LifeStraw®

Safe drinking water interventions for home and outside use

The LifeStraw® Concept

With a passion to achieve the Millennium Development Goals, which include poverty eradication, environmental improvement, gender equity creation, and the reduction by half of the proportion of people without sustainable access to safe drinking water by the year 2015, Vestergaard Frandsen recognizes the immense sense of urgency.

At any given moment, about half of the world's poor (representing more than one billion people) are suffering from waterborne disease; over 6,000 of these people, mainly children, die each day by consuming unsafe drinking water.

Safe water interventions have the potential to transform the lives of millions of people. Water filtration tools provide safe drinking water, creating a positive health impact on the populations most vulnerable to unsafe water, which include young children, pregnant women, and those with compromised immune systems.

A meta-analysis under the Cochrane Collaboration, published in 2006 assessed the effectiveness of interventions to improve the microbial quality of drinking water for preventing diarrhoea. The results of the study demonstrated that water filters are the most effective interventions amongst all point-of-use water treatment methods for reducing diarrhoeal diseases. This systematic review of 33 controlled trials among nearly 56,000 participants also proves that it is not enough to treat water at the point-of-source; it must also be made safe at the point of consumption.

LifeStraw® Personal and LifeStraw® Family are both point-of-use interventions – truly unique offerings from Vestergaard Frandsen that address the concerns for affordably obtaining safe drinking water at home and outside.

Drinking Water Crisis

- More than one billion people in the world do not have access to safe drinking water – i.e. around 1/6th of the world's population[1]
- Five million people, mostly children, die each year from waterborne disease[1]
- Diarrhoea kills over 1.8 million people[2] per year and chronic diarrhoea is a leading killer of people with AIDS
- Diarrhoea and intestinal worm infections account for 10 percent of the total burden of disease in developing countries[3]
- Diarrhoea, a very common symptom of HIV and AIDS, affects 90 percent of PLWHA and results in significant morbidity and mortality[4,5]
- Diarrhoea is one of the leading causes of morbidity and mortality among HIV-infected children[6]
- In a study among HIV-infected persons in Uganda, use of safe water decreased diarrhoeal illness by 36 percent[7]
- In Africa, diarrhoea is four times more common among children with HIV and seven times more common among adults with HIV than their HIV-negative household members[8]

1.1 billion
deprived of safe drinking water[2]

4 billion
annual cases of diarrhoeal illness[2]

440 million
school days lost each year from water-related illness[9]

1.8 million
lives lost each year due to diarrhoeal disease[2]

117 million
disability adjusted life years (DALYs) lost annually[3]

One of United Nation's Millennium Development Goals is to
"halve by 2015 the proportion of the population without sustainable access to safe drinking water"

The Health Impact of Filtration

In the year 2006, the Cochrane Collaboration published a systematic review of 33 randomised, controlled trials of various water quality interventions to prevent diarrhoea titled, "Interventions to Improve Water Quality for Preventing Diarrhoea."

This review, which covered both water source and point-of-use household-level interventions, found that household interventions were twice as effective in preventing diarrhoea as common source-based interventions (wells, boreholes and communal tap stands).

Among household interventions, filters were consistently the most effective in preventing diarrhoea, with an average 63% reduction.

Filtration vs. other Point-of-Use Interventions[10]

Intervention Type (no. of trials)	Relative Risk (random)	% Reduction (1-RR)	95% CI of Estimate*
Filtration (6)	0.37	63%	0.28 to 0.49
Chlorination (16)	0.63	37%	0.52 to 0.75
Solar disinfection (2)	0.69	31%	0.63 to 0.74
Flocculation/Disinfection (7)	0.48	52%	0.20 to 1.16
Flocculation/Disinfection (ex Doocy)	0.69	31%	0.58 to 0.82
Improved storage (1)	0.79	21%	0.61 to 1.03

*95% confidence interval. Estimates outside this range have a likelihood of less than 5%

Of the household level interventions, filtration is the most effective in preventing diarrhoea.

LifeStraw® Personal – an Overview

LifeStraw® Personal is a portable water filtration device that provides access to safe drinking water while the user is away from home.

"Persons who travelled away from the household for extended period of times did not have a way of protecting themselves from the Guinea Worm Disease. In 1994, we tested (at CDC) the efficacy of PVC pipe filters in the removal of copepods, and what length and diameter would be ideal for their use. Those results led to their large scale use in the Guinea Worm Eradication Programs."

