GREGORY BIXLER, STACEY STATHULIS, THOMAS HAUBERT,
DANIEL LAKOVIC, AND GAJAN SIVANDRAN

The LifePump Innovation for Developing Countries

WATER PUMPS INSTALLED IN DEVELOPING COUNTRIES TO PROVIDE ACCESS TO CLEAN WATER OFTEN BREAK, FORCING FAMILIES TO TURN TO SURFACE WATER THAT CAN EXPOSE THEM TO WATERBORNE DISEASES. LIFEPUMP™ HAS BEEN ENGINEERED TO STAY OPERATIONAL AND IS OFFERING COMMUNITIES IN AFRICA RELIABLE ACCESS TO CLEAN WATER.

Numbers have a way of desensitizing us, especially big numbers. Take this number: 780 million. That's the estimated number of people in the world who lack access to a clean, reliable source of water (WHO and UNICEF 2012). Although 780 million sounds like a significant number, it's almost too large to truly understand. Think about this: 780 million is more than double the population of the United States. You might ask, "What can one person do when so many are in need?"

Here's another number: 4,100. Each day 4,100 people, mostly children, die from waterborne diseases associated with contaminated surface water (UNICEF 2008), the only water millions can access. This is a smaller number but is still hard to quantify and make real. Ten may be the best number to consider in a discussion about the realities of limited access to safe drinking water. The 4,100 people dying each day from waterborne diseases transmitted through contaminated drinking water is the equivalent of 10 jumbo jets crashing—*every day*. Can you imagine if that happened day after day? Ten jet airliners crashing each day would shut down the world's air travel system until a solution was found. The attention given in the 24-hour news culture would be unimaginable; government agencies would be scrambling, people would stay home from work paralyzed by the horror of such a spectacle, and worldwide commerce would likely grind to a halt (Stearns 2010).

Here is one final number: 400. This is the approximate number of people in a village who receive clean water when a LifePump™ is installed. The girl drinking water from a LifePump in Malawi, Africa (shown in the photograph on page 49) represents just one of thousands of lives that are likely to be forever changed because of the LifePump.

REACHING DEEPER

The LifePump from Design Outreach is a progressive cavity pump designed to access the hard-to-reach water deeper underground (Figure 1) and is also designed for durability as it brings clean, reliable water to people in developing countries. In fact, the current generation of LifePump can lift water from a depth of 325 ft (approximately 100 m). The next generation LifePump will be capable of reaching water at a depth of 500 ft (approximately 150 m). The most commonly available hand pumps can lift water from a depth of only about 150 ft in certain areas within countries such as Malawi, Africa, where the probability of intercepting groundwater is as low as 68%, according to information from World Vision Malawi (Matipwiri 2013). It is estimated that the success rate of reaching water for a pump increases significantly when a pump can lift water from 325 ft because the volume of the subsurface that can be explored and used for drinking water is vastly greater, thereby increasing the probability of intercepting sufficiently yielding aquifers (Cornet 2012). A higher success rate for a pump means everything to the hundreds of millions of people who are desperate for clean water and to the organizations that work every day to make this access possible.

This also saves money for WASH (water, sanitation, and hygiene) organizations because they should experience fewer dry boreholes as a result of hand-pump depth limitations—lowering the overall cost per beneficiary and increasing the number of people reached. Furthermore, the LifePump is designed to have a lower cost of operation and maintenance at the village level compared with traditional hand or electric pumps because of its unique design, higher quality, and longer-lasting components.

