hoberg Paper Company introduced a brand called Charmin. The packaging showed a woman in profile and the advertising campaign featured the homeliness of the product, whereas previously toilet paper had been advertised as a medicinal or luxury product. In many ways, the packaging and marketing of toilet paper is as important as the toilet paper itself.

Box 5: The selling points of toilet paper | Source: Doctorow, 2010

A popular product from the 1870s was 'Bromo Paper', which came in packs of about 500 individual sheets inside a solid card box. Every sheet had a distinguishing watermark of 'Bromo' so that counterfeit versions could be easily spotted. This toilet tissue had been awarded the highest prize at the Paris Exposition in 1878 and every pack proudly bore reproductions of both sides of the medal to prove it. The paper contained the "disinfectants and curatives" which would "…render its use not only a positive preventive of that most distressing and almost universal complaint, the Piles, but also a thorough deodorizer and disinfectant of the water closet"

Sewers

As noted above, although authorities pushed the adoption of the water closet, dealing with the volume of waste produced lagged far behind. By the 1850s, 2.5 million people were living in London. The waste they produced went into storm sewers and from there into the Thames. The result was that instead of flowing out to sea, the stinking excreta stayed put. In the 1830s, epidemics of cholera, typhoid, and influenza prompted the government to launch an investigation into sanitation. In 1842 the report *The Sanitary Conditions of the Labouring Population* was produced, which showed a direct link between poor living conditions and disease and life expectancy. It led to institutional changes such as the Public Health Act of 1848, establishing a General Board of Health. In the 1850s, miasma theory – the idea that diseases were spread due to unhealthy or polluted vapours rising from the ground, or from decomposed material – was widespread and had influential supporters. Deadly concentrations of miasmata, especially near the Thames, were used to explain the spread of epidemics such as cholera, which had arrived in Britain in 1830.

During the 1848/49 outbreak, anaesthetist John Snow was able to demonstrate the spread of cholera through water. However, his findings were overshadowed by belief in the miasma theory of transmission. Partly in response to the epidemics in London, the Metropolitan Commission of Sewers was brought into being by an Act of Parliament in 1848. It set about surveying the capital's estimated 200,000 cesspits, insisting that all cesspits should be closed and that house drains should connect to sewers and empty into the Thames. This latter recommendation only made matters worse and contributed to "The Great Stink" of 1858. The Commission was absorbed into the Metropolitan Board of Works on 1 January 1856.

The "Great Stink" of 1858 proved to be a turning point, but not because of entirely altruistic reasons. Previous proposals to modernise the sewer system had been rejected on the grounds of cost. However, the proximity of the members of parliament to the stench from the Thames combined with the belief in miasma theory contributed to their fears that they were at heightened risk of catching cholera, which prompted them to act. The Chief Engineer of the Metropolitan Board of Works, Joseph Bazalgette, was given responsibility for the work ("Joseph Bazalgette", 2023). Between 1859 and 1865 an extensive underground sewerage system was designed and constructed. It consisted of a system of feeder and interceptor sewers and incorporated some of London's 'lost rivers' on both sides of the Thames to convey sewage downstream to two wastewater works. The low-level interceptor sewer was incorporated into the Thames Embankment and allowed new roads, public gardens and space for London Underground lines to be constructed. The sewer was opened in 1870. In creating the Embankment the flow of the Thames was also altered from a slow to a fast-moving body of water.

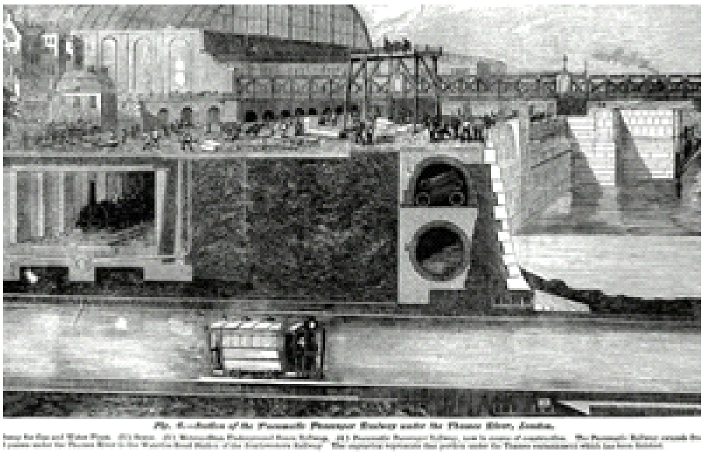

Figure 6: London's Thames Embankment

Figure 7: Terraced housing in London with outdoor toilets – the collector sewer ran down the back of the houses.