Dr. Ernesto Ruiz-Tiben

Technical Director, Carter Center

Guinea Worm Eradication Program (GWEP).

Vestergaard Frandsen supplies pipe filters and family cloth filters used in the Carter Center's GWEP.

Portable Water Filter

- Can be carried around for easy access to safe and clean drinking water
- Filters up to 700 litres of water
- Removes 99.9999% of waterborne bacteria
- Removes more than 98% of waterborne viruses
- Removes particles down to 15 microns
- Requires no electrical power or spare parts for the lifetime of the straw
- Easy to mass-distribute in areas where drinking water is contaminated

LifeStraw® Personal – Usage

Place LifeStraw® Personal in water and sip through the mouthpiece.

Regularly blow through LifeStraw® Personal after drinking to keep the filters clean and to prevent them from clogging.

LifeStraw® Personal is a complimentary tool to LifeStraw® Family – together they have the potential to maximise the impact on all waterborne diseases.

LifeStraw® Personal – Test Data Summary

LifeStraw® Personal was tested at the University of North Carolina for microbial reduction performance. The following micro-organisms were tested:

Bacteria: *Escherichia coli B* (gram-negative bacterial indicator of faecal contamination)
Bacteria: *Enterococcus faecalis* (gram-positive bacterial indicator of faecal contamination)
Virus: *MS-2 coliphage* (~25 nM diameter viral indicator of human enteric viruses)

Various samples of the LifeStraw® Personal were evaluated. The following table shows an overall analysis of the reduction of *E. faecalis, E. coli B* and MS-2 in filtered water.

Overall Log_{10} reductions (% reductions) for each LifeStraw® Personal tested for 700 litres

LifeStraw® models	*E. faecalis*	*E. coli B*	MS-2
1	7.3 (99.999995)	6.2 (99.99994)	1.9 (98.7)
2	7.3 (99.999995)	6.2 (99.99994)	1.9 (98.7)
3	≥7.6 (≥99.999997)	5.6 (99.99975)	1.9 (98.7)
4	7.3 (99.999995)	≥6.2 (≥99.99994)	1.8 (98.4)
5	7.0 (99.999990)	≥6.4 (≥99.99996)	1.9 (98.7)
6	7.0 (99.999990)	≥6.4 (≥99.99996)	1.9 (98.7)

Conclusion

"The LifeStraw models tested were able to reduce bacteria such as E. faecalis and E. coli by at least 6 log_{10} (99.9999%) and viruses by about 1.8 (99.8%) to 2.0 log_{10} (99%) over the 700 litre volume of water tested. These results indicate highly efficacious performance to meet US EPA and NSF-International requirements for bacteria reduction. Although virus reductions did not meet the US EPA and NSF-International performance requirement of 4 log_{10}, the approximately 2 log_{10} (99%) reduction achieved is quite substantial. This magnitude of virus reduction would appreciably reduce human exposure to waterborne viruses by 99% and thereby reduce the risk of waterborne viral infection and illness"

– Prof. Mark Sobsey, University of North Carolina

LifeStraw® Personal – Awards and Accolades

Awards

2008 Saatchi & Saatchi Award
for World Changing Ideas

'INDEX: 2005'
International Design Award

'Well-Tech 2006'
Innovation Technology Award

Accolades

'Best Invention of 2005'
Time

'Europe's Best Invention'
Reader's Digest

'Innovation of the Year'
Esquire magazine

'Invention of the Century'
Gizmag

'A Water Purifier for the Masses'
Popular Science magazine

'A Water Purifier That Could Save Lives'
New York Times

'Gadget Produces Safe Drinking Water'
Newsweek

One of the 'Ten Things That Will Change The Way We Live'
Forbes magazine

"Good design should have a positive effect on the user and if possible on society. LifeStraw® meets these basic criteria, truly an excellent design solution. LifeStraw® offers a simple, elegant solution to a large and complicated problem that profoundly affects many people's lives around the world. By addressing this problem the designers are opening possibilities of limiting the number of people without clean water – and thereby reducing deaths resulting from this lack, especially in the developing world."

- Jury of INDEX: 2005 International Design Award (September 2005)

LifeStraw® Family – an Overview

Instant Microbiological Purifier

- Filters a minimum of 18,000 litres of water – provides safe drinking water for a family for three years (calculated approximately on a family's consumption of 15 litres water/day – considering an average family size of seven in Sub Saharan Africa where an adult man consumes up to three litres, an adult woman drinks at least two litres and five children, each of them consume at least one litre water on a daily basis. We have also considered aspects like increased water intake by pregnant/ lactating women as well as manual labour in high temperatures).