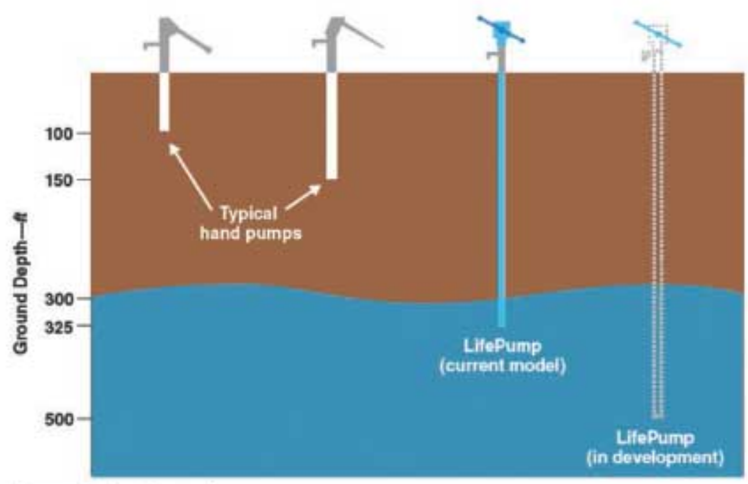
Nongovernmental organizations such as World Vision are already installing LifePumps in Africa in partnership with Design Outreach as part of the multicountry Hundred Pump Project. This pilot program in Malawi, Zambia, Kenya, Ethiopia, and Mali is bringing clean water to nearly 40,000 people in Africa while also supplying field performance data on the LifePump. World Vision has committed to a follow-up monitoring program for these pump installations.

A young girl drinks water from a newly installed LifePump in Malawi, Africa. *Photo provided by Design Outreach.*

ENGINEERS CREATING SOLUTIONS

Engineers Gregory Bixler and Abe Wright cofounded Design Outreach—

FIGURE 1 Operational depth comparison of typical hand pumps and LifePump



Source: Design Outreach

Typical hand pumps that rely on piston or diaphragm mechanisms are placed at a depth of 100–150 ft. The LifePump uses a progressive cavity pump design, which allows for an ergonomically correct pump that can reach to a depth of 325 ft for the current LifePump model and 500 ft for a new LifePump model in development.

A young woman operates LifePump in Malawi, Africa, after one year of the LifePump installation. *Photo provided by Design Outreach.*

a Christian, humanitarian engineering, 501(c)3 nonprofit organization—after they met through mission work in the Central African Republic in 2006. Bixler is part of the engineering faculty at The Ohio State University and Wright is an engineer at DePuy Synthes Inc., a Johnson & Johnson subsidiary.

Both Bixler and Wright had worked as international humanitarian engineers in Central America, South America, and Central Asia and were overwhelmed at the poverty in many countries. However, they were also surprised by the ingenuity in these countries, where they witnessed community members repurposing items out of necessity to make life more livable, such as using a rusted vehicle turned on its side to provide a low-cost retaining wall.

Bixler and Wright founded their organization by gathering with fellow engineers over brown-bag lunches, during which they talked about building better solutions to solve age-old problems in developing countries. Subject-matter experts generously volunteered their time in these efforts because they believed they could use their skills and training to take on a challenge and because they cared about the plight of millions who don't have access to clean water.

Thus began Design Outreach, a humanitarian engineering organization with a mission to prioritize the needs and aspirations of the world's poor by creating and delivering life-transforming solutions. The organization is achieving this through a coalition of industrial, academic, nonprofit, and donor partners. Among its many partners is SEEPEX Inc., from which support in the design and manufacturing of the progressive cavity pump has been invaluable. Many volunteers have emerged from professional and academic organizations such as Battelle Memorial Institute, Depuy Synthes Inc., and The Ohio State University. Together with Design Outreach, these partners have designed, developed, tested, and are bringing into the marketplace the LifePump—a unique, durable, progressive cavity pump.

ELEGANT SIMPLICITY

LifePump users turn pump handles that engage a drive rod that rotates counter-clockwise and turns the rotor (sitting below the water level), which drives water upward from the aquifers below. At the surface, water flows at a rate of 2.5 gpm under normal operation. The LifePump is operable at depth by one person or two, even children (as shown in the photographs on this page) with a person turning one handle each.

