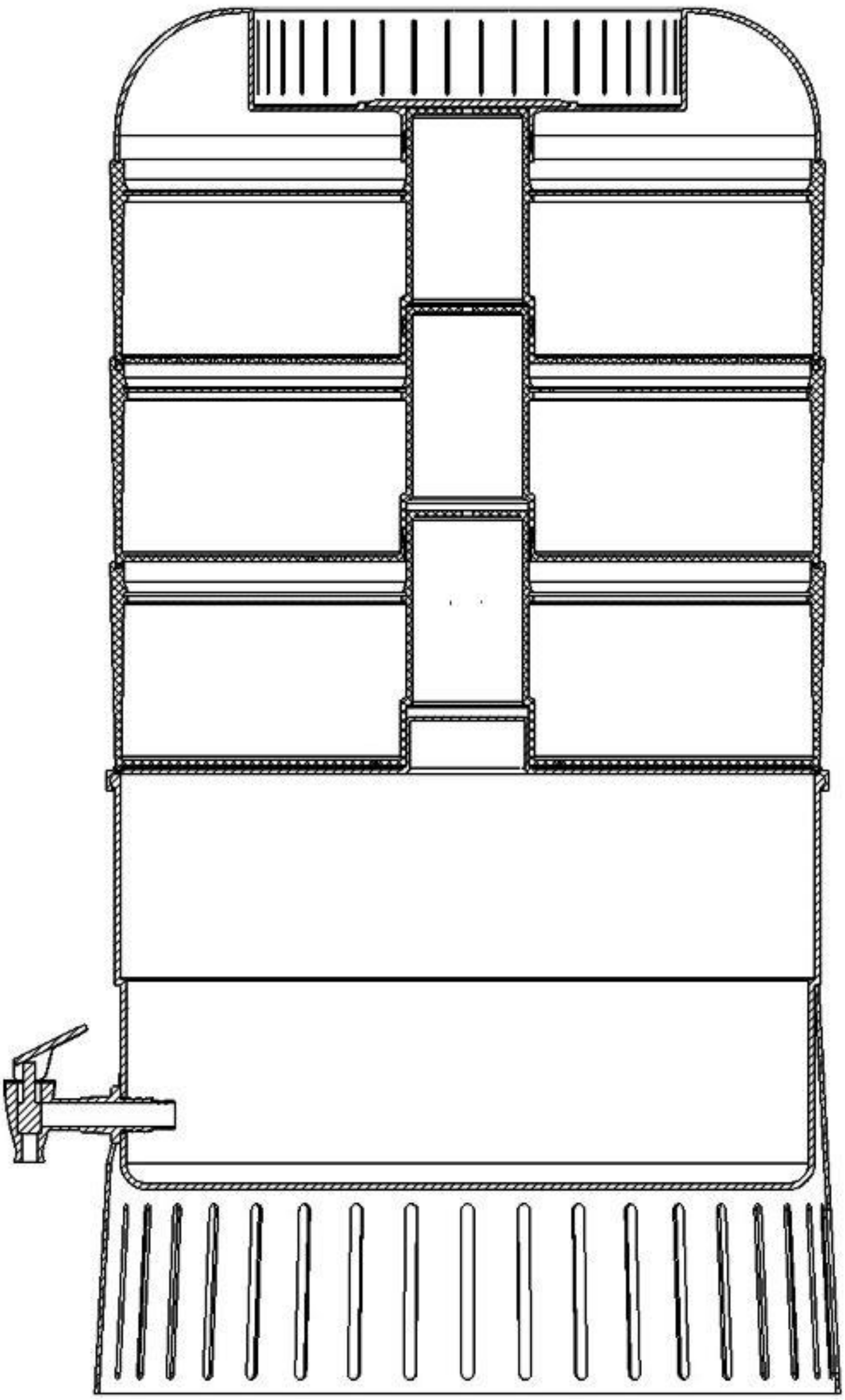
MOREWATER

A Point of Use Water Purifier

Research and Development Report



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1. Overview

Our product focuses on addressing the potable water needs of the 1000 households deemed most vulnerable in the Korail slum in Dhaka, Bangladesh (as determined by their proximity to Lake Gulshan due to the associated waterlogging risk, and an income in the bottom 30% range of less than 9000BDT per month). This high-density population suffers from seasonal waterlogging and flooding which contaminates their government water supply (DWASA). To correct for this, many turn to illegal sources or the market where they can buy jars of clean water. Despite this market resilience, multiple factors lead inhabitants to not accessing clean water consistently, often drinking contaminated water from government pumps.

To address this situation, a PoUWT (Point of Use Water Treatment) device has been designed to meet the specific needs and cultural demands of the environment. It will address and overcompensate for the market gap which has been established as a minimum of 283,800 litres per year across the targeted 1000 households. We have designed it for long term use, to reduce the costs associated with acquiring water from non-DWASA water supplies (DWASA water costs 0.01 BDT per 1 litre compared to 4 BDT per litre from market retail of 10 litre jars).

Furthermore, market analysis of existing water supplies and stakeholders has been conducted, to ensure the product works with existing infrastructure and key players. The product draws from issues with current emergency water distribution methods, such as the distribution of locally procured potable water to Korail by NGOs during emergencies which is associated with high costs, and the inconvenience and difficulty for households to travel to mobile water treatment plants deployed by the Red Cross.