- High flow rate with instant access to clean water

- Complies with EPA guidelines for microbiological water purifiers

  - Removes minimum 99.9999% of all bacteria

  - Removes minimum 99.99% of all viruses

  - Removes minimum 99.9% of all parasites

- Works on highly turbid water

- No electrical power or batteries required

- No spare parts required

- No running water required

- Easy to clean pre-filter as well as purifier cartridge

- Easy to ship, carry and store

LifeStraw® Family – Functioning

1 Dark blue bucket with pre-filter
container for filling with unpurified water

2 Pre-filter
the 27 micron pre-filter removes coarser turbidity and is easy to clean

3 Halogen chamber
releases minimal chlorine to prevent bio-film formation on the membrane

4 Blue tap
outlet for clean and safe drinking water

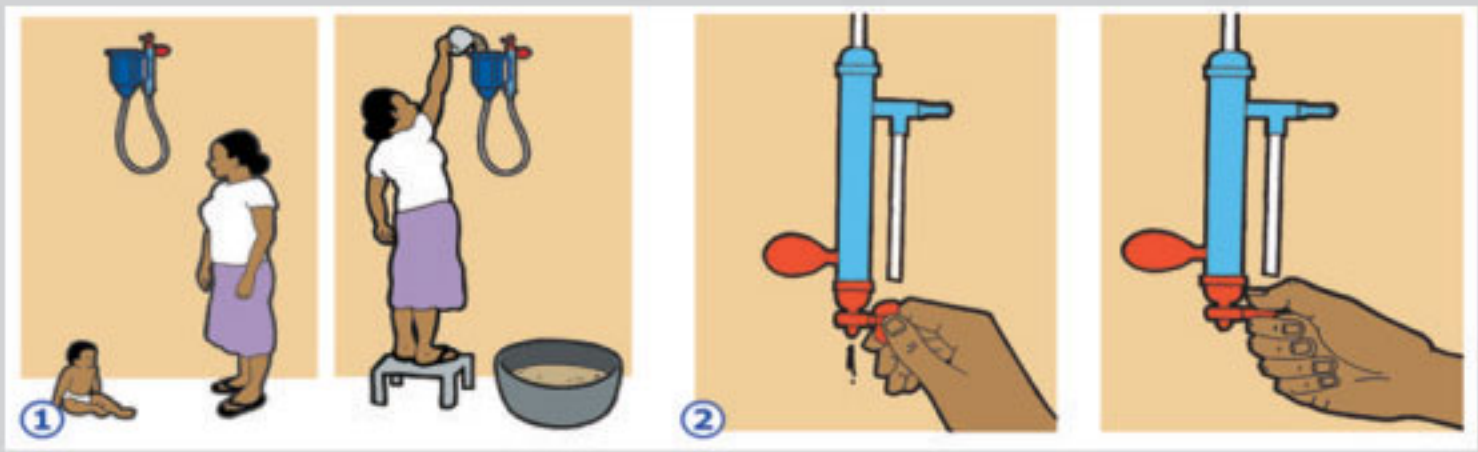
5 Membrane cartridge
ultra filtration takes place in the membrane cartridge – a pore size of 20 nanometre retains bacteria, viruses, parasites and fine dirt particles

