Water Treatment and Distribution in Communities in Developing Countries

'The Challenge'

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May 15, 2007

Introduction

The objective of this paper is to identify, describe and assess the challenges facing the successful implementation of community scale water treatment and distribution in developing countries. With a good understanding of the 'real' problems that need to be overcome, it is possible to identify 'real' solutions. Though the challenges may seem daunting solutions are now available and will be the topic of several future papers which describe how the BioSand Water Filtration (BSF) technology and its related filtration technology, the Low Operating Head Polishing Sand Filter (LHPF) can be used to provide water treatment solutions for communities in developing countries around the world.

Current Practice

Large scale, shared, water treatment and distribution facilities are often considered the ideal method for providing sufficient, safe, drinking water to communities in both developed and developing countries worldwide. In North America and other financially advantaged regions of the world (developed countries) the appropriateness, effectiveness, affordability and sustainability of these water treatment-delivery systems are taken for granted and there are numerous laws which mandate that these types of facilities be provided under threat of severe penalty. All countries aspire to provide their population with the same privileges.

The reason large scale, water treatment facilities are considered the method of choice are:

- It is recognized that provision of pathogen free water supplies benefits the entire community (wealthy and poor together) by reducing exposure to disease, reducing medical costs, improving productivity and quality of life.
- Large scale water treatment plants are the most effective and economical way to treat water for entire communities.
- Pipe distribution systems should be effective in delivering treated water conveniently, safely (without recontamination), and inexpensively to consumers.

Water management, treatment and delivery technologies are widely known and are generally available and it is not unreasonable to expect that delivered water quality in communities throughout the world would be uniformly good. The reality is that outside North America, western European countries, Australia, New Zealand, Japan, Singapore and a few other countries and municipalities, communities are supplied with insufficient

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water that is not safe to drink. Many communities are not supplied with any form of improved water supply at all.

With the development of the BSF and LHPF technologies, prospects for the development of sustainable safe water projects for all communities in developing countries are very good. (See papers titled 'New Horizons for Slow Sand Filtration' and 'Low Operating Head Polishing Sand Filtration - LHPF' published on the web site: www.manzwaterinfo.ca.) Opportunities for using these technologies will be published in papers on the same web site as time allows.

Communities in Developing Countries

Small communities include villages of a few dozen or hundreds of people to those of several tens of thousands of people. Typically, the smaller a community is, the less likely it will have a community water treatment and distribution system.

Large communities include those cities of a few hundred thousand people to several millions of people. The largest cities with populations of several millions such as Lagos, Nigeria; Manila, Philippines; Calcutta, India; Mexico City, Mexico; Managua, Nicaragua; Dhaka, Bangladesh; etc. These cities all provide their communities (at least the formal parts of their communities) with water that is safe to drink near the source (in the case of deep wells) or immediately after treatment. In almost every case the water is contaminated by the systems that distribute the water to the consumers to the extent that it is no longer considered safe to drink or use for cooking (without further treatment in the household).

Community Water Demand

Humans require water for drinking, preparation and serving food, personal hygiene (bathing and toilet), washing clothes, and cleaning the home environment. Water may also be used to water household plants and animals, water lawns, wash cars, etc. (amenities).

The World Health Organization publication, 'Domestic Water Quantity, Service Level and Health, 2003 – available on the internet' includes the following table, which summarizes the relationship between per capita water service level, access to water and health:

Service level	Access measure	*Needs met*	Level of health concern
No access (quantity collected often below 5 l/c/d)	More than 1000m or 30 minutes total collection time	Consumption – cannot be assured Hygiene – not possible (unless practised at source)	Very high
Basic access (average quantity unlikely to exceed 20 l/c/d)	Between 100 and 1000m or 5 to 30 minutes total collection time	Consumption – should be assured Hygiene – handwashing and basic food hygiene possible; laundry/ bathing difficult to assure unless carried out at source	High
Intermediate access (average quantity about 50 l/c/d)	Water delivered through one tap on-plot (or within 100m or 5 minutes total collection time	Consumption – assured Hygiene – all basic personal and food hygiene assured; laundry and bathing should also be assured	Low
Optimal access (average quantity 100 l/c/d and above)	Water supplied through multiple taps continuously	Consumption – all needs met Hygiene – all needs should be met	Very low

The amount of water that will be actually be used per capita will vary with access as described in the following publication by the World Health Organization,

Type of supply	Average consumption (l/c/d)	Service level
Traditional sources, springs or handpumps	15.8	Communal
Standpost	15.5	Communal
Yard tap	50	In compound
House connection	155	Within house (multiple)

Almost all countries or jurisdictions within each country, will define the minimum amount of water to be delivered per capita. In Canada and the United States the amount includes water necessary for human use and water necessary for fire fighting and industry. Per capita water supply (delivered) often exceeds 500 liters per day. Distribution losses must be considered as well (10 to 15% for good systems) and in some instances may equal the quantity of all water distributed (50% loss).