2. Market Research

2.1. Background Information

Through market analysis conducted in a PCMMA (Pre-Crisis Mapping and Analysis) report of Potable Water and Agricultural Labour Market Systems in Korail and Rural Sirajganj, it can be shown that the water market system in Korail provides a sufficient volume of water for the target population. However, ongoing concerns and issues with the consumption of untreated water from unsafe sources remain. During emergencies, there is a nearly universal local contamination of WASA (the government's Water Supply and Sewerage Authority) water points, which are the main sources of drinking water. PCMMA findings illustrate that those Korail households in the lower economic strata face a host of health hazards associated with the rainy season, when very little water from Korail sources is safe to use without treatment.

2.2. Key Problems

The key problem we will focus on (due to its annual and long-lasting impact) is waterlogging, which occurs when seasonal rains do not drain away from dwelling areas, and standing water lingers in houses for hours or days at a time. Accumulated solid waste blocks drainage ditches, pathways and pipes that drain water from the high ground of Korail, over the low ground and into Lake Gulshan. Inundation and standing water contaminates drinking water by entering at imperfectly sealed joints in the pipes that carry water to and through Korail, by spilling into boreholes and be bacteria transmission at the point of use.

2.3. Existing Stakeholders

The water market in Korail presents a complex environment with many NCO, NGO, CBO and government, political and informal stakeholders. Due to this complexity, it is recommended in a market analysis that establishment with the Korail community and those who provide services must come first. The stakeholders currently operating in the environment are as follows:

Dhaka WASA	Government water supply and sewerage authority of the Dhaka metropolitan area, which is more than 360 square kilometres and contains more than 12.5 million inhabitants. Divided into 11 geographic zones, and provides 2.11 million cubic meters of water per day to Dhaka. (Dhaka WASA)
Dhaka North City Corporation	Self-governing corporation associated with the task of running the affairs of Dhaka. Incorporated area is divided into several wards, each with a selected ward counsellor. There is a wing called the 'Slum Development Wing' under the Social Welfare and Slum Development Department of City Corporation. They are tasked with several aspects of life in slums, including increasing potable water supply, improving drainage system and improving sanitary conditions.
Ward Counsellor	One counsellor from each ward, selected by the constituents attend DCC meetings and can formulate development plans relating to their wards with assistance from the staff of the zone. They also monitor ward-level services. They have considerable political influence, and coordination with their office should be a consideration in program design.
Manufacturer	Companies that manufacture materials such as water pumps, pipes, filters, for the Dhaka water supply system. DWASA purchases materials directly from manufacturers, but the Korail inhabitants cannot do so legally.
Local traders / wholesalers of water supply materials	Local traders (wholesalers and retailers) are the key service providers for the slum dwellers. Local traders purchase the water supply materials from the whole sellers and sell to local people (including pipe segments and hand pump parts).

Vending Machine	There is currently one water vending machine in Korail which was installed by Oxfam and costs .25 BDT per litre, producing 4,000 litres of potable water per hour. It is hooked up to a DWASA point, treating water before dispensing it. It cost 5.9 million BDT. It serves 150 households.
DWASA Pipe Water Supply	A water supply network built by Dhaka WASA which treats approximately 450 million litres of water per day at the Saidabad Water Treatment Plant (DWASA, 2010-2011). Slum dwellers have access to the water supply from legal and illegal connections. It accounts for 75% of water consumed by households in Korail.
Community-based water supply system	This is a pipe network water supply arrangement. It includes a deep tube well which pumps water up to a raised storage tank. Head pressure from the storage tank pushes water to households through a network of pipes installed and managed by community members. Households located between hubs of distribution must gather water from their water-connected neighbours, or go on foot to gather water from a public point.
Deep tube well	Tube wells are installed to tap deep aquifers where the water table is very low. A strainer at the base of the pipe keeps out grit. WASA runs 600 deep tube wells in Dhaka to extract water, in conjunction with 2,000 private tube wells throughout the city. 87% of Dhaka's water provided by WASA comes from ground water, with 13% from treated surface water (Khan).
Contractor	A person or firm that undertakes a contract to provide materials or labour to build the water sippy system. They are hired by DWASA.
Existing NGOs	These include but are not restricted to Oxfam and the Red Cross, and their involvement varies depending on the season, emergency and status of the slum. As a result, they would need to be contacted if the product was to go through to implementation, to determine how best to coordinate efforts.
Consumer	Users of the existing water supply from any of the above stated sources. Would also be recipients of the water filter and use in conjunction with the existing water supply.

Table 1: Existing Stakeholders

The government DWASA water supply can be aided by our product – it does not detract from the main market (manufacturers, the North City Corporation or WASA), but may increase usage of the WASA supply in times of flood as people will not need to turn to alternate sources of water such as illegal suppliers and market sales. Therefore, we have solid grounds on which to work and be funded by the Ward Counsellor, Dhaka North City Corporation and WASA. Potentially we would also be able to partner with existing NGO's in the region, specifically Oxfam and the Red Cross.