In addition to durability and depth, LifePump is also easy to use. Because women and children (young girls, mostly) are so often tasked with gathering water in developing countries, the LifePump was designed especially for such users. The handle length, handle torque, height of the pump above ground, and other features were ergonomically designed for people of differing sizes.

The LifePump is operable at depth by one person or two, including children, such as those pictured here in Malawi, Africa. *Photo provided by Design Outreach.*

How it works. Below the ground (below the pedestal of the LifePump) are 3-m lengths of driveshaft and riser pipe, both made of stainless steel for maximum durability. Stainless steel rods and riser pipes are frequently used with hand pumps because of corrosion resistance and ability to withstand pump preventative maintenance with minimal wear on the threaded connections. During installation, the riser pipe is assembled and tightened by hand with a positive O-ring seal. The rotating action of the progressive cavity pump is designed to create reaction torques that tighten both the riser pipes and drive rods—preventing them from loosening during daily use.

At the end of the drive rods are the rotor and stator, which are critical to the pump's performance. These parts are less than 2 ft long and are created to an exact tolerance. The rotor is a corkscrew-shaped, single-helix piece of metal that turns inside a double-helix, elastomer-injected stator (Figure 2). As the rotor turns, cavities are created and progress up the length of the stator. Through this motion, pockets of water in each cavity are pushed to the surface. Clamping force between the rotor and stator, geometry of the rotor and stator, and material selection were carefully engineered to ensure high performance. At the bottom of the riser pipe, past the rotor and stator, is a foot valve that helps prevent water leakage and helps keep out dirt and stones.

DURABILITY BY DESIGN

Bixler, Wright, and the engineers of Design Outreach saw other less-durable pumps in place that had failed, and the parts needed to fix these pumps were not available in the countries in which they were installed. Of the 345,071 hand pumps installed in Sub-Saharan Africa, reportedly 124,709 are no longer functioning (Rural Water Supply Network 2009). Many of the pumps remain broken because of low water tables that cause pumps to operate beyond design specifications (Cornet 2012). Because replacement parts aren't readily available in remote areas of Africa, the frequent breakdown of cheaper parts actually ends up increasing the overall pump-upkeep costs. In such situations, the result is that pumps have more frequent down time.

So what makes the LifePump different from other pumps? Piston or diaphragm pumps rely on a sliding seal or a moving valve. When such components fail, the pump stops working. The LifePump is designed to not stop working suddenly—instead, it will slowly experience less efficiency over time, giving villagers, Design Outreach, and its WASH partners time to restore the pump to its original level of performance. The durability of the LifePump is critical to Design Outreach so that it can supply water to more people over a longer period. Also, if the pump continues performing as anticipated, the long-term cost of the LifePump is expected to be lower than a pump that is cheap to purchase but breaks down in a year or less.

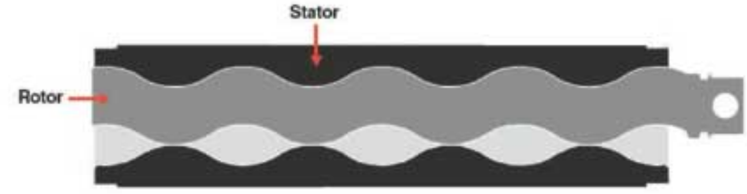
> The 4,100 people dying each day from waterborne diseases transmitted through contaminated drinking water is the equivalent of 10 jumbo jets crashing—*every day.*

One metric for pump performance is counting the number of handle rotations it takes to collect 5 gal (approximately 20 L) of water. Laboratory testing indicates that for 100% volumetric efficiency, the LifePump requires approximately 106 turns; as depth increases, so does the number of required handle rotations. Over time, as the progressive cavity pump wears and the clamping force reduces, the number of required handle rotations will gradually increase to produce the same volume of water. The change in performance is an indication that the pump requires preventative maintenance; however, the LifePump should not abruptly fail as its performance changes, allowing the villagers to continue to have clean drinking water available.