6 Red Bulb
backwashing is done by squeezing the red bulb three times

7 Red exit
disposes the dirt and impurities

LifeStraw® Family – Usage

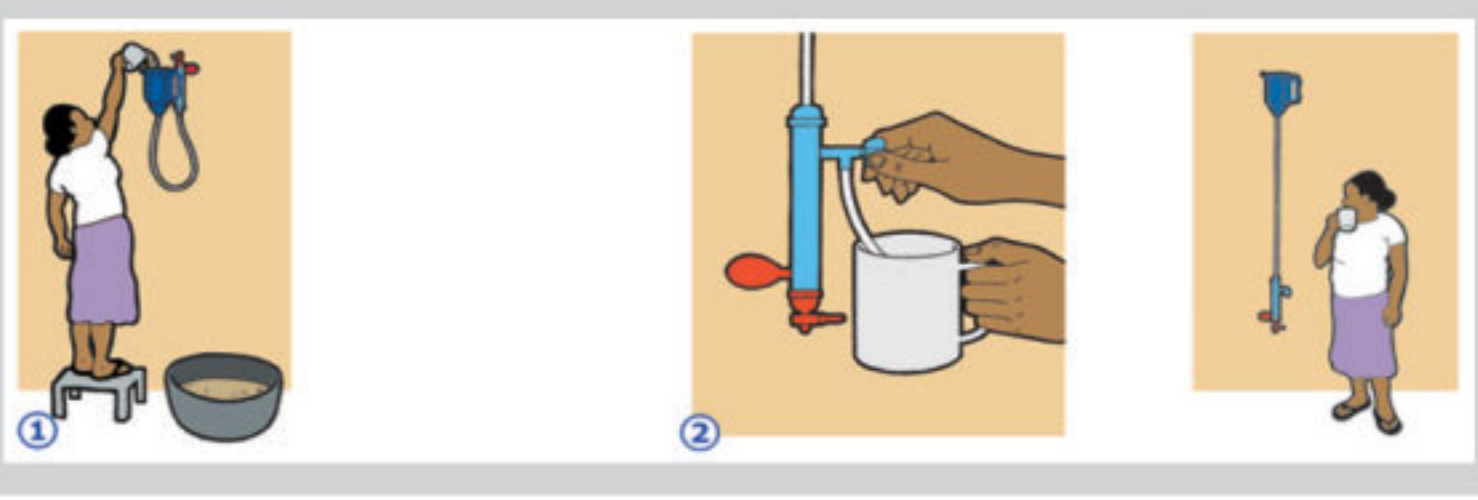
A. Before Use



1. Hang the filter up. Fill the dark blue bucket with water.

2. Open the red exit until some water is released.

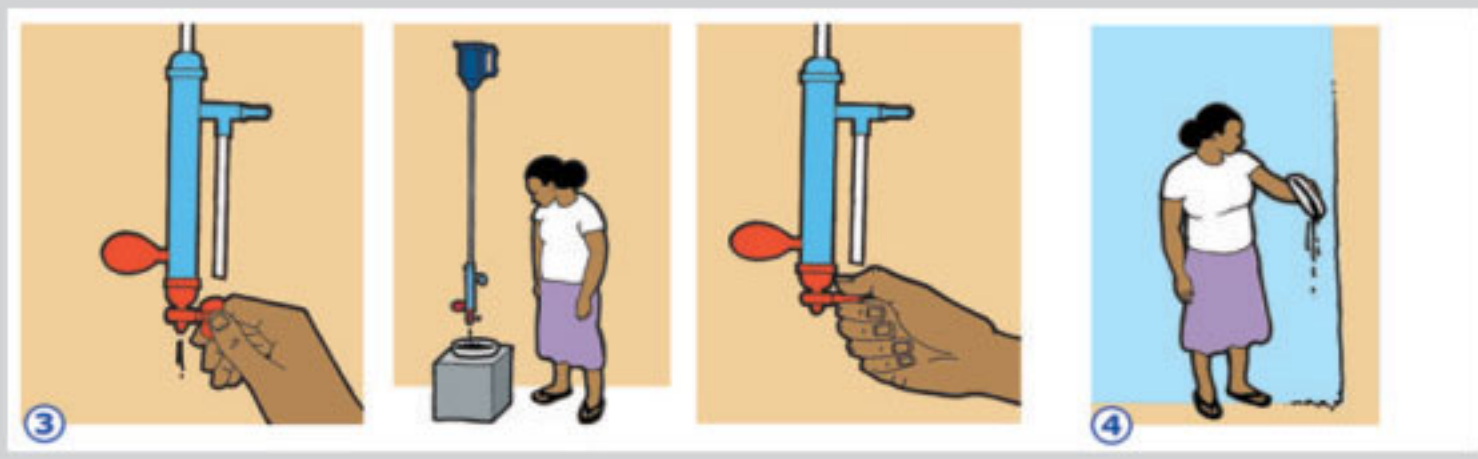
B. Purify Water



1. Fill the bucket with water.

2. Drink safe water from the light blue tap using a clean cup.

C1. Clean Cartridge Everyday



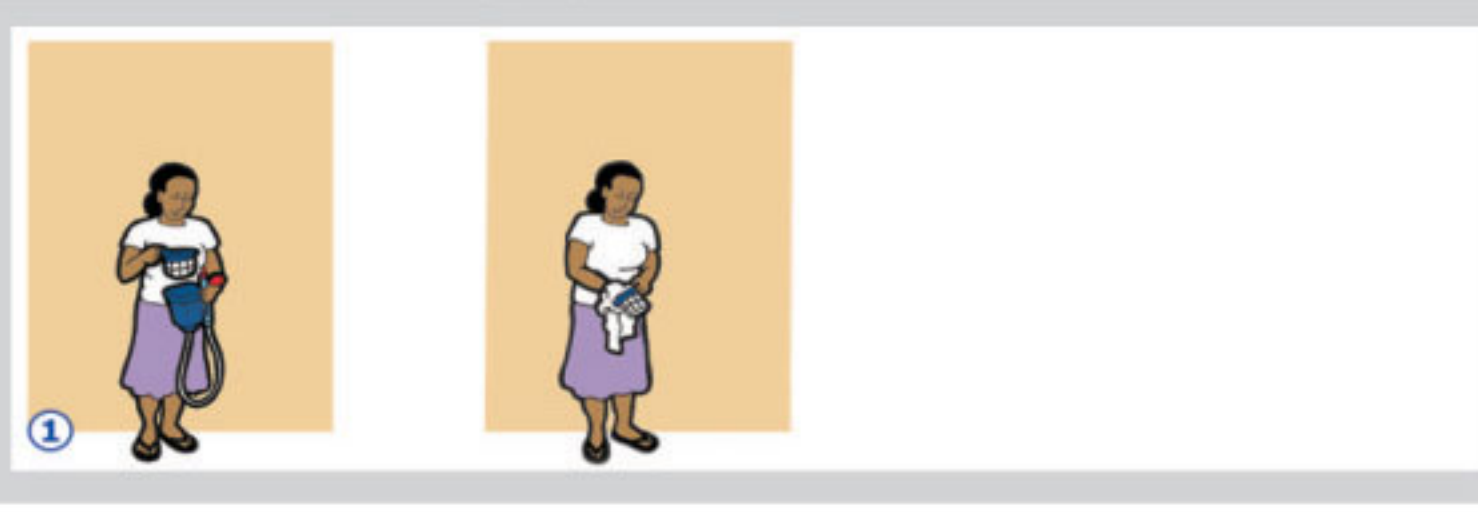
1. Close the light blue tap.

2. Fill the bucket and squeeze bulb 3 times. Wait each time until the bulb refills.

3. Open the red exit and wait for 5 seconds before closing. **Do not drink the water released from the red exit.**

4. Dispose of the dirty water properly.

C2. Clean Pre-filter Everyday



1. Take the pre-filter out and clean it with a cloth and water.

LifeStraw® Family in Comparison to Other Point-of-Use Interventions for Safe Drinking Water

Microbiological Performance

Intervention	Bacteria	Virus	Protozoan cyst	Meets EPA protocol
LifeStraw® Family	99.9999%	99.99%	99.9%	Yes
Boiling	99.9999%	99.99%	99.9%	Yes
Bio sand filter	90%-99%	50%-90%	99.9%	No
Chlorination	99.9999%	99.99%	Low	No
Ceramic filter	>99%	Low	99.9%	No
Solar disinfection	99.999%	99.99%	50%-99%	Unclear
Flocculation disinfection (Pur)	99.9999%	99.99%	99.9%	Yes