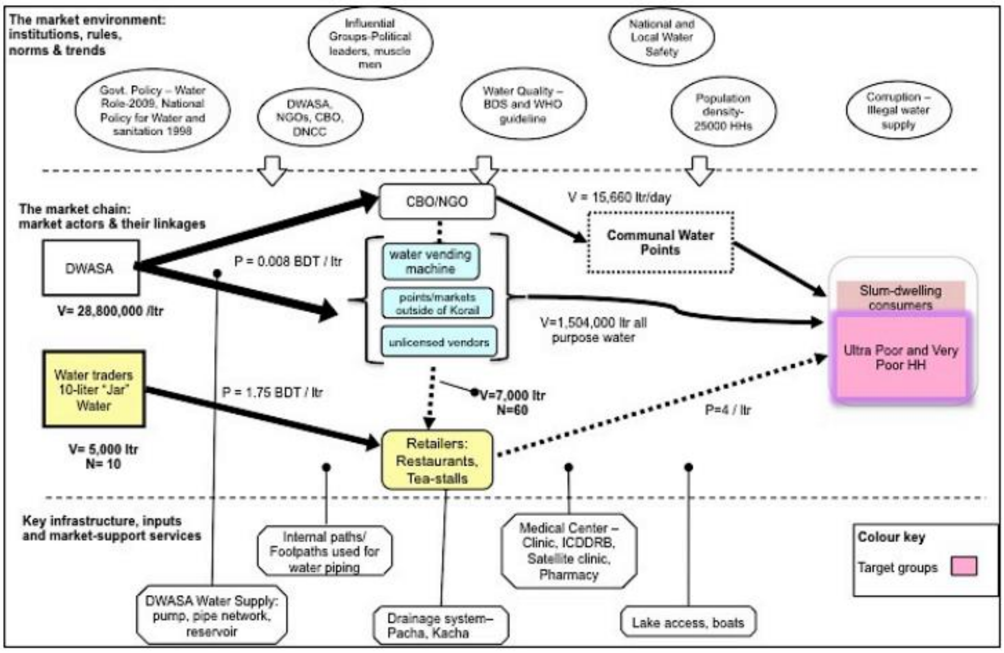

Figure 1: The Potable Water Market Baseline Map for Korail (EMMA , 2015)

2.4. NGO Suggested Market Sensitive Programming Options

In a market analysis report, three culturally sensitive and appropriate options for water relief were advised. They are as follows:

1. Unconditional cash, distributed in envelopes or by mobile money transfer for relief and recovery. An adequate supply of potable water is available nearby – the average cost of water is less than 2% of household expenditure in an emergency context, but households experience a significant drop in income of nearly 20% in times of flood (due to movement difficulties, closure of places of work, illness and lack of customers.) Money can help cover this cost of potable water. However, consumers could choose to spend this money on areas they deem more desperate such as medical care, and risk drinking from contaminated sources anyway.
2. Distribute locally procured water as it is available year-round at retail and wholesale prices with the market in and around Korail. Various market actors can be targeted to supply water purchased by NGOs for distribution. However, this is not sustainable, and does not treat the problem at its source. It also comes at an inflated cost for distribution.
3. Installation of mobile water treatment plants. As water availability is not the issue (WASA pipes and water points continue to yield plentiful water during the rainy season – it is contamination that is the problem), mobile water treatment plans such as those already deployed in Bangladesh by the Red Cross can bring rapid, local access to clean water. They work by pumping water into large collapsible pools where water is then filtered and chemically treated, then distributed to those affected.

Our product considers the cultural and market considerations of these approaches, and aims to solve the shortfalls of each method. It ensures consumers have access to clean water (through a product and not just cash), it has low running costs, and does not require people to travel extensively through flooded areas to reach treatment plants – the water can be treated in their own homes.

2.5. Target Population and High Risk Periods

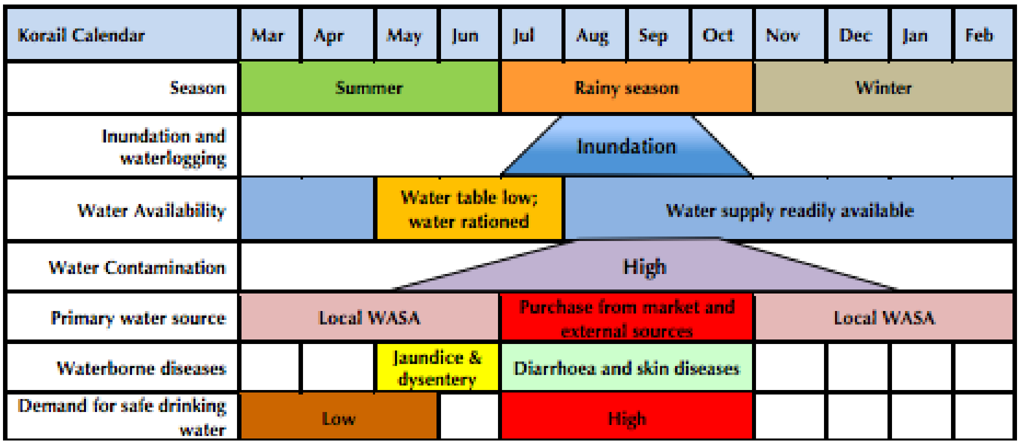

Figure 2: Prevalence of Contamination Over Time (EMMA , 2015)

Water contamination (as shown) is most prevalent during the peak of the rainy season – August and September, which coincides with the highest prevalence of waterlogging. This has a long crescendo and de-crescendo period at the beginning and end of the rainy season respectively. The latter half of the summer also sees increased risk as the water table is low, ambient air temperature high, and contamination is concentrated in diminishing water supplies.

2.6. Identifying a Target Population

20,000 people live in Korail. The entire neighbourhood is an informal settlement, although very longstanding. Households situated at the edge of the settlement bordering the lake are particularly prone to waterlogging and waterborne diseases. Many households interviewed treated their water by boiling or with chemicals some of the time, but few treated it all the time; boiling takes time and required the purchasing of fuel and woof. Chemical treatments cost money and require a trip to the retailer. Households are accustomed to changing their potable water sources, and are experienced in interacting with the market. As such market-based interventions such as our water filter are appropriate.

The most vulnerable households earn less than 9000 BDT per month, which make them in the bottom of 30% of the income range. The most vulnerable are also dwelling on the lakeshore of low-lying areas of Korail as they face the most intense environmental health hazards and often don't have direct or easy access to water points. There are approximately 1000 households that meet the vulnerability.

