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Providing Safe Drinking Water
to 1.2 Billion Unserved People

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ABSTRACT

Despite substantial advances in the past 100 years in public health, technology and medicine, 20% of the world population, mostly comprised of the poor population segments in developing countries (DCs), still does not have access to safe drinking water. To reach the United Nations (UN) Millennium Goal of halving the number of people without access to safe water by 2015, the global community will need to provide an additional one billion urban residents and 600 million rural residents with safe water within the next twelve years.

This paper examines current water treatment measures and implementation methods for delivery of safe drinking water, and offers suggestions for making progress towards the goal of providing a timely and equitable solution for safe water provision.

For water treatment, based on the serious limitations of boiling water and chlorination, we suggest an approach based on filtration coupled with ultraviolet (UV) disinfection, combined with public education. Additionally, owing to the capacity limitations for non-governmental organizations (NGOs) to take on this task primarily on their own, we suggest a strategy based on financially sustainable models that include the private sector as well as NGOs.

INTRODUCTION

Increasing populations, economic pressures on freshwater resources and inadequate sanitation and waste-treatment facilities in high-population areas have placed increasing demands on freshwater supply throughout the world. Despite efforts of international organizations (United Nation's Children's Fund (UNICEF), World Bank, World Health Organization (WHO)), bilateral aid agencies and many national governments, a large fraction of the human population is still at risk because of poor water quality. In 1990, 1.2 billion people did not have access to a safe supply of water according to official statistics collected from their governments. In addition, there are several hundred million people who receive piped pressurized but contaminated water in urban centers of the developing world. The actual number of people without access to safe drinking water is therefore likely to be about 2 billion or 33% of the world

population. According to the UN and WHO data, more than five million people die annually from water-borne diseases. Of these, about four million deaths (400 deaths per hour) are of children below age five (WHO, 1996). The lack of safe drinking water also stunts the growth of 60 million children per year (WHO, 1996). This remarkable state of affairs continues despite substantial advances in the past 100 years in public health, technology and medicine, primarily because these advances have not been systematically applied or implemented to address water quality problems in the DCs. Public policies have also been inadequate to address this issue. Commonly, poor communities in DCs are the victims of poor water quality, and thus any proposed solutions must pay attention to the relevant operating environment.

In 2000, the UN announced its Millennium Goal of reducing by one-half the proportion of people without sustainable access to adequate quantities of affordable and safe water by 2015 (UN, 2000). To meet this target, the global community will need to provide an additional one billion urban residents and 600 million rural residents with safe water in the next twelve years. (Downing and Ray, 2002)

Studies by UNICEF, WHO and the World Bank have concluded that the standard industrialized world model for delivery of safe drinking water and sanitation technology is not affordable in much of the developing world. Furthermore, adequate quantities of water simply may not be available in these regions.

Differences in views on how to best provide water stem from whether water is perceived as a fundamental human right, or as a commodity. If water is seen as a fundamental human right, it is therefore the responsibility of the Government. If it is perceived as a commodity, it may thereby potentially be out of reach for the most needy. Compelling arguments have been made that access to basic water requirements is a fundamental human right implicitly and explicitly supported by international law, declarations and State practice in addition to moral guidelines (Gleick, 1999). Yet recognition of water as a right does not, in itself, ensure global access to safe drinking water. The frequent reality of non-provision of water by governments must be addressed and resolved.

The challenge remains to identify both a practical method of assuring safe drinking water, and a feasible mechanism of provision.

TECHNOLOGICAL MEASURES FOR SAFE WATER

Enormous human and economic costs stem from waterborne diarrheal diseases. These include billions of hours of lost adult productivity annually, and economic and health costs of about 10 million person-years of time and effort annually, mostly by women and girls carrying water from distant, often polluted, sources (Gadgil, 1998). Sickness of the primary adult income earner commonly has a severe impact on the income and nutritional status of children and other family members in poor households (Pryer, 1993).