Physical Performance

Intervention	Capacity of water treated	Flow rate/ processing time	Factors affecting performance	Impact on water taste/ appearance	Repeat intervention required
LifeStraw® Family	18,000 litres	Average 8-10 litres/ hour	Safe storage if water not consumed directly	Neutral for taste; positive for appearance	No
Boiling	Not applicable	20 minutes (includes heating water to 100°C, 1 min. boiling, cooling)	Boiling temperature and safe storage	Neutral or negative	Yes
Bio sand Filter	Up to 50 litres/day	0.1/ 0.3 metre/ hour (when the average depth of sand filter is 0.7 metres)	Proper construction, operation and maintenance	Neutral for taste; positive for appearance	No
Chlorination (dilute $NaOCl_2$)	1000 litres	30 minutes contact time after preparation and dosing	Exposure time, turbidity, chlorine demand	Negative	Yes
Ceramic filter	5000-10,000 litres	1-3 litres/ hour	Pore size and consistency: bacteriostasis; maintenance	Neutral for taste; positive for appearance	No
Solar disinfection	1-2 litre per bottle average	6 hours	Sunlight, turbidity, dissolved solids	Neutral	No
Flocculation disinfection	10 litres	30 minutes	Exposure time, chemical concentration in mix	Negative for taste; positive for appearance	Yes

LifeStraw® Family – Test Data Summary

LifeStraw® Family has been tested at the University of Arizona for longevity and microbial reduction performance.

