‘Drink Water2’; an evaluation of Water2’s Pod™ Technology as a Solution to Inadequate Sources of Drinking Water

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Note

Water2 has invested heavily in scientific research and development for a number of years. This includes two consecutive years of testing at University College London, building upon years of innovation development from our partners in Italy and across the world. This document has been put together as our Whitepaper, collating enormous datasets and various studies into one singular document. This particular version is part redacted to protect the publishing rights of academic journals that wish to exclusively publish certain studies. It is our intention to present an empirical study of the problem of tap water, its implications and the viability of our solution.

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Abstract

While tap water is the most easily accessible form of drinking water, it has many shortcomings including poor taste and dangerous levels of various contaminants like lead and microplastics. Consumers that are unsatisfied with the quality of tap water are left with two options — bottled water or water filters. Bottled water, along with the well-known environmental consequences, can also have drastic consequences on human health. Water filters, similarly, have not yet been perfected — with a wide variety of issues including poor performance, tedious user experience, and unsustainable processes. Water2's Pod presents a unique solution to suboptimal water sources with a high level of performance, excellent user experience, and sustainable production and usage.

Introduction

Water is essential for life because of the diverse roles it plays within the human body, ranging from maintaining blood volume to regulating body temperature (Harvard University, 2018). An adult's body is about 55% water, and for children, this percentage is even higher (Water Science School, 2019). The general quality of drinking water has a significant impact on public health, as evidenced by the various waterborne disease outbreaks including the Cholera outbreak in the early 1800s.

Tap water in the UK is highly regulated and often considered amongst the best in the world (Drinking Water Quality in England, 2021). It is regulated under the water supply regulations and the private water supply regulations of 2016 (Drinking Water Quality in England, 2021). Both of these characterise a wide range of microbiological and chemical parameters, which are health-based to protect even the most vulnerable members of society. Despite this, between 2017 and 2019, 1 in every 2000 water samples taken by the UK's Department for Environment, Food and Rural Affairs was found to be above the regulatory health limits — compromising the health of thousands of Brits (Drinking Water Quality in England, 2021). And this is just a surface level analysis; while the regulatory standards do posit a threshold of acceptable quality of drinking water, they do not characterise the optimal water quality for human health and wellbeing.

Therefore, critical to the analysis of tap water relevant to human consumption is the acknowledgement of the Quality Conflation Fallacy (QFC): the quality of safety does not entail the quality of optimality. More specifically, just because tap water meets a threshold of safety for human consumption, does not ensure that the water is good, healthy, or optimal. Not conflating safe water with optimal water is a rule this paper will stringently observe. This is assuming that such safety thresholds are accurate, which is not self-evident. While regulatory organisations around the world have created standards for water quality, there are inconsistencies between these standards and a multitude of unanswered questions. For instance, while the UK regulatory guideline for lead levels in drinking water is 10 µg/l, the American Academy of Paediatrics has stated that there is no safe level of lead in the blood

(Lanphear et al., 2016). Observing the QFC and starting to look into the contaminants relevant to optimal drinking water, it is clear that any statement on the chemical composition of the best drinking water will be incomplete, partly due to the vast number of contaminants in drinking water, and also attributable to the constantly evolving nature of scientific research.

This paper focuses on the suboptimal quality of tap water in the UK and the shortcomings of the 2 alternatives offered by the current market — bottled water and water filter technology. Then, the paper evaluates why Water2's Pod technology is the optimal solution after considering various variables including performance, user experience, and sustainability.

Suboptimality of Tap Water

Despite tap water in the UK being amongst the best, according to a Times article, 18% of Britons drink bottled water only (Eccles, 2022). The American data is almost statistically identical — 15% of Americans drank only bottled water in 2018 (Riddler, 2022). A report by Zenith Global showed that 2.94 billion litres of plain, still bottled water was bought in the UK in 2021 — an 11% increase from 2020 (Eccles, 2022). Similarly, City to Sea has shown that the average Londoner uses 175 bottles a year, which is around 3.3 bottles per week (Eccles, 2022).

There are a variety of reasons why consumers in the UK may prefer to drink bottled water. According to a survey conducted in 2021, the reasons include bad taste or smell, limescale, wanting portable water, preferences about mineral content, not trusting water quality, and wanting other flavours of water (Kunst, 2022). Many additional independent surveys conducted over the past few years have confirmed these findings. For instance, In 2020, 500 people across the UK were surveyed to rank the quality and taste of the tap water where they live; the reasons the public avoid tap water include the taste of chlorine and high levels of minerals often causing limescale (Jern, 2021). Their survey also showed that 56% of Londoners think that bottled water is healthier than tap water (Jern, 2021).

In addition to the poor perception of tap water held by the British public, there are many regulational failures that have resulted in substandard drinking water in the UK. This can include situations where the regulations are incorrect in the case of lead and PFAS, unenforced in the case of trihalomethanes (THMs), and incomplete in the case of microplastics.

Lead is unlike most other contaminants in drinking water in its source. The leaching of metals, including lead, in the water infrastructure is a severe problem with water quality in the UK, as it is oftentimes overlooked since the government has never directly requested all lead piping to be replaced (which was done in the USA) or required that water suppliers conduct more regular tests at customers' taps (Plimmer, 2022). Many homes in the UK have copper, iron or galvanised pipework that dates back to the Victorian era; this leads to a higher chance of corroded ducts leaking metal into the water (*Does My Tap water Taste like Metal?, n.d.*). Lead piping was also used widely in British homes up to 1970, resulting in many homes having old lead pipes in their water supply network (*Does My Tap water Taste like Metal?, n.d.*). It is difficult to estimate the exact number of households affected, but the industry estimates that a quarter of the 24.8 million domestic properties across England and Wales have some lead piping in their supply network (Plimmer, 2022). While some water companies do conduct tests at customers' taps along with the standard tests at the water reservoirs, the small number of taps tested and the large time gaps between the tests do not ensure the safety of even a small fraction of consumers. An example that validates the severity of this issue was when environmental health officers from Lambeth Council conducted tests on the drinking water at an estate in Herne hills and found that 2 out of the 4 flats tested had lead levels higher than the UK's regulatory limit of 10 µg/l (Plimmer, 2022). Lead has significant health consequences including miscarriages, preterm births, depression, chronic kidney disease, and heart attacks, along with life-long IQ reductions and behavioral problems in children (Centers for Disease Control and Prevention, 2021). As mentioned previously, the regulational failure of lead goes further than lead piping since many researchers have ascertained that there is no safe level of lead in the blood, resulting in the British regulatory limit being too lenient.