3. Economic Potential

3.1. Market Gap

Sphere standards dictate that the minimum volume of drinking water needed per individual per day is 3 litres, and the total daily need which includes water for hygiene and cooking is between 7.5 and 15 litres, depending on the context. The baseline average consumption of potable water per household per day is 18.85 litres. The average household in Korail faces 60 days of inundation over the course of the year. The total gap is the average shortfall of the volume of potable water per day, multiplied by the number of days of shortfall.

No. Targeted HHs	Avg. potable water consumption per HH per day (Baseline)	Avg. potable water consumption per HH per day (Emergency/ Inundation)	Gap in litres, per day per HH	Gap duration in days during 1 year	TOTAL GAP (litres)
1,000	18.85 ltr	14.12 ltr	4.73 ltr	60 days	283,800

Table 2: Korail Potable Water Household Gap Analysis (EMMA , 2015)

This reveals a total gap of 283,800 litres of water per year across the 1000 targeted households. Therefore, the filter has been designed to far exceed this existing requirement.

Monthly household income/ expense	Avg. Baseline (BDT)	Avg. Emergency (BDT)	% Change	Difference (BDT)
Income	12,100	9,750	19%	2,350
Expenses	10,640	10,371	3%	268

Table 3: Korail Household Income and Expenditure Profile (EMMA , 2015)

The seasonality of income and expenditure patterns of the targeted household show that the largest effect of an emergency is a 19% dip in household income. This indicates that the market systems that support households are quite resilient, but household incomes are considerable more sensitive.

3.2. Cost of Existing Water Supplies in Korail

The following table demonstrates the different costs of water from different market players in Korail. It indicates that filtering water directly from a WASA tap (if the filter is at no extra cost to the households) is the cheapest option for those in an emergency situation.

Type of Suppliers	Total volume per day (baseline *and* emergency)	Price per litre, BDT	Number of targeted HH served
WASA	15,660	.01	783
Vending Machine	200	.25	10
Illegal Suppliers	3,140	.012	157
Market retail (10 litre jar)	1,000	4	50
Total	20,000		1,000

Table 4: Korail Market System Actors

3.3. Stakeholder Needs and Potential Funding

3.3.1. NGO Needs and Funding

As discussed in NGO Suggested Market Sensitive Programming Options the three options suggested are unconditional cash for purchasing water, distributing water and installation of mobile water treatment plants.

The product achieves a permanent version of the mobile water treatment allowing for unsafe water to be converted. If an NGO pays for the initial filter the minimal maintenance of the device will allow for the users to maintain it. According to Ben Mountfield, who has worked for NGOs for three decades and is now a leading consultant for the UN, WHO, Red Cross and Oxfam, NGO's can often find a large company interested in fronting the capital costs of the product, and then the NGO takes over the running costs. Therefore, this represents an attractive option for NGOs looking to provide water stability, as it would not deplete their funds through high running costs, as with other current market solutions.

Its potential for continued uptake also means NGOs can direct their attention elsewhere, not having to focus on potable crises from waterlogging and flooding. This freeing up of resources could greatly benefit other areas of humanitarian aid.

3.3.2. Government Funding

The Ward Counsellor for Dhaka North City Corporation's 'Slum Development Wing' has a contractual obligation to provide safe, drinkable water to the inhabitants of Korail. This is currently not being met. Furthermore, WASA is a government water supply, which loses income during waterlogging as consumers generally turn away from it and to other 'safer' sources. Therefore, there exist two branches of government invested in the water situation in Korail, who would both benefit in different ways if this product was to be taken up by Korail households. The Ward Counsellor would be making progress along his political agenda, and Dhaka's WASA would be increasing revenue and trust of consumers.

This provides a strong basis for integration into the community and possible government funding. Contact with these branches of the government could be made through the NGOs operating in the area who already have existing ties and relationships.

According the World Bank in 2007 the lack of treatment of household potable water cost US$140.6 million in Bangladesh (World Bank Group, 2017). Accounting for year on year inflation of BDT (values were converted to USD) this equates to US$270.9 million in 2015 (Trading Economics, 2017). During 2015 13.1% of Bangladesh had access to clean water (The World Bank, 2017), which equates to approximately 21.1 million people (The World Bank, 2017). When combined this equates to US$12.84 per person and therefore US$89.87 per household per year. If the product is priced below this US$89.87 threshold the government will have a positive return after the 1st year continuing for up to the 10 year product life after the initial investment. This saved money could potentially be reinvested into a more permanent solution for sanitation for the area. At a 2% projected inflation rate for 10 years and if deployed in 2017 the potential return would be US$3 Billion. It must be noted that this is assuming adequate hygiene practices being followed.

4. Design Research

4.1.1. Capacity

Referring to the SPHERE handbook the minimum required water per person per day is 2.5-3L of drinking water. To cater for a household within Korail the majority are between 5-8 people in size (Pramanik, Dipok, & Ram, 2011). A capacity over 20L allowing for a day of water from the tank while if more water is wanted it can still be topped up.

4.1.2. What Needs to be Filtered

Arsenic

As discussed by WHO, they state that *"Bangladesh is grappling with the largest mass poisoning of a population in history because groundwater has been contaminated with naturally occurring inorganic arsenic"* (WHO, 2000).

Arsenic is introduced into water through the dissolution of rocks, minerals and ores, from industrial effluents, including mining wastes, and via atmospheric deposition (WHO, 2011).