The construction of the London sewer system is notable for a number of reasons (Jackson, 2014). It resulted in a marked improvement in public health, and allowed a greater number of Londoners to benefit from a water supply in the home, including indoor toilets. The potential of technological advances was realised, such as in the use of cement in construction. The creation of the Embankment provided spill-over economic and development opportunities for businesses and investors. The growing appreciation of the benefits of sewers impacted town planning, particularly in the provision of back-to-back terraced housing. However, this also served to reinforce social stratification in which the working classes were provided with outdoor toilets whereas housing for the more affluent included indoor toilets. It wasn't until the 1960s that indoor toilets were retrofitted into working-class terraced houses. Two points can be inferred from the above. First, science and engineering are seldom by themselves enough to spur advances – a large degree of self-interest on the part of decision makers is often called for. Second, the ways in which services are provided can serve to reinforce socio-economic hierarchies.

Dry and Composting Toilets

As the global population grows, and water becomes scarcer, composting or dry toilets, which use precious little, if any, water, have attracted increasing attention. Unsurprisingly, such toilets have been around for millennia in some shape or form, from glazed terracotta urns used in ancient China, which were used to collect night-soil (King, 2004), to more recent container-toilets developed in Haiti, here in the Caribbean (Remington et al., 2016). So what are composting toilets and how do they work?

Box 6: Monitoring sewage for diseases

In August 2022, the United Kingdom's Joint Committee on Vaccination and Immunisation recommended that all children below the age of nine years in London should receive a booster dose of polio vaccine. The advice followed the detection of 116 polio viruses from 19 sewage samples in London. The level and genetic diversity of the viruses indicated that transmission was taking place in several parts of London and although no cases had been diagnosed in the population, vaccination was recommended as a precautionary measure. A further result was that wastewater surveillance was expanded to assess the extent of transmission and identify localised areas of concern.

Sampling sewage as a surveillance measure is not a new idea and in fact it is one that has been used to track polio from the early 20th century. However, it was the COVID-19 pandemic which really spurred interest in the approach. It has been realised that monitoring and testing wastewaters can be a powerful tool to predict the spread and peaks of infection and identify new variants of diseases. The challenge is data analysis and interpretation, and its integration into public health systems. Wastewater surveillance has the potential to become a powerful tool to monitor public health and inform responses. But as with any new tool, there may be a dark side.

As US-based Greywater Action (n.d) explains:

> *"In a modern-day composting toilet, faeces and toilet paper compost with a "bulking agent", such as sawdust, leaf litter, bark mulch or dried coffee granules, which covers the faeces to create air gaps for aerobic bacteria to break down the material. This process is the same as for a household food waste compost. If urine is included in the compost, more sawdust is added to soak up excess liquid. Toilet paper can be disposed of with the solid waste – preferably unbleached recycled paper as it degrades more easily."*

Composting toilets are often used in non-arid areas with easy access to the types of bulking agents mentioned above. The finished product is a moist humus similar to garden compost, which makes a valuable soil conditioner. Another adaptation is to divert urine out of the toilet (making a dry toilet) and dilute it with water (three parts urine to five parts water). This forms a fertilizer rich in nitrogen, potassium and phosphorus (Randall & Naidoo, 2018).

In areas with arid climates, dry toilets are preferred, in which ash or lime mixed with dry soil are added to create a dehydrating environment for breaking down and killing off pathogens. Toilet paper, which cannot be added to a dry toilet, is usually burned or buried. Pathogens typically die off more quickly in the dry, high pH environment of a dry toilet. The finished product, which resembles instant coffee granules, can be used as a soil amendment (Greywater Action, 2023). Good ventilation is needed whichever the type of toilet, both to help prevent odour and to aid decomposition.

The Arborloo

The Arborloo, or tree toilet, is a popular, simple, low-cost version of a moveable composting toilet widely used in parts of the rural Global South, from Zimbabwe (where it was pioneered) and various countries in Sub-Saharan Africa (Herbert, 2010), to the Philippines, in Asia (Sayre, 2010), and Haiti, here in the Caribbean (Kramer et al., 2011).