Similarly, PFAS — forever chemicals or Poly and Perfluorinated Alkyl Substances — are chemicals designed to never break down in the environment (*Toxic pfas levels in UK drinking water*, 2022). While the DWI has stated that the regulatory limit for PFAS in drinking water is 100 µg/l, the European Food Standards Agency (EPA) has a tolerable limit of 2.2 µg/l (Salvidge and Hosea, 2022). The BBC took 45 water samples from sites across England and laboratory analysis determined that almost half of the samples exceeded the European limit of 2.2 µg/l, but none exceeded the UK limit of 100 µg/l (Salvidge and Hosea, 2022). A study conducted by the European Environmental Agency linked PFAS consumption with high cholesterol, ulcerative colitis, thyroid disease, testicular cancer, kidney cancer, and pregnancy-induced hypertension (Salvidge, 2021). Professor of toxicology at the University of Maryland, Rita Lock-Caruso, has stated that researchers are finding "health effects at lower and lower concentrations — in the single digits", expressing an urgent need to reduce these toxic chemicals (Salvidge and Hosea, 2022, para 10). However, the Department for Environment, Food and Rural Affairs (DEFRA) is taking the issue lightly and 'developing its approach to managing risk from PFAS'' but is not mandating routine testing of the drinking water by water utility companies, and conventional water treatment is not very effective at removing PFAS from water (Salvidge, 2021).

Likewise, THMs are a family of chemicals formed when disinfectants such as chlorine react with naturally occurring organic matter and other substances in the water. While the DWI regulations state that total THMs should not exceed 100 µg/l at the consumer's taps, many studies show that THMs in water that reaches consumers' taps exceed this concentration (*Bladder cancer linked to thms in UK Tap Water,* 2020). Many studies suggest a link between long term exposure to THMs and cancer and reproductive effects (*Trihalomethanes in Drinking Water,* n.d.). In one such study, researchers analysed tap water monitoring data from 26 European countries and found that the UK was one of 9 European countries where maximum THMs exceeded the permitted limits of 100 µg/l (*Bladder cancer linked to thms in UK Tap Water,* 2020). The UK also had the second largest number of bladder cancer cases blamed on THMs, with 20.7% of bladder cancer cases per year attributable to the THMs found in drinking water (*Bladder cancer linked to thms in UK Tap Water,* 2020). Additionally, unlike the UK, the USA's regulatory limit has been brought down to 80 µg/l as a result of the various studies linking THMs to a variety of health consequences (Valdivia-Garcia et al., 2016). While regulatory bodies in the UK are aware of the health risks of THMs, they are unwilling to take decisive action immediately due to the benefits disinfecting water with chlorine; the long-term solution to this is optimising water treatment and disinfection to ensure sterility while still preventing the health risks of THMs and other resultant chemicals. However, temporarily, consumers have no choice but to filter their tap water before consumption unless they opt for bottled water consumption exclusively.

Finally, sometimes the regulations surrounding contaminants in drinking water are incomplete, as depicted by microplastics, levels of which are not regulated in the drinking water. Microplastics have been found in 80% of all tap water (Jern, 2022). Professor Peter Jarvis of Cranfield University has said that "tap water in the UK contains between zero and ten microplastic pieces per litre, but bottled water can contain a few hundred" (Moore, 2019, para 2). While the health consequences of microplastic consumption have not been proven yet, many links have been created to conditions such as inflammatory bowel disease, oxidative stress and cytotoxicity, immune system dysfunction, neurotoxicity, and carcinogenicity (Bhuyan, 2022). Moreover, the release of estrogenic compounds from plastic material has been investigated for tap water that is distributed through plastic pipes (Quattrini, Pampaloni & Brandi, 2017). The migration of 2,4-d-t-BP from plastic pipes could result in chronic exposure (Quattrini, Pampaloni & Brandi, 2017). The health consequences of the ingestion of microplastics and the release of estrogenic compounds is discussed further below.

Therefore, while tap water in the UK might be relatively better than tap water in other countries, it is far from optimal. The DEFRA accepts that 0.05% of the water supplied is contaminated higher than the regulatory limit, but the samples tested are not accurately representative of the true levels of lead, PFAS, and THMs due to the selection bias of testing, infrequent testing at the consumer's tap, and testing before the water enters the supply network. Furthermore, certain contaminants are not even included in the regulations such as microplastics. The regulational failure along with the poor taste has resulted in ⅕ of the population swearing off the consumption of tap water.

Shortcomings of Current Market Solutions

Bottled Water

One solution offered by the current market for the suboptimal quality of tap water is plastic water bottles. Globally, more than a million plastic bottles are sold every minute (*The world's population,* 2020). However, there are numerous shortcomings of this source of drinking water including not only the well-known environmental consequences, but also health effects through microplastics and the transfer of compounds from plastic material into drinking water.

A well known consequence of the use of plastic material is the resulting environmental damage. Almost 400 million tonnes of plastic are produced each year, a mass projected to more than double by 2050 (Lim, 2021). More specifically, in the UK, it is estimated that 5 million tonnes of plastic is used every year, nearly half of which is packaging (Smith, 2022). Unfortunately, while much of these plastic products are recyclable, only 43.8% of plastic packing waste is actually recycled every year (Smith, 2022). Plastic has a myriad of consequences on the environment through the process of extracting and transporting fossil fuels for their production, the incineration of plastic leading to emission of greenhouse gases, and microplastics preventing the growth of aquatic organisms, amongst others (Parker, 2021).