Quality of Water Provided to the Community
The quality of water is described in terms of its microbiological, chemical, radiological and acceptability characteristics. Water must be safe and esthetically pleasing to consume or use for purposes of bathing, washing clothes and other household purposes. The quality of drinking water is described by the World Health Organization in the publication, 'Guidelines for Drinking Water Quality, First Addendum to the Third Addition, Volume 1, Recommendations, 2006, ISBN 92 4 154696 4. This publication is

available on the internet. The quality of water for purposes other than drinking, at the household level is rarely if ever described.

Sources of Water

Water for communities is usually taken from the best available source – best meaning best quality, best quantity and most reliable. Sources include: shallow and deep wells, springs, rivers, lakes, reservoirs, dams, ponds, irrigation canals and rainwater. When these sources are first identified and exploited they are usually sufficient, reliable and produce safe drinking water or sufficient quantities of the source water can be economically treated to a safe acceptable quality and distributed to the consumers.

A number of factors may cause a source to become inadequate or unavailable with time. These include: over exploitation that can damage or reduce the available supply, loss of source due to human activities or natural causes, population growth beyond the capability of the source to supply, increased cost of acquisition, treatment and distribution, contamination, decrease in the ability to pay for the acquisition, treatment or distribution, uncontrollable damage to the source, treatment or distribution systems resulting from natural causes such as flooding and earthquakes and civil strife and war. Climate change and global warming is also causing concern.

Each source of water presents its own advantages and disadvantages.

Shallow wells

Shallow wells represent traditional (and often preferred) access to water. They are relatively simple and inexpensive to construct and require little maintenance. Water may be obtained using simple manual techniques such as bailers and hand pumps. Unfortunately, shallow wells are very vulnerable to over exploitation and contamination from surface activities. Shallow wells may prove inadequate or even disappear in periods of drought.

Shallow wells can be covered and protected. The water may have a very low turbidity; but, it will still be unsafe to drink because of the presence of water borne pathogens that seep into the well from the surrounding soil.

Water from shallow wells is usually quite limited in supply, must be treated to become safe for human consumption and is rarely distributed throughout a community, though an entire community may use it as a source.

Household BSF technology is used around the world to effectively and economically treat water from shallow wells to a quality safe for human consumption..

Deep (tube) wells

Deep wells take water from aquifers (water bearing layers of rock or aggregate material) located tens of meters to a few hundred meters below the ground surface. They are isolated from local surface contamination. Special types of hand pumps or mechanical pumping systems may be required to extract water from the wells. The initial cost of pumping water may be affordable but can become quite expensive if the water resource is over exploited or poorly managed such that the vertical distance to the water in the well becomes large. Water from deep wells is usually safe for human consumption (initially there are no waterborne pathogens). Water from deep wells can contain numerous other offending substances such as iron and manganese, iron bacteria, hydrogen sulfide, fluoride, heavy metals (lead, mercury and arsenic) or high concentrations of dissolved solids that may significantly limit its acceptability and require expensive treatment to make it acceptable for use. The quality of water provided by deep wells may be compromised by careless construction that may result in immediate contamination of the aquifer from surface water and treatment may be required to remove water borne pathogens.

Deep wells provide water to many large cities that may network their distribution systems to take advantage of the opportunity to locate their water supplies (deep wells) as needed. In this respect the use of deep wells represent an ideal source. The quality of the water in individual wells may vary considerably; sometimes the quality of water from a particular well is not acceptable. Usually the water from the offending wells is never treated to eliminate the quality problem but is simply blended with the water in the general network – an imperfect solution.