The major factors reducing the significance and impact of diarrheal diseases in public health are sanitation, the quality and quantity of water, adequate disposal of human and animal excrement, and public education in hygienic practices. One analysis has suggested that for a given situation

with poor sanitation and poor quality drinking water, the beneficial impact of improving only the sanitation will be larger than that of improving only the quality of drinking water (Esrey, 1996). As Dr. Haldan Mahler, former director-general of the WHO has said, "The number of water taps per 1,000 persons is a better indicator of health than the number of hospital beds."(quoted in WASH, 1993).

However, irrespective of sanitation improvements (not a topic of this paper) safe drinking water remains an extremely important topic. It is a necessary, although not a sufficient condition for protection from primarily waterborne diarrheal diseases. Since most of the measures to obtain high quality drinking water require substantial societal investments, which inevitably compete with other developmental investments in most DCs, WHO has purposefully avoided prescribing international standards for drinking water quality. A risk-benefit analysis, carried out to determine what is the acceptable level of risk in particular circumstances, is what WHO recommends (WHO, 1996). Unfortunately, as the World Bank points out, the water projects which get implemented in many DCs commonly deliver high quality pressurized drinking water piped only to the homes of the politically and economically powerful strata of the society, leaving the majority of the weaker subpopulations to fend for themselves (Briscoe, 1995).

Most experts in the area of drinking water safety agree that a single barrier between microbiological contamination and end-use is inadequate. Multiple barriers are essential to ensure the quality of drinking water; a single barrier can not always be relied upon, as there might be technical or operational breakdowns. Additionally, the effectiveness of any given barrier might be overcome by rare episodic events. Therefore, expert recommendations (e.g., WHO, 1996) repeatedly stress the importance of implementing multiple barriers between fecally-transmitted diarrheal pathogens and drinking water. Furthermore, WHO recommends (WHO, 1996) that safe drinking water quality be achieved <u>before</u> the final treatment step, so that failure of any one process will not result in waterborne diseases.

Sanitation
The least glamorous of the measures to ensure safe drinking water is sanitation (i.e. safe disposal of human and animal wastes). Fecally-transmitted pathogens multiply in the intestines of their infected hosts, including other mammals and sometimes even birds, and are excreted in copious numbers with fecal matter. Safe disposal of animal and human wastes is critical to keep these pathogens from reaching drinking water sources. This becomes a grave problem as population densities rise steeply in peri-urban areas (peripheral zones around cities) and in rural areas receiving displaced populations, e.g., civil war refugees.

In much of the developing world, proper sanitation is a luxury reserved for the urban middle and upper classes. Rural areas rarely enjoy sewage lines, municipal waste treatment, or septic plants. Even peri-urban areas are almost never connected to the central city water supply and sewage systems (Downing and Ray, 2002). It is exceedingly difficult to build sanitation infrastructure to serve these populations, partly due to the cost involved. In addition, most peri-urban settlements are "illegal," and governments are unwilling to legitimize them by extending them water and sanitation services (Downing and Ray, 2002). Therefore, many slum communities are forced to use the channels between homes for defecation, which leads to contamination of both groundwater and, where available, surface water.

Modern urban sanitation systems with flushing toilets require an enormous infrastructure – water supply, sewers, sewage pumping stations, municipal waste water treatment plants – well beyond what is physically possible in many developing world contexts, even in terms of meeting the water demand alone. Common feasible alternatives include septic tanks or dry pit toilets, as well as the less common deep waste treatment pond. Although these substantially reduce the re-introduction of pathogens into the environment, under certain conditions (e.g., cracked or leaking sewer pipes), they can transmit some pathogens into surface or ground water sources.

Source protection

Source protection is the next step in the multi-barrier process. Industrialized countries, as well as some developing ones, endeavor to protect the watersheds from which their communities draw their drinking water. This usually implies limiting animal and human access to surface water sources, including prohibiting habitation, agriculture and animal grazing in adjacent areas, and prohibiting disposal of municipal and industrial wastes into the water or in the watershed. These measures also apply to zones of groundwater abstraction. Development adjacent to the surface source is restricted or prohibited.

Protecting sources near populations is difficult. The rising cost of land and increasing population can make these measures impractical, particularly if they will interfere with existing or historical-use patterns of rivers or lakes. Indeed, the areas not already protected tend to be the most densely settled. Designating such areas as protected would involve relocating communities and prohibiting traditional agricultural activities; relocating communities raises serious ethical questions. Furthermore, even where voluntary relocation with fair compensation is attempted, the feasibility of finding comparable fertile lands elsewhere, and the costs associated with relocating whole communities, are strong barriers to broader watershed protection strategies in the developing world.