In its simplest form, the Arborloo is a shallow pit, topped by a movable slab, ring beam (made from cement and or bricks) and housing, for privacy (made from cement and/or bricks). After defecation, soil and wood ash is added to the pit, both to mask the odour and accelerate the composting. When nearly full, the pit contents are levelled off and covered with a 15cm-layer of topsoil (if available) and left to compost. In the meantime, a new pit has been dug, and the slab, ring-beam and housing are relocated. At the start of the rains, or immediately, if water is available, a sapling is planted in the topsoil, protected from animals, and watered. Thus, over time, the household is provided with shade trees and potentially extra produce, depending on what is planted (Morgan, 2004). The risk of groundwater contamination, however, is still present, tree or no tree.

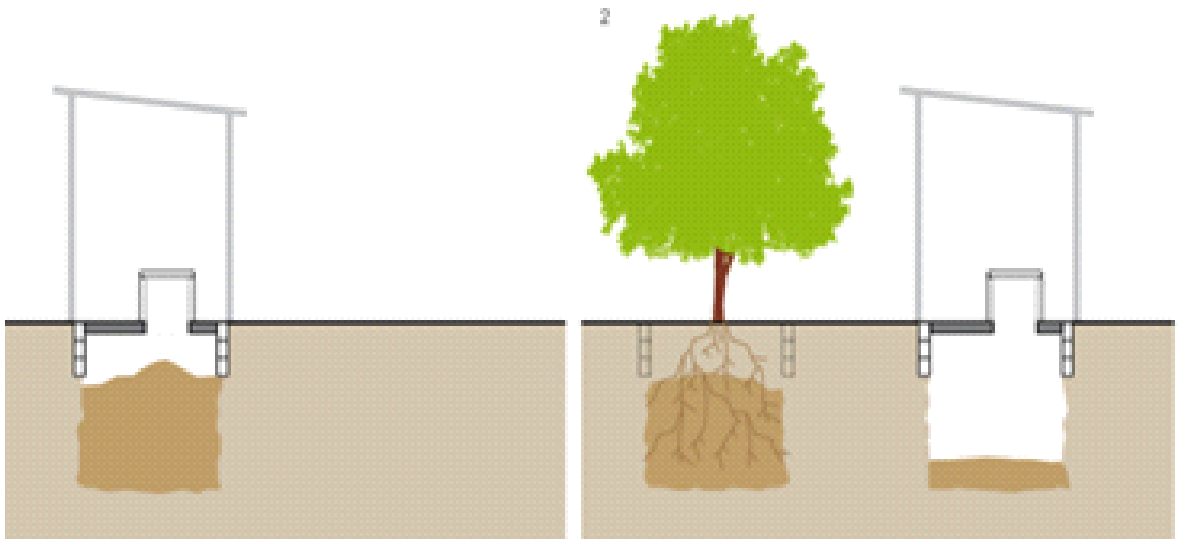

Figure 8: The Arborloo (tree toilet) | Source: Tilley et al., 2014

Sustainable Organic Integrated Livelihoods (SOIL), an award-winning non-profit organisation working in Haiti, has gone on from designing composting toilets to developing a community-wide sustainable EcoSan system, Ekolay, in some of the country's deprived urban areas. It involves collecting and transporting the waste from container urine-diverting composting toilets (UDTs), eventually transforming it into agricultural-grade compost (www.oursoil.org).

The Pros and Cons of Composting Toilets

The advantages and disadvantages of composting and dry toilets vis-à-vis modern flush toilets in any given situation will depend on a range of contextual factors, such as climate, income levels, available space and infrastructure, availability and cost of materials, level of political commitment, cultural (including religious) attitudes with regard to human waste, inclusive community participation, perceived benefits, etc.

That said, the pros and cons can roughly be summarised as follows:

Table 1: Advantages and disadvantages of composting toilets

PROS	CONS
• Huge savings on domestic water consumption. • Water cost savings where water is metered. • Low energy requirement. • Can help plant growth where compost can be used as soil amendment. • Reduced need to buy fertilizers. • Can be installed even where there is no water source. • Simple technology to install in rural areas of LICs where there's no wastewater infrastructure. • Can help keep pathogens out of surface and groundwater.	• Considerably more maintenance for householder than standard flush toilet. • Can be more odorous. • If poorly maintained can lead to serious odours, insects and health hazards. • If the composting process does not function properly (insufficient aeration, non-conducive temperature), the resultant compost can be a health hazard. • Can involve extra costs, such as waste collection, if the end product can not be spread on soils in the immediate vicinity. • Special permits may be needed for installation. • Can be difficult in urban areas to access the necessary mulch, leaf litter, sawdust. • Need to overcome public resistance.