The lesser known consequences of plastic include the health risk to human beings. The water in plastic bottles can contain microplastics (MPs), which are "synthetic solid particles of polymeric matrices with a size ranging from 1 micrometre to 5 nanometer, of either primary or secondary manufacturing origin, which are insoluble in water" (Campanele et al., 2020). A 2018 study tested 259 bottles from leading brands and showed that 93% demonstrated some microplastic contamination (McCarthy, 2018). Similarly, microplastics were found in 92% of all bottled water in Europe. The bottles contained an average of 314.6 plastic particles per litre (Sexton, 2018). A recent report by the WHO emphasised the ubiquitous presence of microplastics in the environment and induced concern regarding the consequences of microplastic exposure on human health (Campanele et al., 2020). Once ingested, microplastics smaller than 2.5 micrometres can enter the gastrointestinal tract through endocytosis or through persorption with a single-layer epithelium at the villus tip of the gastrointestinal tract and into the circulatory system. The resulting toxicity is via inflammation due to the persistent nature of microplastics and their unique properties such as hydrophobicity and their chemical composition (Campanele et al., 2020). While the health risks of microplastics are still being discovered, some correlations have been identified including oxidative stress and cytotoxicity, immune system dysfunction, translocation of cells to other tissues, neurotoxicity, and carcinogenicity (Campanele et al., 2020).

There are further health risks associated with the consumption of water in plastic bottles through the release of chemicals from the plastic to the water that is consumed. PET is the most common thermoplastic resin of the polyester family and is used to create plastic bottles (Quattrini, Pampaloni & Brandi, 2017). PET is a chemically inactive material but studies have shown that certain storage conditions may contribute to the release of chemicals such as DEHP, a plasticizer, from the bottles to the water (Quattrini, Pampaloni & Brandi, 2017). This can result in cancer, birth defects, and other reproductive problems. Similarly, another concern with storing water in plastic bottles relates to the exposure of chemicals with oestrogen-like activity. In one study, researchers looked at 20 brands of mineral water available in Germany in glass, plastic, and composite packaging. The results showed that 33% of all mineral water bottled in glass compared with 78% of water in plastic bottles showed significant hormonal activity (Quattrini, Pampaloni & Brandi, 2017). The National

Toxicology Program of the United States says that it has concerns about potential BPA exposure to the brains and prostate glands of foetuses, infants and children (National Institute of Health Sciences, n.d.). Studies have also shown links between BPA and cancer, heart disease, and a host of other illnesses (Bauer, 2022).

Therefore, both the vast environmental consequences and the emerging health risks should deter individuals from using plastic bottles as a permanent solution to water consumption.

Water Filters

The second solution for the inadequate tap water quality is water filtration machinery. For the environmentally conscious, plastic bottles are not an option. Therefore, many people have to turn to water filtration machinery regularly to ensure both preservation of the environment and drinking water in their home that is conducive to a healthy lifestyle. 3 key metrics have been established to determine the effectiveness of the commonly purchased water filters in the current market. This consists of performance, user experience, and sustainability.

<u>Rating System</u>

Performance refers to the efficacy of the filtration process, determined by the filter's propensity to eliminate harmful physical, chemical, biological, and other contaminants — including microplastics. Different filtration techniques are specialised in their ability to remove one or more types of these contaminants, therefore creating differing levels of performance. Certain filters, like reverse osmosis filters, remove most contaminants — good and bad from the filtrate, which does not result in the optimal water quality for human consumption without the need for remineralization. This metric also takes into account how well the filter ensures bacterial control, and the time-related fluctuations in filtration efficacy.

User experience is defined as how convenient the filter is for the day to day usage by the customer. This includes the price of the filter, the waiting period to obtain the filtered water, the installation — price and simplicity, and how frequently the cartridge must be replaced. The final metric — sustainability — analyses the economic, social, and environmental impact of the entire process ranging from production to the efficiency of the filtration process itself. This includes the raw material used during filtration, total carbon emissions, material of the cartridges, cartridge waste, and the water wastage during the final filtration itself.

3 of the most common filtration products in the UK market — Brita, Phox, and Osmio Zero — will be rated based on the metrics explained above. Brita and Phox are 2 different types of pitcher filters, while Osmio Zero is a countertop reverse osmosis filter.

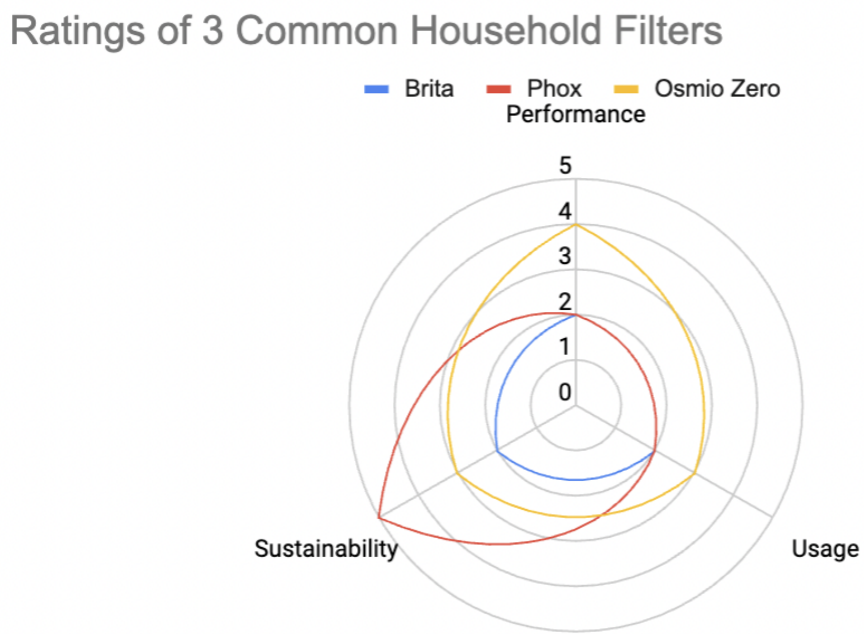

Figure 1: Ratings of 3 Common Household Filters on the metrics of Sustainability, Usage, and Performance