DEPTH MATTERS

Drilling a borehole for a water pump means passing through layers of earth and aquifers (water-bearing

FIGURE 2 Geometric design of a progressive cavity pump



Source: SEEPEX Inc.

The metal rotor within a progressive cavity pump turns inside of an elastomer stator as the rotor turns and pockets of water in each cavity are pushed to the surface.

A LifePump in Malawi, Africa, is outfitted with a spout-mounted data logger, developed by SonSet Solutions (Elkhart, Ind.) to record usage information such as number of handle rotations and volume of water pumped. This information is useful for the multicountry Hundred Pump Project and water organizations interested in monitoring long-term pump performance. *Photo provided by Design Outreach.*

layers) from which the pump can draw water. The current-generation LifePump can draw water from 325 ft below ground, more than twice the depth of most other hand pumps currently in use. Drillers look at the refresh rate of a borehole and, in the event it is slower than desired, they will continue drilling deeper. One metric used by World Vision Kenya is for the borehole to produce at least 12 L/min of water, which indicates that the borehole can produce a sufficient amount of water to justify a pump.

Because the LifePump can draw water at 325 ft, it is more likely to find an aquifer to consistently supply the pump with a refresh rate able to provide a water supply throughout the year during which seasonal groundwater levels fluctuate. The vastness of the African continent in particular means that different countries have different rainy and dry seasons, which can affect the water supply in aquifers. For example, in Malawi the rainy season typically lasts from November to April, and the dry season spans from May through October.

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TESTING AND EVALUATION

Ongoing analysis of the LifePump in both the field and laboratory helps to ensure a high-quality solution with a long service life. Design Outreach is collaborating with World Vision on the Hundred Pump Project to achieve a shared goal of installing 20 pumps in five African countries as part of a large-scale multicultural pilot program spanning 36 months. To date 30 LifePumps have been shipped to Africa, and several have been installed in Malawi, Kenya, and Zambia, with more installations planned for early 2015. The independent evaluation program of the LifePump includes investigating performance, ergonomics, and sustainability.

Initial feedback from end users, WASH managers, and Water and Irrigation ministry officials has been positive. The first two LifePumps were permanently installed in Malawi in November 2013 to begin the pilot program. World Vision Malawi personnel and village water-committee members manually collected data on efficiency, ability to maintain prime, and usability data during site visits throughout the year. The efficiency is measured by comparing the number of handle rotations with the amount of water collected; the ability to maintain prime is measured by counting the number of handle rotations until water exits the spout. Usability is measured through interviews and observations of end users to verify acceptance. Such quantitative and qualitative metrics help evaluate the robustness of the LifePump in real-world conditions.

Efficiency data for two LifePump sites in Malawi is shown in Figure 3, demonstrating no changes over the course of a year in terms of handle rotations to initially produce water or to fill a 5-gal bucket. These results indicate that the LifePump performance was consistent and that it experienced no degradation over one year. Also, LifePump did not require any maintenance or repair during that period. In addition, results of the ergonomics survey demonstrated that women and children were able to pump water easily. Such evaluations will continue for the duration of the pilot program. Future testing will include dynamic and static torque measurements at the handles to determine the amount of work necessary to pump water at depth, which can be used to directly compare LifePump efficiency with other hand pumps. Additionally, accelerated life testing of critical components is ongoing using laboratory test stands as well as an outdoor test well, which is located at Design Outreach facilities in Sunbury, Ohio.

As part of the independent evaluation, several LifePumps in each country are outfitted with spout-mounted data loggers (shown in the photograph on page 52) developed by SonSet Solutions (Elkhart, Ind.). These units record daily use information on a memory card, and certain models transmit the data wirelessly via satellite to Design Outreach for analysis. Total gallons pumped per day are calculated using efficiency information from the well site and the amount of handle rotations for a given day. Such data loggers are also expected to prove important for WASH organizations to monitor in real-time the health of a well site and provide service to ensure minimal or zero mean time between failures.