Sources: Anand & Apul, 2014; Langergraber & Müllegger, 2005; Tilley et al., 2014

The Japanese Toilet

The Japanese toilet differs significantly from those in most western countries, even though they do the same job of removing your waste in a hygienic, efficient way. But these appliances go above and beyond simple waste disposal. While the Japanese were the first to take toilet technology to the next level, inevitably they have spawned imitators. However, toilets that incorporate advanced features are generically referred to as "Japanese toilets". These toilets are equipped with an array of additional features that set them apart from the basic loo. They first started to have added features in the 1980s and by the mid 2010s over 80% of Japanese households had a toilet with additional features. The defining feature is the incorporation of the bidet, or nozzle, to aid washing the anus and genitals, all without needing to stand up. As a result, the appliances are not marketed as toilets, but as "washlets". From the incorporation of the basic bidet feature in Japanese toilets/washlets, the range of features appears to be limited only by imagination. The heated seat is one such feature. Some incorporate a mild soap for rinsing and cleaning; others control the water temperature and even allow a choice of a steady or a pulsating water stream. More features include a blow-dry system, air deodorizing, speakers to play music, glow-in-the-dark options, an air-conditioned toilet rim for hot summer months, and even massagers built into the toilet seat itself. Most incorporate a control panel system, sometimes built into a small handheld remote control (Szczygiel, 2016, 2017).

It gets even better, as some of the functions have been automated. Some models have an automatic lid that lifts when its proximity sensor determines someone is standing close to the toilet. Some go further, with the lid raising only if it senses that someone is facing away from the toilet, e.g. preparing to sit down, but the sensor will lift both the lid and the seat if someone is facing the toilet, e.g. standing to pee. Most of these toilets' built-in bidets also have proximity sensors, so the stream will automatically shut off if the user stands up. Top-of-the-line models collect and analyse data on when and how often the toilet is used. Some models take things further by having the hand basin connected to the toilet so that the water from the hand basin flows into the toilet cistern for flushing, increasing water use efficiency. Many Japanese toilets have features designed to keep them clean. These include automatically rinsing the toilet bowl before use, while the most advanced models use ultraviolet light after a toilet is used, to disinfect the bowl (Sealy, Marsh & Aguro, 2018).

There are, however, drawbacks: the built-in features need electricity to function, which can cause problems due to safety rules and regulations that require the separation of appliances that use water from those that use electricity. Another reported issue is that overzealous use of the bidet function can eliminate 'good' bacteria, leading to irritation and skin sensitivity. It has been argued that Japanese toilets are more environmentally friendly than the 'bog standard' toilet. The argument runs something like this; even though they increase electricity use – most western toilets use no electricity – they eliminate the need for toilet paper, thus reducing the demand for wood pulp and deforestation. And, although such toilets use more water, this is more than offset by the volume of water used in the manufacture of toilet paper. So, on balance, they are more environmentally friendly (Feenstra, 2022).

What Next – The Future of the Toilet?

Reality Check in the Caribbean

Within the Caribbean, with the exceptions of Dominica and Haiti, countries report that over 90% of their populations have access to improved sanitation, meaning flush toilets. However, when we consider how few are connected to a centralised sewer system, the picture changes dramatically. At around 30%, Trinidad and Tobago has the highest percentage of the population connected to a sewerage system, followed by Jamaica, at 20%. According to the Global Environmental Facility CReW+ (United Nations Environment Programme (UNEP), 2020), 70% of the Caribbean's population lack access to safely managed sanitation and hygiene:

> *"80% of wastewater is discharged into the environment without any treatment as a result of weak legislation, political, and regulatory frameworks and lacking financial means to maintain the infrastructure".*