The **ageing wate**r characteristics are mentioned below:

Water characteristics	EPA standard of ageing water	Ageing water used by University of Arizona*
Water pH	6.5 - 8.5	7.5 $\pm$ 0.25
Total dissolved solids	50 - 500 mg/ litre	50 - 500 mg/ litre
Turbidity	0.1 - 5 NTU	15 NTU
Total Organic Carbon (TOC)	0.1 - 5 mg/ litre	5 mg/ litre (as tannic or humic acid)
Disinfectant residue	not detectable	< 0.1mg/ litre in active chlorine
Bacteria/ virus/ cysts	not detectable	CFU or PFU/ 100 ml or unit/ litre

The **challenge water** characteristics are mentioned below:

Water characteristics	EPA standard of challenge water	Challenge water used by University of Arizona*
Water pH	9.0 $\pm$ 0.2	9.0 $\pm$ 0.2
Total dissolved solids	1500 $\pm$ 150 mg/litre	1500 $\pm$ 150 mg/litre
Turbidity	$\geq$ 30 NTU	$\geq$ 100 NTU
Total Organic Carbon (TOC)	$\geq$ 10 mg/ litre	$\geq$ 10 mg/ litre (as tannic or humic acid)
Disinfectant residue	not detectable	at least < 0.1mg/ litre in active chlorine
Bacteria	10^{7-8} CFU/ 100 ml	10^{7-8} CFU/ 100 ml
Virus	$\geq 5x10^{6}$ PFU/ 100 ml	$\geq 5x10^{6}$ PFU/ 100ml
Cysts	$\geq 5x10^{4}$ oocysts/ litre	$\geq 5x10^{4}$ oocysts/ litre

*Higher concentration of turbidity and TOC in the ageing and challenge water is being passed through LifeStraw® Family. This makes the water quality closer to field conditions.

Microbiological Efficacy

On average, the following Log_{10} reductions were observed for each microbe during the lifetime of the filters:

Micro-organism	Log_{10} reductions	EPA requirements
E. Coli	6.8	6.0
MS2 virus	4.4	4.0
Cryptosporidium oocysts	3.6	3.0

Conclusion

The efficacy of the LifeStraw® Family filter has been assessed for the above micro-organisms up to a capacity of 18,000 litres. This filter unit exceeds the EPA requirements of Log_{10} 6/4/3 reductions for these groups of microbes.

The micro-organisms used during the efficacy trial are representative of the ones encountered on the field. They have been chosen because they are particularly resistant to disinfection or particularly small in size, thus rendering their elimination difficult.

Longevity

The longevity of the LifeStraw® Family filter has been assessed for a capacity of 18,000 litres. After this volume of water containing turbidity and organic carbon was passed through the filters, the flow rate was still around 100 to 130 ml/min, which represents 6 to 8 litre/ hour. The flow rate values fluctuated between 200 – 320 ml/ min at the beginning of the longevity trial, i.e. 12-19 litre/ hour, and 6-8 litre/ hour at the 18,000 litre capacity.

The cleaning frequencies during the longevity trial were as follows:

Pre-filter cleaning frequency: approximately every 30 hours
(represents a less than daily cleaning in the real conditions of use)

Filter cartridge cleaning frequency: approximately every 11 hours
(represents a less than daily cleaning in the real conditions of use)

Bucket cleaning frequency: approximately once a week.
(shows that the bucket requires less maintenance)

This longevity trial on the LifeStraw® Family filter demonstrates that the filter capacity lies around 18,000 litres or more.

LifeStraw® Family has been designed to be long-lasting in the field, thus reducing the need for short-term repeat interventions and minimising behaviour change.

LifeStraw® Family – Consumer Acceptance Study

A pilot study in the Democratic Republic of the Congo

In cooperation with USAID-funded project AXxes, a large rural health organization that builds and maintains a health infrastructure for rural Congo, Vestergaard Frandsen has set up a pilot study to investigate the functioning and acceptability of LifeStraw® Family by its intended target group.