User Experience

In terms of user experience, there are many factors to be considered. Osmio zero is an extremely expensive countertop filter, making it quite inaccessible to most people and taking up precious space on your counter. An advantage of this is that it replaces your kettle as well by providing boiling water (*Reverse osmosis water filters, n.d.*). There is no installation since it does not have to connect to your pipe, but that means the consumer has to fill water in the filter every time and there is a waiting period to obtain the filtered water. Finally, the cartridges have to be replaced only 1 every 6 months, but it has a flow monitor and alarm to remind consumers (*Reverse osmosis water filters, n.d.*). The price, the re-filling process, and the countertop space are the reasons it has been given a rating of 3. Brita, on the other hand, is very cheap and also does not require to be installed. Like Osmio Zero, the jug needs to be filled with water before each use and there is also a long waiting period in obtaining the filtrate, making the process of obtaining the water quite inconvenient for consumers. Furthermore, the cartridges have to be replaced once every 4 weeks and many consumers do not remember to do this because of Brita's poor flow monitor system (BRITA, n.d.). Therefore, Brita was given a rating of 2. Phox was given a rating of 2 for similar reasons. There is also no installation process and it is very cheap and accessible as a pitcher. However, the drawbacks are similar to Brita in that the pitcher has to be refilled every time and there is a waiting period to obtain the filtrate. Phox cartridges have to be refilled rather than replaced every 45 days, which can be a tedious task for consumers (*FAQ's, n.d.*). However, on the plus side, Phox ensures to remind consumers on their mobile app whenever this is necessary (*FAQ's, n.d.*).

<u>Sustainability</u>

Phox is rated the highest with 5 points due to their paramount focus on being environmentally conscious. To begin with, according to Phox, their production and shipping process itself releases 75% less CO2 than other brands (*Phox v2 - 2.2L Glass Water Filter,* n.d.). Furthermore, the cartridges do not go to waste since they can be refilled, and the new cartridge granules are left in the letterbox to ensure delivery on the first attempt (*Phox v2 - 2.2L Glass Water Filter,* n.d.). The wrapping for the cartridges is also eco-friendly, making use of recyclable cardboard and biodegradable rice paper. Furthermore, no water is wasted (*Phox v2 - 2.2L Glass Water Filter,* n.d.). Alternatively, Brita — rated at a 2 — is not very sustainable. This rating was given because the cartridges are replaced, on average, once every 4 weeks (BRITA, n.d.). These cartridges are made of single-use plastic and are not recyclable after use, which contribute to over 100 million cartridges that end up in landfills each year (*100 million water filter cartridges,* n.d.). As of recently, however, Brita has partnered with TerraCycle, to keep its products out of landfills. Lastly, Osmio Zero was given a rating of 3, owing primarily to the fact that the cartridges have to be replaced every 6 months, and that there is 1 litre of water wasted for every 5 litres of water provided (*Reverse osmosis water filters, n.d.*). Furthermore, the cartridges are plastic and, like Brita, contribute to the many cartridges that end up in landfills (*Reverse osmosis water filters, n.d.*). This is a very high level of water wasted and many filtration techniques outside of reverse osmosis do not create this problem.

Performance

Performance is the final metric that will be used to compare these 3 brands of water filters. As mentioned earlier, while reverse osmosis filters including Osmio Zero are very efficient at removing almost all of the contaminants from drinking water, this is not necessarily ideal for human health since certain minerals are required for essential metabolic functions in the human body (Jern, 2022). This therefore results in remineralization being needed before consumption. On the plus side, Osmio Zero monitors the water quality and has a fail-safe built in to never dispense bad water, ensuring high quality, safe drinking water at all times (*Reverse osmosis water filters, n.d.*). On the other hand, the brita countertop filter employs an activated carbon block to filter the water, and is effective at removing chlorine, zinc, copper, cadmium, and mercury (BRITA, n.d.). However, it is not as effective when it comes to removing all dissolved minerals, nitrates, and bacteria or viruses through the filtration process (BRITA, n.d.). In terms of microbial contaminants, since the filter is not designed to kill bacteria or viruses, it may actually become a breeding ground if the filter is not replaced on time, implying a relatively weak bacterial control mechanism (BRITA, n.d.). Phox, similarly, is also a relatively ineffective water filter. While this data is hard to track because many filter companies are wary of releasing this information, Phox has stated on its website that it removes 90% of limescale, copper, and lead, as well as 98% of chlorine in testing (*FAQ's, n.d.*). However, it does not remove fluoride, and cannot confirm the extent to which hormones, microplastics, and other contaminants are removed since they have not undergone comprehensive testing.

In terms of the overall ratings of the filters, Osmio Zero has been given the highest overall rating of 10/15 due to its relatively strong filtration efficacy and fail-safe mechanisms, which is offset by the high price and necessity to refill. Phox has received an overall rating of 9/15 primarily due to its emphasis on sustainability, average filtration quality and the low price. Finally, Brita has been given a rating of 6/15 because while it is cheap, it is difficult to use, not very sustainable, and does not filter many important contaminants out of the water. Therefore, while these filters do have their benefits, none of them present as the optimal solution to water consumption at home.

Water2 as the Optimal Solution

Water2's Pod overcomes the shortcomings seen in the current solutions offered by the market — bottled water and existing water filtration machinery. As seen in the previous section, the overall efficacy of this filter can be determined based on the 3 key metrics of performance, user experience, and sustainability. Pod uses 0.1 micron filtration and carbon block technology added with silver and combined with an ultrafiltration step that prevents the passage of 99.999% of bacteria and microplastics, while also creating water that is optimised for taste. Water2's Pod technology has been rated using the same metrics as the previous section to analyse its efficacy as a water filter — performance, user experience, and sustainability.