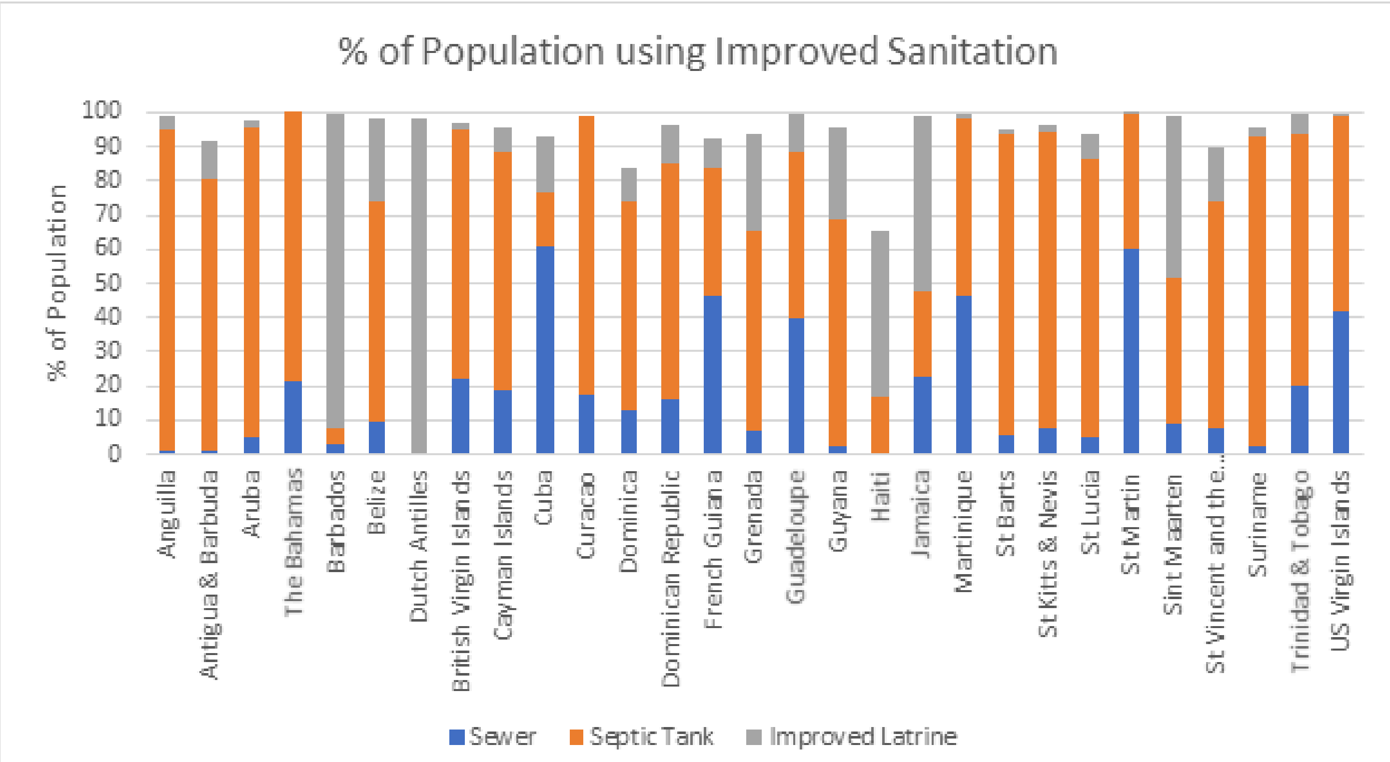

Figure 9: Percentage of population using Improved Sanitation in the Caribbean | Source: Author's own calculations

Governments and water utilities across the Caribbean are faced with a dilemma. Although sections of their populations lack access to improved sanitation as they may still rely on pit latrines, the majority have some form of indoor toilet. Yet this very improvement in access unaccompanied by an adequate regime of collection, treatment and disposal is creating an environmental problem and recalls the situation in London, described above, during the early part of the 19th century CE. For example, poorly designed and maintained septic tanks have contributed to groundwater pollution. Studies of Kingston Jamaica's Liguanea aquifer have demonstrated that it is not suitable for potable use, as it is polluted with nitrate contamination, due to years of improper sewage disposal (Mandal et al., 2020; Water Resources Authority (WRA) Jamaica, 2022). Other examples include Barbados (Cashman, 2014). Arguably, the situation will worsen as climate change begins to affect water security. There is a growing realisation that something needs to be done, yet the scale of the task facing governments and societies is daunting. How to raise the millions of dollars in funding required to put the infrastructure in place? How to create the capacity to operate the infrastructure? And how to afford to repay and maintain the infrastructure when set against other competing needs? These are questions to which there are no easy answers. Although many creative ideas, papers and reports have been produced, suggesting what funding is required and how these funds can be made available, progress is painfully slow.

