The Water Chariot

In the 21st Century, all people—no matter how poor—deserve adequate and safe water.

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The Environmental Resource Council (ERC) is a non profit organization that for 40 years has received support from government agencies and private foundations to find solutions to problems in health and environment.

Environmental Resource Council

Serving our social and physical environments since 1973

PROJECT SUMMARY

The Burden of Water in the 21st Century

In 2012, two leading economists with the World Bank, Karina Trommlerova and Gabriel Demombyne reported a well-documented drop in childhood mortality among low-income families in Africa. The World Bank goal of reducing childhood mortality by 50% within a decade was, in fact, becoming a reality. Michael Clemons, representing the Center for Global Development, described the report as, "the biggest, best story in the history of development."

While heroic medical surgeries and food lifts have been part of outreach to stressed populations for generations, this real life miracle was mostly about water – greater quantities of water for hygiene and safer water for drinking. The "Water Chariot" we are developing is intended to build upon this success. While still a work-in-progress, it is an approach that has huge promise in safeguarding and enriching the lives of those among us who are most in need.

What is the Water Chariot?

The Water Chariot is a tank also serving as an axle; it can hold 18 gallons of water and can be pulled over both smooth and rough terrain with minimal human effort. Its wheel hubs hold 14 used PET plastic beverage containers filled with water, which are vigorously agitated/oxygenized, or possibly filtered, as the Chariot is moved. Once arriving at its destination, the Chariot can be suspended upright and the wheels removed. The PET bottles resting in the multi-spectrum, reflective wheel bays can then be exposed to direct sunlight and enhanced levels of ultraviolet radiation and solar heat for 6 to 8 hours. Agitation, filtration, and enhanced UV radiation are all passive systems we are experimenting with to achieve water potability in conjunction with better transportation.

Limited access to water for hygiene and ingestion of contaminated water will cause dysentery involving diarrhea and consequent dehydration – the leading causes of illness and death among the world's children. Use of a system like the Water Chariot would have a profound impact on both the quality of life and especially the health of water stressed families.

Our Hope

The relationship between low-income people and water access is not apparent to most who live in developed nations. Reaching out to water stressed families is the most physically humane act in which we can engage in the 21st Century. Quite simply, as we responsibly help families obtain access to water for hygiene and to potable water for drinking, we proportionally enrich and safeguard their lives. With support from engineers and public health and water scientists, we hope to create something of special value to water stressed families.

Bruce Bomier, MPH
Board Chair
Environmental Resource Council

The Water Chariot

Introduction

The Water Chariot permits people to move water far more easily than carrying or rolling it like a drum, and ideally will also provide a means to purify a portion of the transported water for safe drinking.

One approach is to use discarded PET plastic beverage bottles – to hold water that is agitated or filtered as it is moved. When the Chariot arrives at its destination, it can be suspended off the ground via use of a lever, and the wheels containing the 14 PET bottles in "bays" are removed and laid on the ground, exposing them to direct sunlight. Ideally, this will introduce another element of chemical free passive purification.

The oxygenation and ultraviolet radiation, enhanced by the multi-spectrum bays, and the selective introduction of chemical additives when needed, will purify the water.

The Chariot standing upright.

The wheels may be removed and directly exposed to sunlight to maximize solar UV radiation disinfection.

Human Water Needs

Access to water is a basic human need. More than any other factor, the availability and quality of water determine the likelihood that low-income families will thrive.

The World Health Organization estimates that, to remain healthy, the average adult male must ingest .8 gallons (3.028 liters) of fresh water per day, and an adult woman, .6 gallons (2.271 liters). Although variable by age, weight, and climate, a reasonable estimate is that a child should ingest .5 gallons (1.89 liters). If additional water is available for hygiene purposes, even if its purity is not assured, health is further improved, especially among children. Limited and compromised water are the leading causes of illness and death among the world's children.

The amount of water needed for general hygiene and basic sanitation, which does not necessarily need to be potable, is variable. The amount of water needed for washing clothing and personal hygiene is around three times the amount for ingestion. The quantity and quality of water a typical water-challenged family can acquire directly correlates to income. Wealth equates to having more ready access to water and to better health, and is usually simply a factor of distance to a water source. The United Nations has estimated that "low income" populations are typically 1.5+ miles from a water source. The UN defines "low income" populations as families earning $995 or less per year, with an average of four children, while "lower middle income" families earn $996-$3,945 per year and have an average of three children. As incomes rise, family size, statistically, is smaller.