The acute effects of Arsenic on people include vomiting, abdominal pain and diarrhoea. These are followed by numbness and tingling of the extremities, muscle cramping and death, in extreme cases (WHO, 2010). The long-term effects can include lesions, pigmentation change of skin and hard patches of skin on hands and soles of the feet. Other effects include peripheral neuropathy, gastrointestinal symptoms, conjunctivitis, diabetes, renal system effects, enlarged liver, bone marrow depression, destruction of erythrocytes, high blood pressure and cardiovascular disease. Furthermore, Arsenic has been shown to cause cancers of the skin, bladder and lungs. (WHO, 2010)

Waterborne Bacteria

Severe illness can be caused by many waterborne bacteria in the water supply. These can include Botullism, Campylobacteriosis, Cholera, E. coli Infection, M. marinum infection, Dysentry, Legionellosis (two distinct forms: Legionnaires' disease and Pontiac fever), Leptospirosis, Otitis Externa, Salmonellosis, Typhoid fever, Vibrio Illness.

Waterborne Protozoa

Illnesses include Amoebiasis (hand-to-mouth), Cryptosporidiosis (oral), Cyclosporiasis, Giardiasis (fecal-oral) (hand-to-mouth), Microsporidiosis.

Giardia, Cryptosporidum, Entamoeba histolytica (Amoebiasis) and have been identified as being resistant to chlorination, although remain susceptible to UV rays. (CDC, 2007)

Waterborne Viruses

Illnesses include SARS (Severe Acute Respiratory Syndrome), Hepatitis A, Polio and Polyomavirus infection.

Chemicals

WHO provide a list of numerous chemicals which can be found in drinking water from various sources. As in in Tables 5-9 there is a breakdown of chemicals and their subsequent potential for removal through various treatment options.

	Air stripping	Coagulation	Ion exchange	Precipitation softening	Activated carbon	Ozonation	Advanced oxidation	Membranes
Cadmium		+++ <0.002	+++ <0.002	+++ <0.002				+++ <0.002
Mercury		+++ <0.0001		+++ <0.0001	+++ <0.0001			+++ <0.0001
Benzene	+++ <0.01				+++ <0.01	+++ <0.01		
Carbon tetrachloride	+++ <0.001	+			+++ <0.001			+++ <0.001
1,2-Dichlorobenzene	+++ <0.01				+++ <0.01	+++ <0.01		
1,4-Dichlorobenzene	+++ <0.01				+++ <0.01	+++ <0.01		
1,2-Dichloroethane	+				+++ <0.01	+	++	
1,2-Dichloroethene	+++ <0.01				+++ <0.01	+++ <0.01		
1,4-Dioxane						+++ no data		
Edetic acid (EDTA)					+++ <0.01			
Ethylbenzene	+++ <0.001	+			+++ <0.001	+++ <0.001		
Hexachlorobutadiene					+++ <0.001			
Nitrilotriacetic acid (NTA)					+++ no data			
Pentachlorophenol					+++ <0.0004			
Styrene	+++ <0.02				+++ <0.002			
Tetrachloroethene	+++ <0.001				+++ <0.001			
Toluene	+++ <0.001				+++ <0.001	+++ <0.001	+++ <0.001	
Trichloroethene	+++ <0.02				+++ <0.02	+++ <0.02	+++ <0.02	
Xylenes	+++ <0.005				+++ <0.005		+++ <0.005	

[a] Symbols are as follows:
+ Limited removal
++ 50% or more removal
+++ 80% or more removal

[b] The table includes only those chemicals for which some treatment data are available. A blank entry in the table indicates either that the process is completely ineffective or that there are no data on the effectiveness of the process. For the most effective process(es), the table indicates the concentration of the chemical, in mg/litre, that should be achievable.

Table 5: Treatment achievability for chemicals from industrial sources and human dwellings for which guideline values have been established (WHO, 2006)

	Chlorination	Coagulation	Ion exchange	Precipitation softening	Activated alumina	Activated carbon	Ozonation	Membranes
Arsenic		+++ <0.005	+++ <0.005	+++ <0.005	+++ <0.005			+++ <0.005
Fluoride		++			+++ <1			+++ <1
Manganese	+++ <0.05	++					+++ <0.05	+++ <0.05
Selenium		++	+++ <0.01		+++ <0.01			+++ <0.01
Uranium		++	+++ <0.001	++	+++ <0.001			

[a] Symbols are as follows:
++ 50% or more removal
+++ 80% or more removal

[b] The table includes only those chemicals for which some treatment data are available. A blank entry in the table indicates either that the process is completely ineffective or that there are no data on the effectiveness of the process. For the most effective process(es), the table indicates the concentration of the chemical, in mg/litre, that should be achievable.

Table 6: Treatment achievability for naturally occurring chemicals for which guidelines values have been established (WHO, 2006)