Box 7: Reinventing the toilet

In 2011, the Bill and Melinda Gates Foundation embarked on a challenge to "reinvent the toilet". Up until 2018, the foundation had spent US$200 million developing toilets that don't need water or sewers and use chemicals to turn human waste into fertilizer. The foundation is expected to spend the same amount again before the toilets are viable for widespread distribution.

The Future of Toilets

The point has been made that the toilet as we know it has evolved as a result of innovation and improvements, and is contingent on a host of supporting developments across disciplines, as well as cultural acceptance. These developments include advances in materials technology and manufacturing processes, engineering design, economic growth, public health concerns, town planning, regulatory requirements, marketing opportunities and advertising, and the list could go on. So looking to the future, what might it hold for the further development of toilets?

The challenges, and hence the potential innovations, may be thought of in two parts. The first concerns the toilet itself, and the second the supporting environment – in the sense that the environment captures the sanitation elements touched on above. For the toilet itself, future interest will continue to be on the improvement and extension of its functionality. In other words, there is unlikely to be a radical change until toilets as we know them are replaced by some other mechanism. In the case of the supporting environment, the toilet is but one part of a system to serve people's sanitation needs; in addition, the necessary infrastructure and institutions need to be established. This is a big task. Although these are essential components – as we have seen through history – exploring them is beyond the remit of this paper.

As for the toilet itself, three trends are emerging: improving the efficiency and effectiveness of water use; resources recovery; and extension into personal health care.

Efficiency and Effectiveness

Improving the efficiency and effectiveness of water use entails reducing the volume of water used to flush away urine and faeces. Toilet water use is a major contributor to household water use, making up between

20% and 30% of overall consumption. Over time, the volume of water used per flush has decreased. Before the 1980s, approximately 26 litres were being used per flush, but gradually this has reduced to around four litres per flush while achieving the same result. At the same time, advances, such as dual-flush systems, have come onto the market, also as a means of conserving water, along with product certification schemes, such as the US WaterSense labelling. Recent designs have reduced the volume even further to two litres per flush while still achieving the same level of performance. The requirements to reduce water use have become embedded in national product standards; Barbados, for example, is looking to allow the importation of efficient water-use products, according to specifications by the National Standards Institution. A further step is the waterless toilet concept, which is of particular interest where access to a water supply is problematic. One solution, which has been around for a long time, is the composting toilet, as discussed above.

Box 8: The Arumloo – Interview with the developer, Jonny Harris (https://arumloo.com)

What's the inspiration for the Arumloo toilet?

The Arumloo is inspire by the arum lily, the elegant white flower that incorporates a natural vortex to bring insects into the heart of the flower and promotes pollination. Both the form and function of the arum lily has been mimicked in the Arumloo, to enable beautifully efficient bathrooms.

What's the operating principle? How does it work?

The Arumloo rimless toilet looks and feels much like a conventional flush toilet. The design incorporates a vortex shape bowl to provide the path of least resistance for efficient cleaning of the pan. This circular flow path continues through the trap to effectively clear waste from the toilet.

How did you get started and how many prototypes have you gone through?

We started developing the product in 2015. Our early prototypes included a flush discharge directly into the water seal to clear waste. This worked well; however, to achieve the target performance of flushing on less than two litres, we quickly realised that the flush water needed to clean the bowl before it cleared the waste. By 2017, we had incorporated biomimicry into the design of the toilet and realised that the arum lily held the key for our desired flush performance. Since this time we have been working on refining the design to align with the manufacturing process.

How much water does it use?

The Arumloo is able to effectively clear waste with a two-litre flush, and urine and small amounts of paper with one litre. Based on average usage patterns, this gives us an average flush performance of 1.3 litres.

That doesn't seem a lot; is it effective in flushing away?

The toilet is very effective. It is not acceptable to us that a toilet should be flushed twice to clear toilet paper trapped in the bowl. The vortex design effectively clears waste from the bowl and through the water trap

What's been the biggest challenge?

As a small start-up company, our biggest challenge has been to finance the development of the toilet and to align the design with the manufacturing process. This has added three to four years to the development timeframe, which has been frustrating when we know that we have an excellent product that is much needed to enable water efficient sanitation.