Water treatment

In the industrialized world, there is a common sequence of treatment processes for water collected from such protected sources. The water is impounded in large reservoirs, with residence times of the order of 3-4 weeks, where there is some self-purification from sunlight, and from settling of particulate matter and attached bacteria. This may be followed by storage in an additional sedimentation basin after adding a flocculent or coagulant, and then rapid filtration through sand (depth ranging from 0.4 to 1.2 m) to remove more microorganisms and turbidity. The water is then disinfected with chlorine before being sent off to residential taps and faucets.

The above treatment sequence is impossible for small-scale systems required for rural poor communities, and for the large number of "new" migrants arriving to metropolitan centers in recent decades, more of whom will continue to arrive in the next several decades. These immigrants have created huge, dense peri-urban settlements around the metropolises of DCs. They have marginal or no services for safe drinking water and sanitation because the original relevant infrastructure for the urban centers have already been strained beyond capacity, and are thus unable to support these growing peri-urban populations. The developing world context poses challenges for each individual step of the treatment system described above. Thus far,

governments in the developing world have been ineffective at providing such services to the peri-urban settlements.

In the rest of this section, we briefly discuss specific steps in water treatment and their implementation feasibility for the bottom 33% of the world's population without access to safe drinking water.

Sedimentation
In many DCs, the cost of construction, including materials and the price of land, and or its availability, makes sedimentation ponds prohibitively expensive. Sedimentation also faces the same barriers as watershed protection-- it is difficult to establish the land area necessary for such ponds, especially in regions of high population density or agricultural production.

Filtration
Sand and ceramic filters are often used in conjunction with other disinfection techniques, and in some cases, on their own. Rapid sand filters do not by themselves disinfect water adequately, as they do not remove fecal pathogens, but can prepare water for further treatment, e.g., by ultraviolet disinfection or chlorination.

Ceramic filters are similar to rapid sand filters, in that there is no biologically active layer. Ceramic filters have pore sizes too large (three microns and higher) to block individual free-floating bacteria and virus particles. They only block protozoa, larger parasites, and particles of turbidity, and not all bacteria attach to such particles. Therefore, ceramic filters can not be relied upon for complete water disinfection.

Slow sand filtration is relatively inexpensive and can be very effective, but requires ample land area and takes significant time. Other limitations of slow sand filters depend on the characteristics of the water to be disinfected. For proper treatment through slow sand filtration, inlet water must have a low concentration of suspended solids, and only minor quantities of algae. If these criteria are not met, the filter can clog rapidly, requiring more frequent maintenance. In addition, low operating temperatures, low oxygen content in the inlet water or low nutrient content can inhibit the effectiveness of this technology, since slow sand filters depend on a top layer that contains an active biological community.

Disinfection Techniques
Boiling
Boiling water is no doubt the most widely known method of drinking water disinfection in the developing world. However, boiling water for drinking requires substantial quantities of fuel, usually wood. For an average family of five with a drinking water need of 35 liters daily, boiling their drinking water will consume about 12 kg of wood (Gadgil, 1998). Given that a family would use only 2 - 4 kg of wood for cooking its daily food, the addition of boiling water would increase their daily fuel wood needs many times over.

Gathering fuelwood for daily cooking is already a heavy burden on hundreds of millions of women and girls in the developing world. Furthermore, it can put tremendous pressure on already waning forests. Therefore, increasing fuelwood consumption four fold throughout the developing word is clearly infeasible.

Another serious concern is the substantial additional smoke inhalation attributed to boiling drinking water on indoor cookstoves. Exposure to indoor air pollution from biomass cookstove emissions has been shown in numerous studies to cause acute respiratory infections (ARI), chronic obstructive pulmonary disease and lung cancer (Smith, 2002).   Boiling water for drinking would increase exposure to cookstove emissions many times over that from typical food preparation.