A reasonable extrapolation is that low-income families would require around 10.2 gallons (38.61 liters) of water per day, or essentially 85 pounds (38.6 kilograms) of water. In lower middle-income families, the amount would be 8.6 gallons (32.6 liters), or 73 pounds (33.11 kilograms) of water, 24 pounds (10.9 kilograms) of which should be potable (fewer children).

Each day, 9 or 10 gallons (30-35 liters) of water should be available to a low or lower middle income family, 3.5 or 4.0 gallons (10-12 liters) of which, optimally, could be converted to safely ingested water. Public health data clearly demonstrate that this is not occurring.

Although improved sanitation and other health care advances have substantially improved over the last 50 years in many developing countries, with subsequent reductions in infant mortality, we still have unacceptably tragic levels of childhood disease and death attributed to compromised water quality. Childhood mortality within low-income populations is 120 per 1,000 live births; among lower middle-income groups, it is 60 per 1,000 live births. This compares to childhood mortality rates of 7 per 1,000 among high-income populations.

The leading cause of serious illness and death among water-challenged children involves bacteria-induced gastrointestinal infections, resulting in diarrhea and consequent death through dehydration and related complications.[1] The exception would be HIV/AIDS, particularly within certain African communities, where diarrhea-related disease ranks second as a

In a rural Eastern European community, there is a single, shared point of water availability. Community members fill containers and carry the water to the place of final use.

cause of childhood mortality.[2] Among low-income, water-challenged populations, childhood mortality involves 3.3 million deaths, worldwide, annually.[3] Where adequate water and soap for hygiene have been provided, and hand-washing promoted, diarrheal disease has been reduced by 45% among low-income populations.[4]

Low-income populations are located throughout Africa, in portions of Central America and in Haiti, and lower-income populations in sections of Eastern Europe, portions of the Caribbean, the Middle East, India, and Indochina, and in more remote areas of China.

Problems also exist in the more populated "emerging" nations, often referred to as the BRICS nations (Brazil, Russia, India, China and South Africa). The "BRICS" term has also come to include other rapidly developing nations, e.g. the Philippines, Ecuador, Vietnam, etc. These are regions or nations where responsible public health and civil engineering/infrastructure have not caught up to rates of more obvious commercial development.

In India, government census data sought to quantify water availability and identified that 45% of its citizens do not have "routine access" to safe drinking water. Those people are termed, "away" people, since they must carry water from a water distribution site at least several kilometers "away." This means that 540 million Indians—more than the entire populations of the United States, Mexico, and Canada—must physically move heavy burdens of water to survive. Understandably, this population has an array of health problems relating to poor hygiene, especially gastrointestinal disease.[5]

Because of water access challenges in India, 40 children under five years of age die per hour, principally from contaminated water and consequent diarrhea.[6] Put another way, 365,000 contaminated-water deaths of children under five occur each year in India, more than 10% of the population of the United States.[7] While India has the most targeted data, allowing projections based on the link between water availability and childhood mortality, it is reasonable to assume that other developing countries have similar public health situations. These emerging populations have some disposable income but also have serious water challenges.

Beyond health issues, the significant time and effort required for obtaining and transporting water

This well in southern India provides drinking water for several communities. Those who use the well typically travel 1.5 miles (2.4 kilometers).

degrade quality of life, especially that of women and children. Typically, it is the women and children, especially young girls, who are responsible for making the trek to a water site, filling the containers, and then transporting the water supply back to the family. They usually have to make this journey twice a day, since an adult can carry only about 40 or so pounds (18 kilograms) of water, or 5 gallons (19 liters), and a child, less. The better part of a day must be committed to physical transport of water. In developing nations, this "water burden sacrifice" has been identified as a leading factor in limiting a girl's educational opportunity. The physical and psychological quality of life debilitation among women and young children is hard for 21st Century water-privileged communities to comprehend.

Almost by definition, poor civics is inherent within water-deprived communities. Access to limited water resources is often denied to the most vulnerable and least empowered families in these poorly governed communities. Similarly, the rapid but poorly managed development in emerging nations is problematic. Sewage drainage systems are often unprofessionally constructed, using low-grade and poorly joined PVC plastic piping laid in shallow ditches. These are typically placed in close proximity to piping used for fresh water delivery. In other words, ditches bringing in PVC-piped potable water also carry out PVC-piped sewage. Responsible soil testing, which is an institutionalized part of civil engineering projects in developed nations, is not typically part of water and sewage projects in developing nations. If there is an abrasion or insult to the physical subsurface area shared by both systems, especially if the pipes were laid in incompatible soils with low-grade piping, the drinking water likely will become directly contaminated with sewage. When the system fails, potable water must again be either physically transported from a great distance or treated. Finding or creating wholesome, potable water, and moving that heavy burden of water via human labor over a distance, is a constant struggle for an eighth of humanity.