Larry Sthreshley, director of project AXxes, writes the following about this research:
"We have been involved in improving water availability and quality for 36 years in Congo. Over the years we have put in thousands of clean water sources but we have been looking for an affordable technology that would provide clean water to families that do not have access to a clean water source. The LifeStraw® Family seemed like it might fit our needs so we jumped at the opportunity to test it in Congo.

The product was given to 10 Congolese families that had limited access to safe drinking water. The usage was followed for a month. Three visits were done during this time period – one to hand out and explain the product, one after a week to check for any problems and questions, and one after a month to evaluate the product with the people.

After the purpose and usage of the product was explained and demonstrated, the product was greatly appreciated and accepted by all families. The products showed no malfunction or damage after a month's usage, and showed impressive flow rate of one litre in less than five minutes. The participants found them easy to use and maintain, and several participants mentioned that their children had no diarrhoea since using the product. We suggested some small improvements to the product, which Vestergaard Frandsen is now working on implementing.

Both Vestergaard Frandsen and AXxes intend to expand on this trial with more long-term and intensive studies with LifeStraw® Family. Together, we are also elaborating on how to properly communicate the usage to the people to increase acceptability and impact of this great intervention."

Complete report on the pilot study available on request.

Abbreviations/ Definitions

Aging water: Water passed through the filter with determined known PH-TOC-total dissolved solids and turbidity to measure the filter's resistance to clogging, flow-rate and lifetime.

CI: Confidence Interval.

CFU: Colony-Forming Unit (CFU) is a measure of viable bacterial numbers. It allows users to assess the degree of contamination in samples of water.

Challenge water: Water passed through the filter for microbiological efficacy tests. In this water, disinfectant is completely removed and residue level should be non-detectable. This is to ensure that there is no interference from residual chlorine (most tap water is chlorinated) on the contaminants introduced in the water and give a more accurate measure of the filter's microbiological efficacy.

E.P.A.: The Environmental Protection Agency (EPA or USEPA) is an agency of the federal government of the United States charged with protecting human health and safeguarding the natural environment, namely air, water, and land.

Log reduction: "Log" stands for logarithm, which is the exponent of 10. For example, $\log_2$ represents 10^2 or 10 x 10 or 100. Log reduction stands for a 10-fold or one decimal or 90% reduction in numbers of recoverable bacteria in a test food vehicle. Another way to look at it is: 1 log reduction would reduce the number of bacteria by 90%. This means, for example, that 100 bacteria would be reduced to 10 or 10 reduced to 1.

MS2 *coliphage*: A virus which is easily cultivated in laboratories and used to measure viral reduction efficacy of the filter.

NTU: Nephelometric turbidity units. Turbidity refers to how clear the water is. The greater the amount of total suspended solids (TSS) in the water, the murkier it appears and the higher the measured turbidity.

***Oocyst*:** The spore phase of certain protozoa, such as *Cryptosporidium* and *Toxoplasma*. This state can survive for lengthy periods outside a host and is very resistant.

PFU: Plaque-Forming Unit (PFU) is a measure of viable numbers of viruses in the water.

Point-of-use interventions: For those who have access to sufficient quantities of water but whose water is of poor microbiological quality, an alternative is to treat water at the household or other point of use. Such a household treatment may minimise recontamination in the home, a well-known cause of water quality degradation.[11] Interventions used in the studies include: filtration (ceramic), solar disinfection, chlorination, flocculation/disinfection and improved storage.

RR: Rate of reduction.

SoDis: Solar Disinfection.

TOC: Total organic carbon: material in the water derived from decaying vegetation, bacterial growth, and metabolic activities of living organisms or chemicals.

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Product Delivery and Customer Support

Delivery
Vestergaard Frandsen works with a multitude of local partners to provide the exceptional service of delivering products to in-country destinations rather than simply shipping them to the container port, as is the case with most other suppliers.

We have developed a distribution network across the African continent, establishing delivery channels for deeper penetration inlands and ensuring a seamless delivery to the end destination.

Warehousing
Vestergaard Frandsen also has warehouse facilities in the remotest parts of the world, allowing the company to help international aid agencies provide rapid relief in times of natural or man-made disasters.

Customer Support
With 11 regional offices across Africa, Asia and the Americas, Vestergaard Frandsen provides an exceptional local and international customer service. Being close to the market is an unequivocal benefit for our customers and partners, allowing rapid and proactive service and market intelligence.

This unique profile makes Vestergaard Frandsen the optimal partner for disease-control needs.

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