Chlorination
Chlorination is unique among the disinfection techniques listed here in that it provides residual disinfection, which can help to prevent recontamination of treated water. Chlorination is a fairly low-cost treatment method on a large scale, but rapidly becomes expensive when scaled down. For large systems for cities of 100,000 people or more, chlorine disinfection costs are low, approaching about $.02 /m^3 of water (Gadgil, 1998). With small-scale systems, however, the costs rapidly increase, as does the impracticality of having skilled technical operators continually present.

The primary disadvantage of chlorine is the necessity of maintaining an appropriate supply chain of source chemical to the water treatment location. Cholera outbreaks have been reported in India when impassable roads blocked the chlorine supply chain during heavy monsoons. Other equally serious disadvantages include the need for a skilled and trained operator as well as a properly executed safe operation and maintenance program.

UV Disinfection
UV water disinfection relies on the germicidal properties of 240-280nm UV-C light. At this wavelength, UV light causes severe damage to the DNA of microorganisms, so that they can not easily reproduce. This germicidal effect is strongest at 260nm, and conveniently, low-pressure mercury lamps (similar to common indoor household fluorescent lamps) emit 95% of their energy at 254nm. Because this method relies on efficient UV lamps, UV water disinfection is, in itself, an inexpensive way to disinfect drinking water where there is a reliable electricity grid. It uses 6000 times less primary energy than does disinfection by boiling water over a biomass cookstove. Unlike chlorination, there are no cost-penalties for scaling it down to serve communities of about 1000 persons. This allows superior matching of the size and number of treatment plants to the community size and needs, and also permits rapid deployment.

However, to better ensure inactivation of protozoa cysts like *Giardia* and *Cryptosporidium*, and to reduce turbidity, UV disinfection is often coupled with filtration, which raises the cost. When pumps are also required, or where electricity generation must be provided through photovoltaic (PV) panels, system costs will rise, as PV electricity costs about five times as much as grid electricity.

For illustration, we consider UVWaterworks, a UV water disinfection technology invented at Lawrence Berkeley National Lab (LBNL) and licensed to WaterHealth International (WHI) (Feder, 1996 and Reuther, 1996). Performance and cost parameters for UVWaterworks are excellent and well established, and therefore it provides a useful data point in discussing what could be accomplished. However, if a comparable or superior technology were to become available, the estimates given here should be revised accordingly.

Although the total cost of disinfecting water with UVWaterworks alone (assuming no other equipment cost, amortizing capital costs over 15 years, and including costs of consumables and electricity at 8 cents/kWh) is only US$0.04 per ton of water, this is almost never the final cost in practice. In most installations of UV Waterworks, users and communities have demanded not just a stand-alone water disinfector, but also pumps, power for the pumps, storage tanks for raw and disinfected water, dispensing faucets, and filters to take out particulate matter.

In addition, community education in relevant aspects of public health has been essential in rural areas. This very important component also increases costs. The full system, including the components listed above, structural foundation frame and shelter, transaction costs, and an initial community education program, pushes the initial cost of the system to between US$8,000 and $12,000, and the cost of disinfected water to about US$0.40-$0.50 per ton of water. This excludes any cost of land or rent for a storefront, salaries of store personnel for water sales from a kiosk, or the cost of continuing community education in public health. These will greatly vary from place to place, and in some places will be negligible or irrelevant.

Furthermore, there is an additional important point learned by WHI and its distributors and clients based on installations of UV Waterworks in the field. Consumers of safe water are not easily persuaded that the water they drink after full UV disinfection is significantly better for their health than the raw water they were drinking earlier, unless there is a *perceived* difference in quality of water they are drinking (e.g., reduced turbidity and odor, improved color or taste). Therefore, for sustained use of UV disinfected water by the intended users, the system has to include particulate filters, activated carbon filters, or any other appropriate additional treatment to create the perception that the water is "improved" even if these treatments are not essential for rendering the water safe. There is no possible improvement in public health unless the safe water actually replaces raw contaminated water as the drinking water source, which is only likely to happen if the users are convinced the disinfected water is improved. These are real, not just theoretical, issues, and the cost of a practical system for actual applications is, as a result, higher than that of simple UV disinfection despite the fact that UV disinfection unit might be adequate to kill all waterborne pathogens.