<u>Performance</u>

Expanding upon the original definition, performance refers to Pod's ability to filter out physical, biological, and chemical. Various chemical tests have been performed to corroborate the filtration efficacy of Pod, which corresponds to certain health benefits and a clean taste. These are independent test results recorded at University College London.

Physical

Physical Parameter	Implication	After Filtration	Reduction (%)	UK Regulatory Limit (*Drinking water standards,* n.d.)
Turbidity	Measure of relative clarity of a liquid. Lower turbidity	0.036-0.054 FTU	40-60%	4 NTU at customer taps, 1 NTU at water treatment works

	indicates more clear water.			
Colour (Pt/Co scale)	Measures the "yellowness" of water	0.6-0.9 mg/l	40-60%	20 mg/l
Electrical Conductivity	Ability of water to conduct electricity; functions as an indicator of ionic solid concentration and salinity. Salts of calcium, magnesium, and sodium can impact the hardness and alkalinity of water supply.			2500 µS/cm at 20°C

In terms of physical water quality parameters, the turbidity, electrical conductivity, and UV_{254} were tested. Amongst these parameters, turbidity is the most relevant to indicate the performance efficacy of the filtration process. Turbidity is an indicator of the relative clarity of a liquid, which is measured by the amount of light scattered by the materials in the liquid. A high turbidity demonstrates a high concentration of particulate matter, which could be representative of further issues with the water quality depending on the contaminants. The turbidity of tap water reduces by between 40 and 60% depending on the quality of the water inputted, making the water significantly more clear at between 0.036 and 0.054 FTU.

Chemical

Chemical Parameter	Health Implication	After Filtration	Reduction (%)	UK Regulatory Limit (*Drinking water standards,* n.d.)
Hydrogen Ion (pH)	Low pH: may contain heavy metals, poor dental health, poor bone health (McGrane, 2020) High pH: N/A	7.9-7.7	-	6.5-9.5
Total Organic Carbon ©	N/A	0.96-1.44 mg/l	40-60%	No abnormal change
Total Hardness ($CaCO_3$)	Overexposure: N/A Underexposure: magnesium and calcium deficiency (*Hardness in*	265 mg/l	10-15%	-

	Drinking Water, 2022)			
Alkalinity (CaCO3)	N/A	190 mg/l	-	-
Ammonium (NH4)	Long term ingestion may be damaging to internal organ systems (Office of Environmental Public Health, n.d.)	0.11 mg/l	-	0.5 mg/l (guide value)
Chloride (Cl)	N/A	50 mg/l	-	250 mg/l
Chlorine (Residual)	Vomiting, diarrhoea, stomach aches, dry skin, production of trihalomethanes (Hanson, 2018)	0.2-0.3 mg/l	85-90%	-
Cyanide (CN)	Rapid breathing, tremors, neurological effects (EPA Cyanide, n.d.)	0.2-0.3 µg/l	40-60%	50 µg/l
Fluoride (F)	Overexposure: Possible dental fluorosis, skeletal fluorosis, arthritis, bone damage, osteoporosis, muscle damage, fatigue Underexposure: weak	0.14 mg/l	-	1.5 mg/l

	teeth, increased cavities (WebMD, n.d.)			
Nitrate (NO_3) & Nitrite (NO_2)	Skin colour changes, weakness, excess heart rate, fatigue, dizziness, methemoglobinemia (*Safe drinking water for your baby,* n.d.)	0.69 mg/l	-	-
Sulphate (SO_4)	N/A	55 mg/l	-	250 mg/l (guide value)
Aluminium (Al)	Can potentially cause diseases of the nervous system, including Alzheimer's disease (*Facts on Aluminium,* n.d.)	4.2-6.3 µg/l	40-60%	200 µg/l
Antimony (Sb)	Inflammation of the lungs, chronic bronchitis, and chronic emphysema (EPA Antimony Compounds, n.d.)	0.12-0.18 µg/l	40-60%	5 µg/l

Arsenic (As)	Changes in skin and blood circulation, cancer of the lung, skin and bladder, damage to stomach, kidneys, liver, and heart (*Arsenic: General Information,* n.d.)	0.4-0.6 µg/l	40-60%	10 µg/l
Boron (B)	Affect stomach, intestines, kidney, liver and brain (EPA Boron, n.d.)	0.02-0.03 mg/l	40-60%	1 mg/l
Cadmium (Cd)	Kidney damage, liver damage, bone damage, and blood damage (*Cadmium and Drinking Water,* n.d.)	0.1-0.14 µg/l	50-70%	5 µg/l
Chromium (Cr)	Lung and nasal cancer, nausea, gastrointestinal distress, stomach ulcers, skin ulcers, kidney and liver damage, reproductive problems	0.8-1.2 mg/l	40-60%	50 µg/l

	(Government of Alberta, n.d.)			
Copper (Cu)	Anaemia, liver poisoning, kidney failure Underexposure: poor host defence mechanisms, required for infant growth (*Essential minerals found in drinking water*, 2019)	0.016-0.117 mg/l	60-70%	2.0 mg/l
Iron (Fe)	Overexposure: Constipation, nausea, diarrhoea, vomiting (*Iron in Drinking Water,* n.d.) Underexposure: Fatigue, weakness, pale skin, chest pain, brittle nails, cold hands and feet (Mayo Foundation Iron, 2022)	2.4-2.8 µg/l	60-70%	200 µg/l
Lead (Pb)	Damages brain, kidneys and nervous systems (Centers for Disease	0.18-0.36 µg/l	60-80%	10 µg/l