One recent study estimates that "women in developing countries (low income) presently walk an average of 3.7 miles daily to get water."[8] This is likely a worst-case situation, but the distance is comparable to other estimates. Potable and non-potable water supplies are moved through muscle, either animal or human. In low-income communities, less than 6% of the population has access to any sort of motorized transportation; among lower middle-income populations, it is around 20%.[9] In both cases, "motorized transportation" usually refers to motorcycles or scooters that are unable to safely transport quantities of water. For a substantial portion of the one billion low-income family members, and the four billion who are lower middle-income, a less debilitating way to move and purify water would profoundly improve health and enhance quality of life.

Development of the Water Chariot

The goal of the Environmental Resource Council (ERC) was to develop an economically feasible device that could be purchased through non-government organizations (NGOs), government programs, community groups, or even by the low-income families, themselves, to enable a lifetime of far less debilitating transportation and purification of water.

We are working to design a low cost way to move large quantities of water while simultaneously facilitating water purification. Specifically, the mechanism can transport up to 175 pounds (79 kilograms) of water while vigorously agitating, and potentially filtering, water contained in fourteen 20- or 24-ounce (8.3-10 liters) PET beverage bottles. The goal is that a single, somewhat non-stressful trip to the water site would provide two days' water supply for a family for hygiene and, hopefully, safe ingestion.

With support from professionals in public health, civil engineering, and water science, ERC developed and field tested a rickshaw-like device, allowing easy movement of a large amount of water while simultaneously designing a way to create some potable drinking water.

Obviously, the need for purification support in this process depends upon the nature and quality of the initial water. While the enhanced SODIS (Solar Disinfection) process involving multi-spectrum refraction from UV radiation to oxygenated water may help, we are still attempting to isolate the optimal mechanisms for securing water that is safe to drink using passive, non-chemical procedures.

We selected iodine-based support because the active ingredient, Tetraglycine Hydroperiodide, has been safely and cost effectively used for decades in dose-controlled water purification procedures. The typically 30-minute contact time would likely be shortened through the agitation process and, considering that the UV radiation would also require the PET containers to remain sealed and exposed to sunlight for at least six hours, chemical reaction time would not be an issue. It is also important to note that a number of reliable corporations have mass-produced and distributed this compound with appropriate hydrophilic treatment safely for decades.

There is both taste and color impact on the water using this process, which can be mostly neutralized through introducing an inexpensive ascorbic acid compound. We are testing this process in India. One consideration is that an emerging health-conscious, water-challenged population may actually identify the taste and color differentiation as a sort of "safety verification" of the water. It may make sense to retain the taste and color identifier among some groups.

We are also considering introduction of both nutrient additives and a blue tint to the water, which would help indicate to the final user that the water has been appropriately treated for ingestion. Unfortunately, inappropriate marketing of non-potable water as potable has become somewhat common among many water-challenged communities.

The fundamental enabling component of the Water Chariot approach is the relatively new introduction of PET plastic beverage bottles into the environment of low-income, water-challenged communities. Globally, Coca-Cola and Pepsi-Cola PET bottles have become ubiquitous and identified with containing both a safe and pleasurable soft drink. As incomes have increased and availability of some consumer goods has opened up, these bottles are looked upon as a quality of life asset and have even inspired a number of cottage industries:

- In parts of the world where electricity is unavailable or prohibitively expensive, used PET plastic bottles are inserted into roofing systems. The bottles are filled with water and then essentially cemented into roofs, allowing darkened interiors of buildings to be brightened through light refraction. Use of these bottles in roofing systems is a thriving industry throughout Africa, Asia, and Central America.

- Another use for PET bottles is in footwear, where the bottles are filled with sand, then crushed, then molded to an individual's feet and converted into sandals. While less than optimal for walking, there is no question that village craftsmen have learned how to make the bottles functional as footwear, to the advantage of locals with limited income.

- In some emerging communities, two-stage septic systems use shredded PET bottles in the second stage to increase non-degradable surface areas for enhancing bacterial degradation of waste products.