Based on these considerations, WHI currently quotes the cost of installations of community water systems at about US$10 per capita, with some variability depending on the remoteness of the location, economies of scale, logistical obstacles, and the degree of secondary water treatment required. For comparison, studies by UNICEF and the World Bank have estimated the investment for supplying pressurized treated water to urban dwellers at about $100 per capita, and for supplying untreated water at a community water collection point at about $30 per capita (Christmas, 1990).

DISCUSSION
Technology
The unfortunate reality of every DC includes insufficient funds to do many, if not most of the public works and public health projects needed to keep its citizens healthy. Every project

undertaken must be considered against other projects that can then not be initiated. As such, there is an opportunity cost to every technology implemented.

Based on the reality above, and the costs of proper sanitation, the most rapidly effective approach to combating diseases borne of unsafe drinking water may be a short-term band-aid approach of disinfection alone, with or without basic filtration, but always combined with appropriate community education in hygiene practices.. Such a limited point of intervention could be achieved with limited funds.

Implementation of Technology

The issue of how to best provide safe drinking water to the world's population inherently comes back to the issue of whether access to safe water is to be seen as a right of the people, or as a commodity like any other, in which the market determines who will have access and for how much, potentially putting this necessity out of reach of the poorest. NGOs and charities have not been able to foster substantial progress, and governments responsible for such provisioning have been unable, unwilling or negligent in fulfilling this obligation.

The estimated infrastructure investment needed for supplying approximately 1.2 – 2.0 billion people faced with contaminated drinking water supply ranges from US$12 billion (1.2 billion people at $10/capita) to US$200 billion (2 billion people at $100/capita). Most of these people have low economic and political status even within the poor countries in which they reside. Generally, it is their poor political status that has kept them dependent on contaminated drinking water sources in the first place (Briscoe, 1995).

The Role of the NGOs

NGOs are often the organizational resource bringing safe drinking water technologies to those in need since the state may be overwhelmed with other pressing demands or may not have appropriate funds

In the latter half of 2002, several experts were polled on behalf of a US non-profit (Blue Planet Run Foundation) regarding the organizational feasibility of delivering safe drinking water to a significant fraction of the 1.2 billion people in the next 10 years, if the necessary funds were raised.   The striking finding from this survey of experts was that NGO capacity falls greatly short of being able to take on a task of this magnitude (Downing and Ray, 2002).

The largest NGO focusing on safe drinking water supply to poor communities in DCs, WaterAid, has a current annual budget of US$15 million. We estimate the annual budgets of all other drinking water NGOs put together to be at most three times this amount, for a total of US$60 million per year. Using the lower end of the investment scale ($10 per capita), this will provide water to a maximum of only six million additional people annually. At this rate, it would require 200 years to reach the 1.2 billion people.

Even if substantial funds (~US$1 billion/yr) were made available, many of the NGO experts surveyed felt that they did not have the personnel resources to take the funds and successfully scale up their operations (Downing and Ray, 2002). Another problem with expecting NGO initiatives to grow some tenfold is that it requires local selfless and charismatic leaders with

management skills, which are generally in short supply. The NGO approach alone is clearly prohibitively slow and restrictive, and therefore, infeasible as the primary delivery mechanism.

Shortcomings of the NGO Approach

It is widely recognized within the field that many water projects implemented by aid agencies and charitable organizations have had low success rates (Downing and Ray, 2002). Multiple causes exist for these failures. Projects sometimes are unsuccessful due to lack of community organization, lack of a maintenance and repair structure, lack of incentives or training to properly implement the project functions, or lack of integration of the new technologies or its associated behaviors into daily life necessary to achieve any long-term benefits. When projects are introduced without properly educating or training the users, misuse or neglect can result. Similarly, when projects are ill suited to the users' daily life, and modifications are not made to optimize compatibility, these projects tend to fail. Water projects must fit the technical capacity and appropriate social placement in order to succeed.