	Chlorination	Air stripping	Coagulation	Ion exchange	Activated carbon	Ozonation	Advanced oxidation	Membranes	Biological treatment
Nitrate				+++ <5				+++ <5	+++ <5
Nitrite	+++ <0.1					+++ <0.1	+++ <0.1		
Alachlor					+++ <0.001	++	+++ <0.001	+++ <0.001	
Aldicarb	+++ <0.001				+++ <0.001	+++ <0.001		+++ <0.001	
Aldrin/dieldrin			++		+++ <0.00002	+++ <0.00002		+++ <0.00002	
Atrazine			+		+++ <0.0001	++	+++ <0.0001	+++ <0.0001	
Carbofuran	+				+++ <0.001			+++ <0.001	
Chlordane					+++ <0.0001	+++ <0.0001			
Chlorotoluron					+++ <0.0001	+++ <0.0001			
Cyanazine					+++ <0.0001	+		+++ <0.0001	
2,4-Dichlorophe-noxyacetic acid (2,4-D)			+		+++ <0.001	+++ <0.001			
1,2-Dibromo-3-chloropropane		++ <0.001			+++ <0.0001				
1,2-Dibromoethane		+++ <0.0001			+++ <0.0001				
1,2-Dichloropropane (1,2-DCP)					+++ <0.001	+		+++ <0.001	
Dimethoate	+++ <0.001				++	++			
Endrin			+		+++ <0.0002				
Isoproturon	++				+++ <0.0001	+++ <0.0001	+++ <0.0001	+++ <0.0001	
Lindane					+++ <0.0001	++			
MCPA					+++ <0.0001	+++ <0.0001			
Mecoprop					+++ <0.0001	+++ <0.0001			
Methoxychlor			++		+++ <0.0001	+++ <0.0001			
Metalochlor					+++ <0.0001	++			

Table 7: Treatment achievability for chemicals from agricultural activities for which guidelines values have been established (WHO, 2006)

	Chlorination	Coagulation	Activated carbon	Ozonation	Advanced oxidation	Membranes
DDT and metabolites	+	+++ <0.0001	+++ <0.0001	+	+++ <0.0001	+++ <0.0001
Pyriproxyfen			+++ <0.001			

[a] Symbols are as follows:
+ Limited removal
+++ 80% or more removal
[b] The table includes only those chemicals for which some treatment data are available. A blank entry in the table indicates either that the process is completely ineffective or that there are no data on the effectiveness of the process. For the most effective process(es), the table indicates the concentration of the chemical, in mg/litre, that should be achievable.

Table 8: Treatment achievability for chemicals from agricultural activities for which guidelines values have been established (continued) (WHO, 2006)

	Chlorination	Air stripping	Coagulation	Ion exchange	Activated carbon	Ozonation	Advanced oxidation	Membranes	Biological treatment
Simazine	+				+++ <0.0001	++	+++ <0.0001	+++ <0.0001	
2,4,5-T			++		+++ <0.001	+			
Terbuthylazine (TBA)			+		+++ <0.0001	++			
Trifluralin					+++ <0.0001			+++ <0.0001	

[a] Symbols are as follows:
+ Limited removal
++ 50% or more removal
+++ 80% or more removal
[b] The table includes only those chemicals for which some treatment data are available. A blank entry in the table indicates either that the process is completely ineffective or that there are no data on the effectiveness of the process. For the most effective process(es), the table indicates the concentration of the chemical, in mg/litre, that should be achievable.

Table 9: Treatment achievability for pesticides used in water for public health for which guidelines values have been established (WHO, 2006)

4.1.3. Filtration and Purification Methods

Method	Required Energy Source	Longevity	Filter Size	Eliminates
Reverse Osmosis	200 – 1700KPa Approximately	Shortest time till clogged	0.0001 μm to 0.001 μm	Mostly all molecules except for water.
Microfiltration	100-400 KPa (Minnesota Rural Water Association, 2017)	Longest until clogged	0.1 to 10 μm	sediment, algae, protozoa or

				large bacteria
Nanofiltration	600-1000KPa (Minnesota Rural Water Association, 2017)	Medium time until clogged	0.001 µm to 0.01 µm	multivalent ions, synthetic dyes, sugars and specific salts and those from larger filter sizes
Ultrafiltration	200-700KPa (Minnesota Rural Water Association, 2017)	Shortest time till clogged	0.1 µm to 0.01 µm	proteins, endotoxins, viruses and silica and those from larger filter sizes
Activated Charcoal	Water Pressure	Needs to be tested. Approximately 1000L		Organic Chemicals
Iron Modified Activated Carbon	Water Pressure	Unsure without lab testing and arrangement		Organic Chemical and Arsenic
Centrifuge	Various generally over 400W	Until motor or motor failure with maintenance		Bacteria
Pulsed Electric Field	Around 60000kV 50hz (Mini Tesla Coil?)	Unsure without lab testing and arrangement		Bacteria and Virus
Gamma Radiation	Radioactive materials	Caesium-137 (Half-life = 30 Years)		Bacteria and Virus
UVC Radiation LED or Lamp	<1W for LED 10+W for Fluorescent Bulbs	50000 Hours for LED Approximately 7000 for bulb		Bacteria and Virus

Table 10: Filtration and Purification Methods

4.2. Activated Carbon Filter Types

Types of Activated Carbon						
Type	Cost	Particulate removal	Reactivation Period	Reactivation mass loss	Particulate size	Positives Properties
Granulated Carbon	$1.14 per kg.	Uses high flow rate to push fluid through grains.	18 months.	Separation and back washable - 5-15% of effective mass.	0.2-5mm.	Large quantity viscous purification.
Powdered Carbon	$50,000 per 10 million gallons a day.	Bacteria within liquid phase absorption.	Cannot be regenerate due to condensed	NONE	0.5 – 1 nm.	Lower Production costs, simple manufacture.
Extruded Carbon	$6.45 per kg.	Low pressure removal from gaseous heat exchange.	Heavy duty non-reusable components.	NONE	1-5mm.	Emission and purification control.