Does the arum toilet comply with any international standards?

The toilet has been successfully tested against several flush performance standards, confirming the water efficiency of this low flush toilet. The toilet complies with all requirements for the initial target markets in Southern Africa and East Africa. We are currently in the process of adapting certain design elements, to ensure that the toilet complies with specific requirements for toilets in the EU and other parts of the world.

What next?

We are busy developing additional versions of Arumloo, including a wall-hung version and a toilet for the European market. These should be available in 2023. We have been prototyping a package ecological wastewater treatment plant as a back-end treatment solution for the toilet. This will also be available in 2023.

The work of the Bill and Melinda Gates Foundation has aimed to develop solutions for populations living where there is little or no access to a water supply. Several approaches have been developed (Bill and Melinda Gates Foundation, 2023). One approach has been to modify a conventional toilet but replace the use of water with a barrier material lining in the bowl, which is collapsed and twisted, sealing the waste and compressing it into the bottom of the container.

Other waterless versions use chemical processes, or the use of nanofiltration, to convert waste to water and ash. For public toilets, there is the option of including waterless urinals. These work in one of three ways: by having some form of microbiological cartridge that treats the urine, a liquid barrier system, or a valve barrier system. It is likely that low-flush toilets using water will be with us for the foreseeable future. The roll-out and uptake of waterless appliances is likely to face many challenges, such as cost, social acceptability, manufacturing capabilities, and plumbing services expertise.

Resource Recovery

An extension of water-use reduction is the growing interest in resource recovery, which in some ways harks back to historical perceptions of human waste as a resource. Resource recovery can take place either ‘on site’, or the place where the waste has been transported. The on-site resource recovery approach tends to apply to toilets that are not coupled up to a water system, from which water can be reclaimed, waste composted and, in some cases, energy produced. The reclaimed water would be used for secondary (non-potable) purposes, whereas the composted waste would be taken away and used in agriculture, for example. This model will necessitate a new and different ecosystem to support and facilitate its functioning. Although advancing the technology would not be a problem, rolling out this form of resource recovery practice at the individual level is likely to be a greater challenge because it will require institutional support and development.

Resource recovery after collection is already being promoted at different scales, servicing small cluster developments through to towns and cities. In some cases, this is being done by upgrading or replacing existing wastewater treatment facilities, recovering and reusing the treated wastewater primarily for non-potable purposes. Beyond water recovery, there are opportunities to generate energy from biogas and apply the resultant dried sludge to soils, to recover heat from the water treatment process, and also recover nutrients, such as nitrates and phosphates. Obviously, as the range of recovery processes increases, so too does the complexity and cost. Scale and location are also important considerations. What might work and be financially viable in an urban setting may well not be viable at a community level. It’s also worth pointing out that for some of the resources, the recovery technology may not have matured sufficiently to engender confidence. In the Caribbean, as for many other regions, resource recovery beyond water is largely at the conceptual stage, and the region will be looking at advancements elsewhere, in order to leapfrog the development and implementation processes.

However, this is not to say that the Caribbean is sitting around doing nothing. Several initiatives are putting in place the building blocks that would underpin resource recovery. These are not primarily in engineering or technology but relate to creating the necessary regulatory environment – again highlighting that successful implementation depends on advances across many different spheres. One of the weaknesses in the water sector has been with respect to water quality and related public and environmental health concerns. Gradually, this is being addressed in various Caribbean countries with the development of water quality standards and regulations governing the treatment and reuse of water for various purposes and applications. We would expect that this will spread across the Caribbean and hopefully include some degree of regional collaboration and uniformity. At this stage, it is too much to expect the development of standards addressing other forms of resource recovery. This is partly because water regulation – beyond simply water quality – impacts other sectors, and needs to be tied in to building standards and planning requirements. Building developers respond to market forces and what they provide depends on what they are required to provide, what a client is prepared to pay for, and the profit they can make. In such instances, planning and regulation have an important role to play. Barbados's planning system, for example, has been moving towards creating a regulation-led demand for the provision of wastewater systems in new developments. The government also recognises that addressing the associated costs will entail involving the financial sector. Maybe in the future, the toilet will itself be the resource recovery system, doing away with all the infrastructure we presently associate with wastewater collection and treatment. But even then, there will have to be a supporting ecosystem – we can only speculate on what that might look like.