However, a broader reason why these projects often do not deliver is that an incorrect measure of success is used. For example, aid agencies and/or charities may base success on the number of water purification units installed, and not on whether the benefits of clean water, such as a decrease in the number of deaths due to contaminated water, are attained. Another reason for unsuccessful projects is that water projects are commonly one-sided; directives come only from donors to recipients and not vice versa. The two parties are not politically equal, leaving little room for users to provide criticism to donors lest the donors rescind the project offer. Consequently, communities often have little participation in or influence over the planning or outcome of the project. Since customer satisfaction is not part of the defined success of the project, agencies and charities are not held accountable for projects deemed successful in their installation, but deemed to have failed in providing users with the desired outcome.

The Role of the Fee Market

The discussion above suggests that an implementation approach relying exclusively on aid agencies or NGOs is inadequate to address the problem in a significant manner or in a reasonable timeframe. An alternative is the market-based approach by which other useful new technologies have reached the poor communities in the DCs.

With a market-based approach, meeting customer satisfaction, by necessity, defines the success of the endeavor—enterprises with dissatisfied customers will inherently not stay in business. This is one advantage to approaching water projects using a market mechanism. Technologies such as bicycles, kerosene lanterns and kerosene stoves, and transistor radios have successfully reached the poor communities in DCs. These technologies are factory produced, but marketed by small-scale enterprises, with distributors, spare-parts producers and repair shops that are sustained by appropriate profit margins allowing for self-propagation and diffusion of the technology. Note however, that each of these technologies is privately owned, not community property.

Private sector small-scale businesses can increase capacity relatively easily depending on the demand and deliver the goods in substantial numbers. However, a small-business based approach runs the risk of lacking in social equity – those who can afford the safe water will

purchase it, and others will be left behind. When it comes to socially beneficial community-scale technologies, e.g., the community-scale biogas plants in India, or public-access hand-pumps or even public toilets, the success rate is dismal or spotty. Although there do exist a few outstanding success stories such as the Sulabh International public toilets (Sulabh International, 2003), or the Social Work and Research Center's organization of village women technicians who provide maintenance of hand-pumps (Barefoot College, 2003), and the Grameen Phone's organization that hooked up rural Bangladesh with village cell phones (Grameen Phone, 2003).

Shortcomings of the Free Market Approach
Treating water exclusively as a commodity has led to some disastrous results. In September 1999, in accordance with the "structural reforms" accompanying an IMF loan one year prior, the Bolivian government handed over Cochabamba's municipal water system to the sole bidder, Aguas del Tunari, a multinational consortium of private investors and the major shareholder of a Bechtel Corporation subsidiary. Within weeks of the transfer of ownership, water prices rose to pay for the expansion of the city's water system. Some bills doubled or tripled, and ordinary workers suddenly had bills that amounted to a quarter of their monthly income. The World Bank, in anticipation of rate hikes, had published a report the summer before maintaining, "no subsidies should be given to ameliorate the increase in water tariffs in Cochabamba."

In response to their inflated water bills, protesters shut down the city for four days in January 2000. The peaceful protest turned violent the following month when riot police met marching demonstrators with teargas. By April, protests had spread to other cities, protest leaders were arrested, and the President declared a martial law-like "state of siege." Within days, the Bolivian government rescinded the water contract from Aguas del Tunari, and turned over control of Cochabamba's water to the cooperative leading the protests. In the end, thousands were injured, many blinded, one young student shot, and Bolivia's economy has since suffered from the subsequent nervousness among foreign investors. (Finnegan, 2002; Frontline, 2002)

Water privatization also has not been successful in many other places. Vivendi, the French multinational, had its thirty-year water contract with the Argentine province of Tucumán terminated after two years because of alleged poor performance. Major water privatization projects in Lima, Peru and Rio de Janeiro, Brazil were cancelled because of popular opposition. Protests against water privatization have also erupted in Indonesia, Pakistan, India, South Africa, Poland and Hungary (Finnegan, 2002).

However, note that these (often spectacular) failures are always associated with privatization of the *entire* water resource for the community – all water including that for bathing, cleaning, washing clothes and drinking. We are unaware of popular protests related to privatized supply of water for drinking, since safe drinking water is probably easily recognized as being harder to procure, having more value, and being more critical to good health. People in urban Mexico, the Philippines, and India may be quite unwilling and outraged if they have to pay US$0.10/gallon for bathing, but are quite willing to pay prices higher than this for safe drinking water.