Sheet Carbon	Size dependant cost - $92.00 per square metre.	Meshed carbon weave to remove solid particulates.	Not found	Back washable – 10% effective mass per removal.	20-50µm.	Liquid purification and water desalination

Table 11: Types of Activated Carbon Comparison and Suitability (Heycarb - Activated Carbon Solutions, 2017)

4.3. Activated Carbon Filter Effectiveness

Activated carbon reduces by 80% or more; Mercury, Benzene, Carbon tetrachloride, 1,2-Dichlorobenzene, 1,4-Dichlorobenzene, 1,2-Dichloroethene, 1,4-Dioxane, Ethylbenzene, Toluene, Trichloroethene, Xylenes, Alachlor, Aldicarb, Aldrin/dieldrin, Atrazine, Carbofuran, Chlordane, Chlorotoluron, Cyanazine, 2,4-Dichlorophe noxyacetic acid, 1,2-Dibromo-3- chloropropane, 1,2-Dibromoethane, 1,2-Dichloropropane, endrine, isoproturon, lindane, MCPA, Mecoprop, Methoxychlor, Metalochlor, simazine, "2,4,5-T", Terbuthylazine, Trifluralin, DDT and metabolites and Pyriproxyfen. (WHO, 2006)

4.4. Granular high-rate filtration effectiveness

As discussed by WHO, granular high-rate filtration removes 70% of protozoa at baseline levels. (WHO, 2006)

4.5. Microfiltration Effectiveness

As discussed by WHO, microfiltration can remove 99.9 – 99.99% of bacteria, 90% of viruses and 99.9-99.99% of protozoa. (WHO, 2006)

4.6. UVC Radiation Effectiveness

As discussed in the WHO Guidelines for Drinking Water Quality, UV irradiation can inactivate 99% of viruses at 59mJ/cm^2, 99% of bacteria at 7mJ/cm^2 and 99.9% of Protozoa at 10mJ/cm^2 (WHO, 2006).

LG manufactures a 70mW UVC LED providing 70mJ/s (LG Innotek, 2017) which would allow for a relatively fast flow rate when 4 are used in parallel. Further research will be taken to identify the best flow rate for maximal efficiency and speed requirements.

4.7. Combined Effectiveness

When Granular high-rate filtration, microfiltration and UVC Radiation are combined the baseline removal of viruses becomes 99.9%, bacteria 99.999% and 99.999995% of protozoa.

4.8. Preliminary Pricing

Parts	Material	Quantity	Price per Unit	Total Price
Storage Bucket	Food Grade and UV Resistant Polycarbonate	1	$1.00**	$1.00
Basic Filter Stage	UV Stabilized Food Grade HDPE	3	$0.68**	$2.04
Basic Filter Stage Lid	Food Grade HDPE	2	$0.08**	$0.16
Top Unit	UV Stabilized Food Grade HDPE	1	$0.28**	$0.28
UV Filter Stage Lid	Food Grade HDPE	1	$0.09**	$0.09
Steel Microfilter	Stainless Steel	1	$8.00**	$8.00
UVC LED	Bought in	2	$7.99*	$15.98
Status LED	Bought in	1	$0.01*	$0.01
Lithium Ion Battery 2000mah	Bought in	1	$4.00*	$4.00
2 Watt Solar Panel	Bought in	1	$3.72*	$3.72
UVC LED Housing	Stainless Steel	2	$0.21**	$0.42
Microcontroller	Bought in	1	$1.00**	$1.00
Activated Carbon	Bought in	2kg	$1.14**	$2.28
Sand	Bought in	4kg	$0.44*	$1.76
				$40.74

*Table 12: Preliminary Estimate Pricing * denotes price found from retailers **denotes price found from wholesaler*

4.9. Method of production of low cost micro filters

As discussed in the report Microfiltration Membranes with Straight Pore Challenges Formed by High-speed Fiberlaser Perforation of Stainless Steel Foils (Baumeister, Dickmann, Duka, & Hoult, 2006), a limiting factor in producing microfilters is the speed of production. The paper suggests a manufacturing method involving a laser to perforate steel then proceeding to cold roll the foil.

5. Final Design

The MoreWater Water Purifier is a long-life point-of-use water purifier with built in safe water storage designed for a household of seven people.

5.1.1. Consumer impact and uptake

To ensure the response to the product by consumers is positive and result in continuous use, the product has been designed with their specific needs and the stakeholders needs in mind. First and foremost comes the cost of clean water to the consumer. Current prices from local water sources if one source was used for the entire year are as below:

Supplier	Price of water (BDT) per year per household	Price (BDT) premium per year over WASA
WASA	91.25	0
Vending Machine	2281.25	2190
Illegal Supply	109.5	200.25
Market retail (10 litre jar)	36500	36408.75

Table 13: Water prices from local sources

As is evident, WASA provides the cheapest water source. As our target consumers represent the 30% poorest of the Korail population, this is a large consideration. The MoreWater purifier allows consumers to reduce their overall water costs throughout the year if the unit is provided upfront. The purifier would allow households to rely solely on the WASA water supply at only 0.01BDT per litre.

Most importantly, the MoreWater purifier will prevent the drinking of contaminated water when alternate clean supplies are not used (such as the vending machine, and market retail options). As this happens in our target households for 4.73 litres per day per household, this represents a substantial quantity of contaminated water that would be prevented from being consumed.

Furthermore, the household by household design prevents consumers from having to travel to alternate water sources, creating a more convenient and easy to access potable water supply. Additionally, this product allows the families dignity, as they have the ability to be self-reliant – acquiring clean water in their own homes as opposed to relying on charity and scheduled water collections.

SDG 6 strives for continued and sustainable access to clean water for all. Current water aid in Korail tends to happen during a crisis, triggering an influx of aid agencies during that period. This does not present a sustainable solution to the situation. According to Ben Mountfield, crisis consultant for the UN, Red Cross, Oxfam and WHO, emergency crisis scenarios present an opportunity to introduce a new routine to populations that had dangerous practises pre-crisis (such as drinking contaminated water). Therefore, a flood leading to seasonal waterlogging would present an opportunity to provide Korail with the MoreWater purifier, and upon positive reception of the product, could result in a continued uptake after the crisis subsides. This would allow the sustainable availability of clean water, year-round.