The number and operation of deep wells must be carefully managed to avoid depleting or damaging the aquifer supplying the water. As the depth that the water needs to be pumped, increases, so does the cost of pumping. At some point the cost may be prohibitive and alternative poorer quality water supplies must be used. Even local decreases resulting from the operation of nearby deep wells using high flow rate pumps can cause adjacent shallower wells that take water from the same aquifer to dry out. In some cases the quality of the water replenishing the aquifer may not be acceptable. Groundwater may become saline when salt water replaces the fresh water in wells located near the sea shore (known as saltwater intrusion). Aquifer depletion may result in the quality of water changing from very good to an unacceptable quality such as when naturally occurring arsenic becomes soluble and causes the groundwater to be toxic (Bangladesh, West Bengal State, India and northern Mexico).

Treatment methods have been developed using the BSF and LHPF technologies to eliminate most of the water quality problems associated with deep wells and can treat alternative water supplies if needed.

Surface Water Supplies

Water from rivers, lakes, reservoirs and ponds will need to be treated to make it safe for human consumption. Treatment may be required to remove skin penetrating parasites such as Schistosomiasis and a variety of other organisms that may cause skin, eye and other infections. Treatment may be complicated by the fact that the quality of surface water can be very poor and difficult to treat. The quality is often quite variable, fluctuating seasonally and with every rain storm and other phenomena that affect flow or replenishment of supply. The quality of the water can deteriorate as a result of contamination from increased human and industrial activities.

Historically, surface water treatment can be complex and require several chemical treatments to produce water safe for human consumption. Treatment plants are expensive to construct, operate and maintain. Required chemicals are often not available and very poor quality water is distributed to the community. Communities have found that even when considerable surface water supplies were available it was often cost effective to access uncontaminated groundwater reserves using deep wells.

With the development of large capacity BSF and LHPF technologies effective treatment of surface water is practical and affordable.

Irrigation Canals

Irrigation canals are often a readily available surface water supply. Water may flow seasonally; but, reservoirs can be constructed to store sufficient water during periods when the canals do not carry water. The quality of the water will be similar to or slightly poorer than that of the source providing the water. Water provided by irrigation canals can introduce waterborne pathogens that the community would otherwise never be exposed to (e. g. Schistosomiasis).

Again, with the development of large capacity BSF and LHPF technologies effective treatment of irrigation water, irrespective of source, is practical and affordable.

Springs

When water flows from the side of an embankment or wells up from the ground the source is named a spring. The spring results from the movement of water through an aquifer, a layer of porous, permeable rock or granular material, isolated from local surface contamination, that eventually surfaces or outcrops, the location of the spring. The water in the aquifer may have traveled many hundreds of kilometers from where it is recharged or it may only have traveled a few hundred meters. The quantity and quality of water from springs may vary considerably with location and time. The reliability and variability of the quantity and quality of water produced by a spring can only be known if the spring has been observed over long periods of time. Springs may disappear or they may be the only supply available during times of drought.

Springs may consistently provide large quantities of very good water if the recharge area of the aquifer supplying the spring is large and is isolated from animal, human and industrial activities. In some circumstances the quality of spring water may be very good in terms of its physical characteristics (clarity, taste and smell) but may be compromised chemically and biologically.

Springs are typically found in hilly or mountainous terrain and the communities that require the water are located at lower elevations. This relationship can be exploited by providing necessary treatment using the BSF or LHPF technology at an elevation that is still much higher than the community to be served, storing the treated water in large tanks and connecting the safe water supplies though pipes to the community below. There may be no energy costs.

Brackish Water and Sea Water
Brackish water (water with very high concentrations of dissolved solids – two to three times and greater concentration than that recommended for drinking water) and sea water (approximately thirty times the concentration of dissolved solids recommended in drinking water) can only be treated to drinkable quality using technologies such as reverse osmosis and distillation. These technologies are complex and expensive to build and operate and not normally suited to developing country conditions except, perhaps, for production of drinking water.

Rainwater
Captured rainwater may be the only water supply. Rainwater is always contaminated as it drains off the capture areas into the storage reservoir. Despite efforts to minimize this contamination stored rainwater can never be assumed safe for human consumption. As well, the reservoir containing the rainwater must be protected from further contamination from animals and indiscriminate human use. Water from protected reservoirs can be easily treated to safe, drinkable quality using the BSF and LHPF technologies.

Water Treatment Technology
Water treatment can be very simple, seem not required in some cases, or be very complex and expensive in others. Access to any of the numerous water treatment technologies, from the simplest to most complex technology, is available everywhere in the world (internet). It is safe to say that *any* water source that exists can be treated to a quality that would make it safe and desirable to drink. However, if capital, operating, maintenance and repair costs are too high the water supply may be abandoned and the treatment plant never built. Worse, a treatment plant may have been built and is no longer possible or affordable to operate.