Personal Health Care

What is perhaps more likely in the near future is that the toilet itself will become integrated into the provision of personal medical care. We have become familiar with the idea of the analysis of sewage providing useful insights into the prevalence of COVID-19 even before it was detected by public health surveillance systems. We are familiar with the medical profession testing our urine for blood sugar levels and faeces for bacteria. In this article, we have seen how analysis of the contents of cesspits has shone a light onto the state of health of past human societies. There is already thinking around the idea that toilets could one day become mini laboratories capable of analysing urine and faeces, which along with other health monitoring devices, could infer the state of a person's health and deliver personalised health care. Incorporating sterilising technology (e.g. ultraviolet lights) into toilets could provide protection against harmful micro-organisms. Exciting as these possibilities are, they raise ethical questions which up to now we have not worried about. What might be the privacy and confidentiality concerns associated with such new technological innovations? Could they be used in coercive ways that would be inimical to democratic freedoms?

Box 9: The role of culture

Culture is important to shaping practice and facilities. In several Latin American countries used toilet paper is placed in a bin alongside the toilet and not flushed away. Originally this was to avoid clogging of the small sized pipes but has now become accepted practice. In some cultures and religions water is used to clean the anus either by having a vessel called a lota or by having a bidet spray nozzle or hose attached to the sides of the toilet.

It is worth remembering that history is littered with examples of failed innovations and products that have not caught on. One of the common reasons is failure to recognise the role and importance of the presumed beneficiary and what they think. Technology is only one part of the equation: context, community, culture and the customer are equally, if not more, important.

Coming to the End

Over the preceding sections, we have put forward the notion that the toilet constitutes a central point at which different water-related services intersect; where water supply arrangements and wastewater management come together, coexist and then deviate. We have also developed the idea that technologies, institutional arrangements and regulation do not suddenly appear, but are the products of processes of innovation and improvement, and responses to opportunities and changing circumstances. What drives these processes? Is the adoption of technological solutions, institutional arrangements and regulations driven by epistemic communities of knowledge-based experts who help decision-makers to define the problems they face and identify various policy solutions (Cross, 2013)? Alternatively, does change normally proceed incrementally, due to the inertia of institutional cultures and practices, vested interests, and the bounded rationality of individual decision-makers? In this case, policy change happens when the equilibrium can no longer hold in the face of changing conditions, or changes in public opinion (Levinthal, 1998). Or is it a combination of the two?

In the natural world, one animal’s waste becomes a resource input for another organism, a circular approach. Yet humans have, with some exceptions, adopted a linear approach in which human urine and excreta are considered to be waste. The toilet is the most visible manifestation of this approach; it is designed to provide a convenient and comfortable way to take away our liquid and solid by-products. As we have illustrated, a toilet can achieve this in many different ways, whether by focusing on performance, like the Arumloo toilet, or as an immersive experience, like the so-called Japanese toilets. From this, we can see that the toilet has been transformed from being a basic appliance to a socio-cultural artefact.

But this narrow emphasis on a toilet’s form obscures more urgent, broader questions around function. We are entering a world of increasing water scarcity (Global Commission on the Economics of Water, 2023), including for the Caribbean, where changes in rainfall patterns and a drying climate will disrupt water resources and supplies. Under these circumstances, can we continue to use large volumes of drinking-grade water just to flush our waste away? Perhaps for some, better water-endowed countries the answer may be “yes”. But for many countries in the Caribbean, changing conditions are going to force a fundamental rethink of function. The relative equilibrium which has characterised the provision of water and sanitation services will have to be punctuated, and the ’stickiness’ in the system challenged (Repetto, 2006). Treated water reuse is likely to become an urgent imperative. We will have to seek new answers to questions about what water and sanitation services should look like, how they should be delivered, and who benefits. This implies: a rethink of the economics of water and investment choices, governance arrangements, and the role of the public private and third sectors, and the technology and what we want it to deliver. The toilet of tomorrow is going to have to deliver more than a hygienic environment, a warm seat and a clean bum.

Glossary

BCE	Before Common Era
BP	Before Present
CE	Common Era
DALYS	Disability-Adjusted Life Years
Km	Kilometres
SDG	Sustainable Development Goals
UDT	Urine Diverting Toilets
UNEP	United Nations Environment Programme
WHO	World Health Organisation

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