- Another, more obvious use for PET bottles is as a functional way to carry and store small quantities of water. The photograph below shows a missionary school with limited access to potable water. The children collect bottles, fill them with the cleanest water they can obtain by straining the water, usually through tightly woven cloth, and then shake the bottles for an extended period of time to promote oxidation. They then place the bottles on a quasi-reflective surface to expose them to variable wavelength ultraviolet radiation. Attachment 1 describes the well-established SODIS process.

PHOTO CREDIT: SVEN TORFINN/PANOS

PET bottles have been placed on a reflective, corrugated metal sheet to hopefully redirect UV radiation generated by sunlight in an attempt to reduce pathogenic microbial colonies.

Moving and treating water through use of the Water Chariot complements the current approach of water-challenged populations. Instead of struggling to manually carry 40 pounds (18.4 kilograms) of water, a person or persons, using the Water Chariot, can "roll" 175 pounds (79 kilograms) with much less effort and no lifting, as well as, hopefully, having a standardized and reliable process for assuring water purity.

These water bearers in southern India will soon have use of the Water Chariot.

The strength of the water bearer(s), the distance to be traveled, and nature of the terrain will always impact the transportation challenge. In addition, the Chariot system is designed to operate at a family or neighborhood level, without involvement of local government. This avoids the often compromised civics of many under-developed communities, where local authorities have turned improved access to water into personal privilege.

Once the Water Chariot has reached its destination, it is easily pulled upright by using the handle as a lever. The Chariot then becomes an elevated water tank from which water can be efficiently extracted. This also allows the wheels to be easily spun by hand, allowing possible purification of additional water. A family would simply fill more beverage bottles from the tank and apply the required procedures for purification. The optional patterns of purification are still being developed and tested, as is the exact design of the Water Chariot.

Presently, a few families in India are already using the Water Chariot.

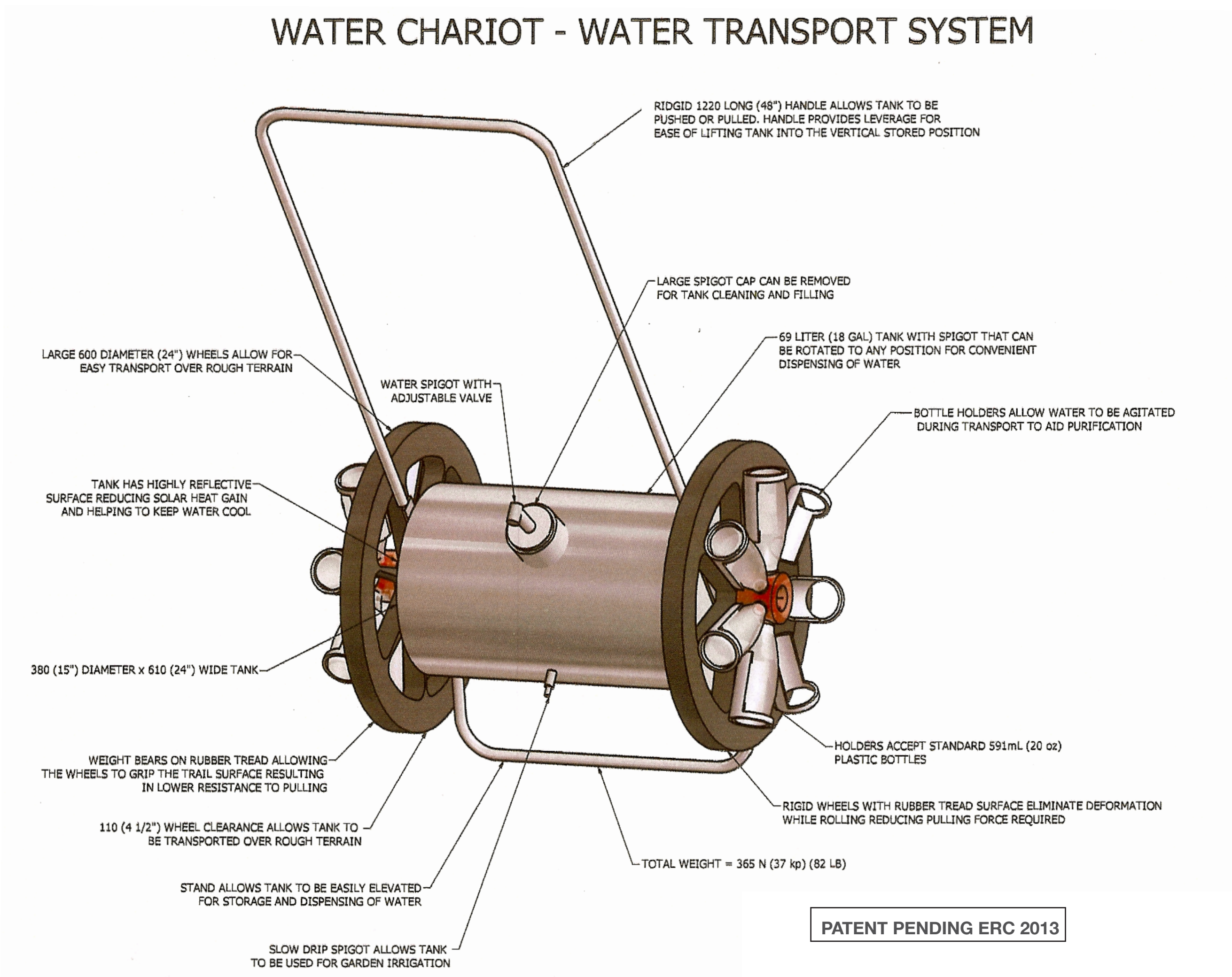
ERC is working with water scientists and volunteer engineers/engineering students on enhancing the design of the Chariot for ease of use, cost effective production approaches, and potability capacity.