Lastly, a market-driven approach does have the weakness of susceptibility to advertising; of perceived value versus reality. Despite many reports that bottled water may be no more

beneficial than tap water, and certainly more expensive, the bottled water industry is booming the world over (Frontline, 2002).

Proposed Solution: Public-Private Partnerships.
The previous discussion suggests to us that neither the NGO nor the free-market approach alone will solve the problem. Every world citizen should indeed have access to safe drinking water, from a moral and international law perspective. Clearly, relying solely on governments or NGOs, or exclusively on market-driven mechanisms is not desirable from both practical and ethical perspectives. How, then, can this issue be better addressed?

Faced with this dilemma, we suggest "public-private partnerships," i.e., partnerships between government agencies and private sector enterprises, in hopes that they will deliver the goods where the two sectors separately have not been able to reach. The mechanism of such a partnership can be flexible, with room for learning and creative arrangements to fit the needs. Such partnerships can be frustratingly difficult to build, owing to very different cultures and perspectives between the two sides. However, where they have been successfully forged, these partnerships have accomplished a great deal.

It should be noted that NGOs have very relevant roles to ensuring access by all under public-private arrangements. In California, for example, it was NGOs that provided the necessary pressure and voice in the regulatory process to establish "life-line" rates; very low cost telephone access for low-income residents, supported by fees to other customers.

The dissemination of UVWaterworks technology has provided several relevant and successful models of such public-private partnerships. In the following section we describe two examples of UVWaterworks implementation. The first is a model describing a partnership between an NGO and a private company, and the second is a purely entrepreneurial model.

UVWaterworks Philippines: NGO model
One organizational model of UVWaterworks disemination in the Philippines is a NGO-community joint venture involving a local branch of Rotary Club International and local community organizations and cooperatives.

Tthe Rotary Club provided revolving loans to various community organizations in the peri-urban slums around Manila. With the loan, community organizations purchased equipment, and operated kiosks to sell water treated on-site with UVWaterworks creating a water store. They negotiated with the private partner, Bendix Corporation, to buy simplified systems at a discounted price of US$3,000, instead of the usual $8,000. The loan also paid for initial salaries and training of kiosk employees and technicians. The community members buy their water from the kiosk for substantially less than they would pay for alternative safe drinking water options, such as bottled water.

The community organizations were able to pay off the capital cost of the loan with the first year profits. Once repaid, each kiosk becomess a viable source of income for the communities, which they have used to reinvest in physical infrastructure and community development. In addition to

affordable safe drinking water, this full cost recovery operation provides training and employment for a few local residents. When each kiosk is repaid, the Rotary Club lends the money again to another community, further propagating access to safe drinking water.

Subsequent to these installations, several community cooperatives have purchased water-store systems directly from the private-sector vendor, Bendix Corporation, to sell water to their own communities. In all such cases, the private-sector partner provides maintenance and repair in return for a monthly fee tied to the volume of water being processed.

UVWaterworks Philippines: Entrepreneurial model
In Manilla, the Philippines, the Bendix Corporation also operates an urban franchise water-store program. In this organizational model, the franchise operator rents a storefront, purchases and installs equipment, and hires staff to operate water kiosks. This model is similar to the one initiated by the Rotary Club and utilizes the same core technology but with higher grade components and better presentation of the store site. Bendix sells its franchises for approximately US$8,000 to entrepreneurs, who pay Bendix a maintenance and training fee equivalent to one peso per gallon of water sold and to follow Bendix-developed quality control standards and price guidelines.

The franchisee then sells the water for about eight pesos (US$0.15) per gallon, at about 80% the cost of the closest competitors. In rural areas where the customer base is poorer, the water could be sold at lower prices.

CONCLUSION

Despite very substantial advances in the past 100 years in public health, technology and medicine, 33% of the world population, comprised of the poorest sectors of poor DCs, still does not have access to a safe supply of water. In order to reach the UN Millennium Goal of halving the number of people without access to safe water by 2015, the global community will need to provide an additional one billion urban residents and 600 million rural residents with safe water in the next twelve years.

While access to basic water requirements may be a fundamental human right, global access to safe drinking water has been far from assured. The challenge remains to identify both a practical method of assuring safe drinking water, and a feasible mechanism of provision.