5.1.2. Technical Specification

1. Designed as a potentially permanent personal PoUWT for Korail in Bangladesh.
2. Removes of 99.999% of bacteria, 99.9 % of viruses and 99.999995% of protozoa through combinations of microfilter and UVC light (WHO, 2006).
3. 21L water capacity which provides enough drinking water for 7 people for a day. (The Sphere Project, 2011)
4. Can purify over 100,000L
5. Provides 10 years of drinking water.
6. Requires annual maintenance.
7. Module based filtration allowing for modification for different markets
8. 2 LG 0.07W UVC LEDs (LG Innotek, 2017) with 1 Red Filter Replacement LED Indicator powered by ≈ 2W Solar Panel.
9. Four Stage Water Cleaning
   - Granular Filter Media to remove sediment
   - Modified Iron Impregnated Activated Carbon to remove, organic chemicals in the water and to improve taste. Arsenic concentrations are reduced to UN standards of 10 10 mgL^{-1}. (Weifang, Parette, Zou, & Cannon, 2007) (Zou, 2009) (WHO, 2011)

- Low pressure microfiltration using stainless steel membranes of between 0.1 and 10 μm which removes any material over the pore size. (Baumeister, Dickmann, Duka, & Hoult, 2006)
- UVC Instant Filter Stage to sterilize viruses and small bacteria. (Silva, Filho, Palha, & Sarmento, 2013)

10. Baseline removal of viruses is 99.9%, bacteria 99.999% and 99.999995% of protozoa.
11. Minimal product footprint of 365x365x685mm
12. Approximately 17kg
13. Basic Material Cost approximately $40.74

5.2. Design for Manufacture

The device is designed to not use any external fixings and is assembled top down with rotation locks for each stage. To ensure it is easy to maintain each module can be easily removed if needed for annual maintenance where parts can be sent for back flushing on a purpose build rig which locks onto the existing geometries of the device.

5.3. Product Materials Used

The product will be made from UV stabilized food grade HDPE for the bulk plastic materials and Polycarbonate or SAN for the water storage section.

5.4. Design for safe use

The device contains a solar panel which provides electricity for the UVC LEDs and the maintenance light which will turn on after a certain amount of use. This will illuminate the water with a red light to indicate its need for service.

5.5. Competing Products

Product	Flow Rate	Product Lifespan	Bacteria removal	Virus removal	Organic Chemical removal	Arsenic	Holding Capacity	Power Requirements	Cost	Availability
LifeStraw 1.0	$0.2Lm^{-1}$	1000L	Yes	No	No	No	0.65L	Human	£23.00	Worldwide
LifeStraw Family 2.0	$0.25Lm^{-1}$	18000L	Yes	No	No	No	2.8L	Gravity	£105.00	Worldwide
Kent Pearl UV household filter	$0.1Lm^{-1}$	819L	Yes	No	No	No	2.8L	Mains Electricity	£107.00	Private
First Need XLE purifier	$2.2Lm^{-1}$	240L	Yes	No	No	No	8L	Gravity	£23.00	AID Product
VestaGaard	$0.2Lm^{-1}$	70000-100000L	Yes	Yes	No	No	25L + 25L	Gravity	£264.00	AID Product – Community purchasable
MoreWater Purifier	Untested	100000L +	Yes	Yes	Yes	Yes	21L	Gravity and Sunlight	US$40.74 (£31.32)	TBD

Table 14: Existing Similar Products (MoreWater Purifier is using a raw material cost not including any other costs)

5.6. Testing Methodology

5.6.1. Purifier Functionality

To ensure proper functionality of the device it will be sent for 3rd party evaluation for certification before release. Due to testing of such a long-term device not being viable for 10 years they will have to be tested faster by having them continuously run through water of testing rigs to simulate the long period of time. Over the period of 1 year running constantly this will simulate 10 years of water assuming a $0.2Lm^{-1}$ flow rate.

5.6.2. User Uptake

To gauge user uptake of the device each device will be encoded with a unique identifier in the microcontroller and initial service date. When the machines return for their first service information on how much water was used will be taken and a new service date scheduled in the software. This could affect the future use of the product: those who use the product less may not need yearly services.

5.7. Potential for Expansion

Data taken will guide the next release of a successor device for potential expansion. A potential situation would be 50% of the people use 21L per day as predicted. 25% use 10L, 15% use 40L and 10% are missing. The next version of device potentially would have two capacities: a large and small edition that caters to those who need the extra 19L. The 10% of missing devices, if registered at the beginning, could have a service technician dispatched to inquire as to why they have not been brought for service. This could be done if the device is registered to a house or phone to find if the device just isn't used or even doesn't work. Using analytical methods and identifying further what people want from the device would assist in the future of product expansion.

As the purifier has been designed in a modular form, simple modifications with the addition, removal or changing of filtration levels will allow for use in different markets minimising new product setup costs. An example would be removing the iron impregnated activated carbon for plain activated carbon if there are no dangerous levels of arsenic in the water. Similarly, colours can be changed for different markets where different colours hold cultural significance. The microcontroller could be upgraded to unlock the potential for a smart device in the home, or recreational camping for wealthier consumers. Solar panels could be removed and changed for mains power in areas with running contaminated tap water such as areas of mainland China, Mexico, Russia, Brazil and countless others.

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