Present Specifics of Operation

Although the design may be altered, at present, the following is the description of the Chariot as field tested in Southern India:

The Water Chariot mechanism is essentially a cylinder with a diameter of 15 inches (.38 centimeters), and length of 24 inches (61 centimeters). The cylinder itself serves as an axle attached to two wheels with a unique set of grit resistant discs that allow the wheels to be easily rotated. Vulcanized rubber wheel covers significantly minimize friction (see Att. 2).

Each of the wheels contains "bays" that can secure 7 bottles containing 20- or 24-ounces (8.3 or 10.0 liters) of water. Depending upon the strength of and/or number of people pulling the mechanism, the tank can be filled with up to 18.35 gallons (69.45 liters) of water, weighing 153.25 pounds (69.5 kilograms). If all 14 PET bottles are filled with water, an additional 6.2 gallons (23.5 liters) of water can be transported. The potable water would weigh 21.86 pounds (18.4 kilograms). At a maximum, 175 pounds (79.4 kilograms) of water, or 21 gallons (79.5 liters), would



be transported from the source to the family home. In addition to purifying the water, one trip would accomplish what previously required about four trips.

Once the Water Chariot arrives at its destination, the tank can be easily lifted off the ground using leverage from the handle. There are two orifices in the tank – one is a plastic faucet, the other a smaller nozzle that can be opened to permit ambient air to displace the water as it is drawn, allowing a smooth, controlled flow of water from the tank. This smaller nozzle can also be adapted for drip irrigation purposes; a small hose can be run from the nozzle to different plantings to slowly add moisture.

The water in the tank can also fill a second set of PET plastic bottles. The wheels (which are off the ground) can be easily spun by hand, with minimal friction, and the SODIS process or filtration process is repeated to enhance the purification process.

Current prototypes of the Water Chariot filtration are designed of corrugated metal and purposely overbuilt. Optimally, the device would be stamped out or molded with different blends of plastic. The only non-plastic portions of the mechanism would likely be the rubber wrapping around wheel edges, the snaps and straps to secure PET bottles, the coatings for the wheel discs, and other reflective coatings to enhance the SODIS process.

The multi-color, reflective coatings on the tank and bays have several purposes. First, the reflective material in the bays makes it easy to determine when the tint of the water is best for assuring potability. Second, the surface reflects sunlight and heat, keeping the water in the tank cooler, consequently restricting growth of microbial colonies. The reflective nature of the Chariot also makes it safer to use. Typically, women and children transport the family's water, often along poorly regulated, poorly lit roads.

In terms of imagery, the multi-color design resembles a rainbow, the cross-culture symbol of both life-giving moisture and calm following the passing of a storm.

Conclusion

Our least affluent populations have, by and large, been out of the line of vision and interest of those capable of developing new products. As our human values refocus toward a better world for all people in the 21st Century, reaching out with new, real-world innovations to address the needs of the least fortunate among us takes on a new and proper significance. There is simply no more valuable gift to a challenged family than providing continued, reasonable access to wholesome water.

I hope you will judge yourselves not on your professional accomplishments alone, but also on how well you have addressed the world's deepest inequities… And how well you treated people a world away who have nothing in common with you but their humanity.

*—**Bill Gates** (addressing the 2007 graduating class at Harvard)*

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