Given developing-world budget constraints, water systems comparable to those in industrial countries are impractically expensive. Innovative point-of-use water treatment systems, coupled with community involvement, and public education in healthy practices regarding diarrheal diseases, sanitation and basic hygiene, may be the best hope for providing low-cost, safe water for drinking and hygiene at the household or village level.

There is also a need for new organizational models of delivery. Governments of DCs, aid agencies, NGOs and charities have been unable to make real progress towards providing safe drinking water to over 1.2 billion currently unserved people. The for-profit sector may be able to provide such services to a large fraction of the unserved population, but these services will likely

be out of reach of the poorest; "public-private partnerships" may be the key to providing safe drinking water in a timely and equitable fashion. Additionally, NGOs have a crucial role to play in such partnerships by being involved in public policy to ensure access of safe drinking water to all of those in need, especially the poor and unserved.

ACKNOWLEDGEMENTS

REFERENCES

Barefoot College, **2003**. http://www.barefootcollege.org/

Briscoe, J. When the cup is half full: improving water and sanitation services in the developing world. *Environment.* **1995**, *35(4)*, 7-37.

Christmas, J. and de Rooy, C. The decade and beyond: at a glance. New York: UNICEF Water and Sanitation Sector, Program Division. **1990**.

Downing, J. and Ray, I. (Post-doctoral candidate and Assistant Professor at the Energy and Resources Group, University of California, Berkeley, respectively). Safe Drinking Water for Everyone: A Review Paper for the Blue Planet Run Foundation (December, 2002, unpublished), and personal communication with the authors in November and December, 2002.

Esrey SA.. Water, waste, and wellbeing: a multicountry study. *Am. J. Epidemiol.* **1996,** *143(6),* 608–23.

Esrey SA, Potash JB, Roberts L, Shiff C. Effects of improved water supply and sanitation on ascariasis, diarrhoea, dracunculiasis, hookworm infection, schistosomiasis and trachoma. *Bull. WHO*. **1991,** *69,* 609–21.

Feder, Toni. LBNL Creates Water Purifier for Developing Countries. Physics Today, July, **1996**, p. 57

Frontline Timeline: Cochabamba Water Revolt, based on "Leasing the Rain" by W. Finnegan. **2002**. Available at: http://www.pbs.org/frontlineworld/stories/bolivia/timeline.html Downloaded 1/23/03.

Finnegan, W. Leasing the Rain. *The New Yorker*. **2002**, *78(7)*, 43-53.

Gadgil, A.J. Drinking Water in Developing Countries. *Annual Review of Energy and the Environment*. **1998**, *23,* 253-86.

Gleick P.H. The Human Right to Water. *Water Policy*. **1999,** *1(5),* 487-503.

Grameen Phone, **2003**. http://www.grameenphone.com/

Pryer J.. The Impact of Adult Ill-Health on Household Income and Nutrition in Khulna, Bangladesh. *Environ. Urbaniz.* **1993**, *5(2),* 35–49.

Reuther, Christopher.. "Brighter Light, Better Water," Environmental Health Perspectives. **1996**, v 104, (10) pp. 1046-1048.

Smith, K.R. Indoor Air Pollution in Developing Countries: Recommendations for Research. *Indoor Air*. **2002,** *12*, 198-207.

Sulabh International **2003**. http://www.sulabhinternational.org/   also try http://www.sulabhinternational.netfirms.com/

United Nations. **2000**. The Millennium Goals. United Nations Millennium Declaration A/RES/55/2 8 Sept. 2000.

WASH. **1993**. Lessons Learned in Water, Sanitation and Health—thirteen years of experience in developing countries. Water and Sanitation for Health Project (WASH) of USAID's Office of Health, Bur. Res. Dev., Washington, DC

World Health Organization. Water and Sanitation Fact Sheet. N112. **1996** http://www.who.int/inf-fs/en/fact112.html

WHO-UNICEF. Global water supply and sanitation assessment. **2000** Report. http://www.who.int/water_sanitation_health/Globassessment/GlobalTOC.htm

KEY WORDS

Safe drinking water; ultraviolet water disinfection; public-private partnerships, non-governmental organizations