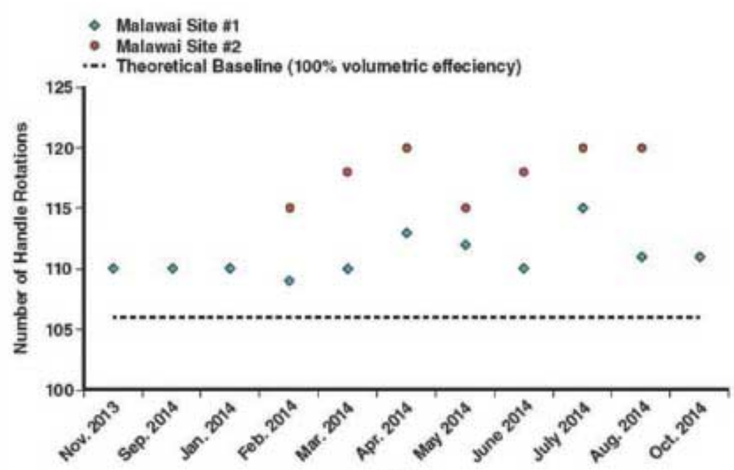
LOOKING FORWARD

With positive preliminary results indicating that the LifePump is a needed solution, Design Outreach is working to provide clean water to people in developing countries. As of early 2015, a total of 30 LifePumps were ready to be installed in Malawi, Kenya, Zambia, and Ethiopia, and the organization is actively seeking funding to complete the Hundred Pump Project to give safe drinking water to nearly 40,000 people. A supply chain for pumps and spare parts, service models, and distribution models is being implemented to ensure sustainability. Cost analyses of the LifePump are favorable, showing that success in deeper boreholes saves money, even using the higher low-production LifePump costs. Cost-reduction efforts by Design Outreach will continue to drive down the cost of the LifePump and increase the value to water-pump installation organizations. These are important factors in providing a sustainable LifePump solution.

With the help of its coalition of industrial, academic, nonprofit, and donor partners, Design Outreach will continue alleviating the need for clean water access one village at a time in an effort to continue its mission of creating life-sustaining solutions for developing countries. The LifePump can bring new life to villages with defunct well sites and life-changing hope to people who have to walk several kilometers several times a day to retrieve unreliable, disease-ridden surface water. Access to clean, safe, and reliable water is transformative, especially for the women and young girls who are most often tasked with retrieving water, because it frees up their time for education, work, care for the home and family, and more.

The LifePump can bring new life to villages with defunct well sites and life-changing hope to people who have to walk several kilometers several times a day to retrieve unreliable, disease-ridden surface water.

FIGURE 3 LifePump efficiency field data from two sites in Malawi, Africa, for one year based on number of handle rotations to fill a 5-gal container



Source: Design Outreach

Efficiency data indicate that LifePump performance remained consistent and no repair or maintenance was required. The baseline 100% volumetric efficiency data are shown as a theoretical baseline for comparison (in which approximately 106 handle rotations are required to draw 5 gal of water). At depth, the efficiency is less than 100% as indicated, with the higher number of handle rotations required at each site.

ABOUT THE AUTHORS

Gregory Bixler (to whom correspondence may be addressed) is part of the engineering faculty at The Ohio State University in Columbus, Ohio, and chief executive officer and cofounder of Design Outreach, POB 763, Winona, IN 46590 USA; greg@doutreach.org. Bixler holds a PhD in mechanical engineering and is a registered professional engineer. ***Stacey Stathulis*** *assists the Design Outreach marketing communications team.* ***Thomas Haubert*** *is technical manager for Design Outreach.* ***Daniel Lakovic*** *is marketing manager for SEEPEX Inc. in Enon, Ohio.* ***Gajan Sivandran*** *is assistant professor in civil, environmental and geodetic engineering at The Ohio State University.*

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