	Control and Prevention, 2021)			
Magnesium	Overexposure: N/A Underexposure: Heart disease, strokes, lack of mineralization and development of the skeleton, hypertension, type II diabetes (Eske, 2019)	4.32-4.56 mg/l	5-10%	-
Manganese (Mn)	Harmful effect on nervous system and brain development (*Manganese in drinking water*, n.d.)	0.32-0.48 µg/l	40-60%	50 µg/l
Mercury (Hg)	Kidneys, brain, and damages developing foetuses (*Mercury,* n.d.)	0.028-0.042 µg/l	40-60%	1 µg/l
Nickel (Ni)	N/A	0.44-0.66 µg/l	40-60%	20 µg/l
Selenium (Se)	Hair and fingernail changes, damage to	0.15-0.45 µg/l	70-90%	10 µg/l

	peripheral nervous system, fatigue, and irritability (*Selenium in drinking water,* n.d.)			
Sodium (Na)	Overexposure: hypertension resulting in increased risk of developing coronary heart disease, stroke, congestive heart failure, renal insufficiency, and peripheral vascular diseases (*Sodium in Drinking-water*, 1996) Underexposure: nausea and vomiting, headache, muscle weakness, seizures, coma (Mayo Foundation Hyponatremia, 2022)	35 mg/l	-	200 mg/l
Benzo (a) pyrene	Cancer, skin rash, burning, bronchitis, warts (*Benzo[a]pyrene in Drinking Water,* 2015)	0.0008-0.0012 µg/l	40-60%	0.010 µg/l

PAHs	Teratogenic, carcinogenic, and mutagenic — lung, bladder, and skin cancer (Karyab et al., 2013)	0 µg/l	40-60%	0.1 µg/l
1,2 dichloroethane	Cancer, central nervous system disorders, lung, kidney, liver, circulatory, and gastrointestinal effects (*1,2-Dichloroethane*, n.d.)	0.04-0.06 µg/l	40-60%	3.0 µg/l
Benzene	Cancer, chromosome aberrations, anaemia, temporary nervous system disorders, immune system depression (*Benzene in drinking water*, n.d.)	0.04-0.06 µg/l	40-60%	1.0 µg/l
Tetra- & Trichloroethene	Cancer, nervous system effects, kidney damage, gastritis, diarrhoea (*Tetrachloroethylene,*	0 µg/l	40-60%	3 µg/l

	2016)			
Tetrachloromethane	Damage liver, kidneys, and nervous system (*Carbon tetrachloride,* n.d.)	0.04-0.06 µg/l	40-60%	3 µg/l
Trihalomethanes	Cancer, adverse developmental and reproductive effects during pregnancy (*Trihalomethanes in Drinking Water*, n.d.)	7.72-11.58 µg/l	40-60%	100 µg/l
Bromate (BrO3)	Acute poisoning: kidney effects, nervous system effects, hearing loss (*Bromate in Drinking Water,* n.d.)	0.6 µg/l	-	10 µg/l
Total Pesticides	Cancer, damage to the nervous system, and birth defects (Division of Environmental Health Services, n.d.)	0.008-0.012 µg/l	40-60%	0.5 µg/l
Microplastics	Immune system			

	dysfunction, oxidative stress & cytotoxicity, inflammatory bowel disease, neurotoxicity, cancer (Campanele et al., 2020)			

In terms of the numerous chemical contaminants, there are a few key parameters that are more relevant to the consequences on human health. Metals such as copper and lead in drinking water can be very damaging to the individuals that consume it. Copper, for instance, is a metallic element that is essential to human health and is primarily found in drinking water through the leaching of copper pipes and fittings. This implies that both a copper deficiency and overexposure to copper in the form of copper poisoning are problematic. In the case of a copper deficiency, this can cause a reduction in iron levels and subsequently result in the development of anaemia (*Essential minerals found in drinking water,* 2019). It can also modify infant growth and host defence mechanisms (*Essential minerals found in drinking water,* 2019). Alternatively, copper poisoning is very harmful and drinking water with high levels of copper can cause nausea, diarrhoea, gastrointestinal illness and muscle pain (*Essential minerals found in drinking water,* 2019). More severe cases can also result in anaemia, liver poisoning and kidney failure (*Essential minerals found in drinking water,* 2019). To reiterate a point mentioned in the section about tap water, lead is found in drinking water through the leaching of lead piping in properties built before 1970 (*Does My Tap water Taste like Metal?, n.d)*. Lead is extremely toxic to both children and adults, resulting in damage of the brain, kidneys, and nervous system (Centers for Disease Control and Prevention, 2021). While the UK regulatory limit for lead is 10 µg/l, many regulatory agencies and researchers have stated that any level of lead consumption can be harmful, which is why it is imperative to bring this down as low as possible. Therefore, the reduction of lead and copper by Pod is crucial in maintaining health and wellbeing while still consuming tap water.

In addition to certain metals, trihalomethanes (THMs) are also a key contaminant to consider when determining the safety of drinking water. As mentioned earlier, long-term exposure to THMs can result in cancer and reproductive issues and the UK has been found as one of the countries where maximum THMs concentration exceeded the permitted limit of 100 micrograms per litre of water (*Bladder cancer linked to thms in UK Tap Water,* 2020). The stark relationship between bladder cancer and THMs demonstrate the importance of using Pod to filter these contaminants out of tap water before consumption.

There are two other chemical parameters that are not excessively altered when water is filtered by Pod — hardness and fluoride. Hard water is considered to be water that has a high concentration of dissolved minerals such as magnesium and calcium, and is not a health hazard. While many people dislike hard water because of its impact on taste or the inconvenience caused by limescale build up, hard water is actually very beneficial to health and can contribute to the recommended intake of magnesium and calcium. A deficiency of calcium can result in osteoporosis in adults because of the role calcium plays in blood clotting, bone and dental health, and regulating muscle contractions (*Essential minerals found in drinking water,* 2019). Similarly, magnesium deficiencies can cause numerous health problems including high blood pressure, diabetes, osteoporosis, and migraines (*Essential minerals found in drinking water,* 2019). The health benefits of hard water and unclear relationship between hard water and poor taste are further demonstrated through popular bottled water brands such as Evian having hardness levels of around 291 mg/l (*Evian,* n.d.). Similarly, fluoride is a mineral found in water, levels of which have been correlated with tooth decay. There is a common misconception that fluoride levels are linked to a variety of health conditions, but reviews of the risks have found no evidence to support these concerns (NHS, n.d.). Therefore, Pod maintains fluoride levels optimal to prevent tooth decay and ensure robust dental health.

In addition to the health impacts of drinking water, the taste is a key issue that prevents individuals in the UK from enjoying the tap water to the fullest extent. Pod primarily combats the poor taste of drinking water in the UK by reducing chlorine levels during the filtration process. Chlorination is the process of adding chlorine to drinking water to prevent the growth of microbiological contaminants. Drinking water with small amounts of chlorine is vital in protection against waterborne disease outbreaks, but high levels of chlorine can have significant health impacts including the possibility of bladder cancer (Rahman et al., 2010). After water is filtered with Pod, chlorine levels are reduced by 85-90% to reach 0.2 mg/L, which is well below the regulatory limit of 40 mg/L, while also allowing for residual bacterial protection. Chlorine is also a key element in determining the taste and smell of water, with chlorinated water being unpleasant to the palates of certain individuals. Furthermore, iron and copper can also cause metallic tasting drinking water through leaching from metal pipes; since the pod removes 60-70% of these metals, it also combats the possibility of metallic tasting tap water.

Biologicial

Biological Contaminant	Implication	Before Filtration	Reduction (%)	UK Regulatory Limit (*Drinking water standards,* n.d.)
Clostridium perfringens	Causes illness rarely, can indicate persistent contamination in water supply (*Clostridium Perfringens,* n.d.)	0 no./100 ml	-	0 no./100 ml
Coliform bacteria	Increased risk of waterborne illness from some strains, sensitive measure of microbiological quality of water (Michigan Department of Environment,	0 no./100 ml	-	0 no./100 ml

	n.d.)			
Colony count (22° C)	Detect wide range of bacteria, assess the microbiological quality of drinking water	0 no./100 ml	-	No abnormal change
Enterococci	Found in the gut of humans and warm blooded animals, presence in water supply indicates faecal contamination requiring immediate action (*Escherichia coli in Drinking Water,* n.d.)	0 no./100 ml	-	0 no./100 ml
E. coli		0 no./100 ml	-	0 no./100 ml

Fortunately, no biological contaminants have been found in UK tap water to begin with. However, the activated carbon technology used in Pod is capable of eliminating 99.9999% of bacteria and viruses in the water. To ensure further bacterial control, silver has been added as a bacteriostat in this filter. The silver is deposited onto the carbon granules to potentially inhibit the growth of bacteria on the surface of the carbon particles. Such filters tend to leach trace levels of silver into the effluent water, but at these concentrations, have no detrimental effects on human beings.

In terms of overall performance, not only does Pod reduce all of the chemical and biological contaminants, including THMs, PFAS, lead, and copper to levels below the UK regulatory limit, but also produces clear water filled with essential minerals such as Magnesium, Fluoride, and Calcium to levels that are beneficial to health. However, as discussed, many regulatory agencies have asserted that any level of lead in drinking water might be dangerous, and while Pod reduces lead to a significant extent (60-80% depending on the quality of water inputted) preventing a range of issues, it does not eliminate lead entirely. Furthermore, while hardness in water does not have any consequences on health, many UK consumers have an aversion to limescale deposits; Pod reduces this but only by around 10-15%. In terms of the taste, Pod reduces chlorine levels significantly, thereby preventing poor tasting drinking water. Therefore, Pod sets a very high standard of filtration performance and has been given a rating of 4 out of 5 .

User Experience

Considering another metric of filter quality, Pod has been designed to create the most optimal user experience for consumers. In terms of price, Pod retails for approximately £159.20 to £199, which includes both Pod and the cartridge itself. The cartridge has been designed with user experience in mind, only requiring replacement after 1 year of use. Furthermore, the filter will audibly buzz when this time has lapsed, ensuring that consumers are reminded to change their cartridge to maintain the highest quality drinking water in their home. While Pod does require installation, this process is very brief and can be done within 5-20 minutes, unlike most other under-sink filters that require professional installation. There is a straightforward installation guide, manual, and YouTube video that customers can choose from, eliminating the need for external assistance. There is also the option of live support in case any problems are encountered but it is unlikely that this will be necessary. Unlike other jug or countertop filters, once the installation is complete, the filter need not be touched again for another year. It is directly connected to your kitchen tap, providing fresh and clean drinking water as soon as you need it, without the need to refill the filter or wait for the water to get filtered once the refilling is complete. Additionally, since pod is installed under the sink, it does not take up precious space on the kitchen counter or alter the aesthetics of the consumer's home.

While Pod is more expensive than Brita and other water filtration jugs, it is well-priced considering its longevity and the efficacy of its filtration. It is also much more accessible than reverse osmosis filters and other countertop filtration systems, which can cost over £350. The entire process ranging from the installation of the Pod to the replacement of the cartridges has been designed with the user in mind. With no waiting period for water consumption, a quick and easy installation process, infrequent cartridge replacement, and prime location for maintaining home aesthetics, Pod provides a phenomenal user experience. Pod has been given an overall rating of 4 out of 5, purely as a result of the fact that it requires installation, despite that installation being quick and simple.

Sustainability

Finally, in terms of sustainability, the primary purpose of Water2 is to minimise damage to the environment and increase the quality of life. By encouraging customers to replace plastic bottles with our water filter, there is a significant reduction in overall plastic waste and the carbon footprint left behind by the production of water bottles and the environmental impact of the chemicals used to produce them. The entire company has been designed to minimise the carbon footprint and ensure sustainability in all facets of its usage, ranging from production to 0ml of water wasted during filtration. In terms of production, the carbon technology used in the filter is obtained from repurposed coconut shells. Furthermore, all production takes place in a 6,000 sqm production facility that is covered with solar panels for the production of renewable energy. During the actual filtration process itself, no water is wasted. This means that each drop of water that goes through the filter comes out in the form of optimal drinking water. Also, by purchasing Pod instead of using plastic bottles, each user is preventing the wastage of over 1,000 plastic bottles yearly. While the cartridges are made of single-use plastic, they only have to be changed once a year unlike many filters that require the cartridges to be changed semi-annually or even monthly. Right now, the used cartridges are being donated to scientific research to further improve the filtration performance of Pod. However, Water2 is currently in the process of creating a more efficient recycling system for the used cartridges.

Therefore, considering that Pod is manufactured in a solar power factory, does not cause any water wastage, and results in a low level of cartridge disposal due to the yearly cartridge replacement time, it represents a high level of sustainability. However, since the used cartridges are not recycled at present, Pod has been given a rating of 4 out of 5.

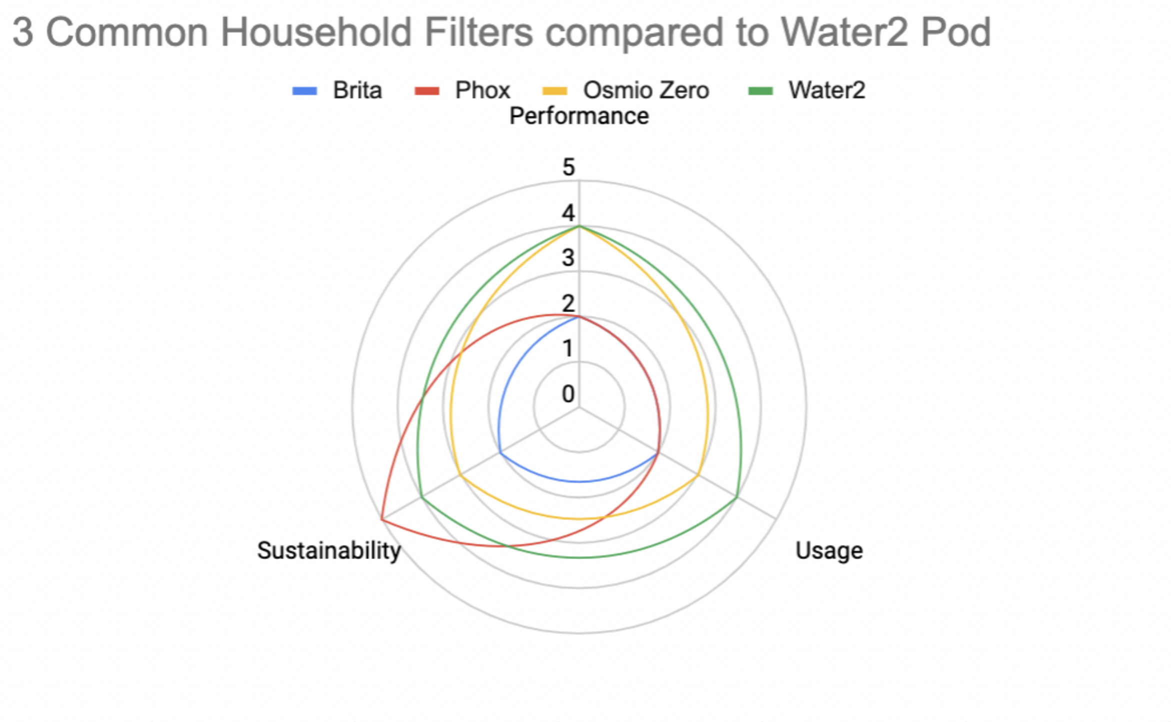

Figure 2: Ratings of 3 Common Household Filters compared to Water2's Pod on the metrics of Sustainability, Usage, and Performance

In overall terms, Water2's Pod technology has received an overall score of 12/15 — the highest score of all 4 filters considered. Whereas Brita, Osmio Zero, and Phox received scores of 6/15, 10/15 and 9/15 respectively.

Pod efficiently filters contaminants that are harmful to health while maintaining optimal qualities of those that are beneficial. This optimal performance can be contrasted with pitcher filters such as Brita and Phox that do not eliminate harmful contaminants very efficiently, and reverse osmosis filters like Osmio Zero that eliminate harmful contaminants in addition to the beneficial minerals in drinking water, requiring that a user find alternative sources of these minerals. In terms of user experience, Pod ensures that cartridges have to be replaced only yearly, while pitcher filters involve the replacement of cartridges every 3-4 weeks, and Osmio Zero requires the same to be done bi-annually, making the usage of Pod very convenient.

Unlike the other most commonly available filtration systems on the market, Pod also involves no waiting period in obtaining the filtrate and the water can be consumed directly from the tap. Pod, while being more expensive than the pitcher filters, and cheaper than the reverse osmosis countertop filters, provides a great middle-ground between performance, convenience to the user, and price. Pod is also extremely sustainable involving no water wastage, infrequent cartridge replacement, and production in a factory powered by solar energy. Therefore, based on this analysis, Pod is the best water filtration system that can be purchased in the market today.

Conclusion

This paper highlights the inadequacies in the current water market by considering the drawbacks of drinking water straight from the tap and the two other choices — plastic water bottles and other water filters. It is clear that these options are far from optimal from the perspective of health, the environment, and consumer preferences.

Water2 presents an elegant solution to the current limitations of tap water, other water filters, and bottled water. In addition to having a high level of performance created with human health in mind, it also offers a seamless user experience and limits damage to the environment.

It is fair to note that Pod can be improved. Research is currently underway to develop a cartridge that will specifically combat the levels of hardness and fluoride further in drinking water, since this a key area of concern for consumers in the UK. Furthermore, Water2 is also examining more sustainable packaging, along with a plan to recycle cartridges to ensure that they never end up in landfills.

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