Technologies used in wealthier communities may be able to treat the water but be too expensive to acquire, install and successfully operate in developing countries. Where practical, technologies used in the treatment plant and distribution system, including chemicals and disposables, should be locally manufactured and supplied. It is also desirable that there is local technological expertise that can be used to support treatment plant design and construction, operation and maintenance. Local sourcing mitigates the impact of hyper inflation or other potentially catastrophic circumstances (drought, disease, war, bad governance).

Design and construction of water treatment plants and distribution systems should be performed by qualified professionals familiar with local business practices including; construction technology, regulatory requirements, labor relations, contractor relations and material suppliers.

BSF and LHPF technologies are designed to be manufactured anywhere in the world in collaboration with local experts.

Water Distribution
Piped water distribution systems are the method of choice to make safe water available to the intended consumers – usually essential in large communities. Piped systems for distribution of water can be very complex to design and operate, a task normally requiring the skills of specially trained engineers. Even the apparently simple task of using a pipeline to take water from a spring supply at a high elevation to a community at a lower elevation can present several complex technical problems.

Often the distribution system is more expensive to construct, operate and maintain than the development of deep wells or the construction of the treatment plant producing the water. In order to minimize costs distribution systems in developing countries may not use looped networks of pipes that provide at least two routes for water to reach intended consumers and always carry some flow. Rather, they use simple branched systems that may contain many dead-ends. Without the use of looped systems pipe breakages can result in entire neighborhoods losing their water supply until repairs are made. Dead ends accumulate particulate matter that can negatively impact on the quality of water in the entire system.

In warm climates distribution systems are not buried very far below the surface (one meter or so) as the pipes are in cold climates (three meters) where freezing during winter months is a serious hazard. The deeper the pipe is buried the more expensive the construction.

All water distribution systems will develop breaks that do allow leakage of treated water when the pressure in the distribution system is positive (system is pressurized) or allow contaminated water to seep into the distribution system when the pressure is negative (vacuum conditions). Breaks can be difficult to find especially in situations where the pipes are buried deep or installed in well drained sandy or gravelly soil.

Soil and water at or near the ground surface is very contaminated from surface sources and from sanitation sewers. Sanitation sewers are usually not buried much deeper than water distribution pipes and may be located close to the water distribution pipes. Sanitation sewers will leak some sewage into the adjacent soil or receive water if the soil is saturated with water.

Because water supply and distribution systems are commonly over subscribed (too many users supplied) portions of the pipe system, furthest from the start of the distribution system, will stop carrying water and be under vacuum (taps will suck air when they are opened). Very contaminated groundwater, soil particles and pathogens, will be drawn into the pipes. Once chlorinated water again fills the pipes most of the bacteria and viruses will be killed; however, encysted pathogens will not be killed or deactivated and must be physically removed. It is common to find particles of soil in the water coming from the tap. Though the water being delivered is not safe for drinking it is still usually of very high quality and perfectly acceptable for all non-potable uses. This water may be readily treated to a quality safe for drinking using technologies such as the BSF and LHPF technologies.

Water Pressure
Water pressure refers to the pressure of the water at the point it is delivered to the consumer. In North America the pressure 'at the tap' is expected to be around 40 pounds per square inch. This pressure is sufficient to operate most household appliances and is carefully controlled (pressure that is too high will damage appliances and plumbing). If the pressure becomes too low many point-of-use water treatment appliances will not function.

As mentioned it is common for the water pressure 'at the tap' to decrease to zero or even become negative (vacuum). Temporary water scarcity is compensated for at point of consumption by provision of storage facilities in the form of buried cisterns or tanks located on the roof tops (or some combination of the two storage systems) that are filled with daily water supplies when the water supply is available in the distribution system. When water is delivered the pressure is normally sufficient for filling the elevated tanks. Pumps are used to transfer water from cisterns located at ground level or buried to the elevated tanks. The pressure of the water taken from the elevated tanks is usually sufficient to distribute it within the household. (Booster pumps can be used but may not be practical if energy supplies are not reliable.) Not only is the water supplied no longer safe to drink because of recontamination in the distribution systems and storage tanks, inadequate pressure may not permit use of any but the simplest household appliances including those that might otherwise be used to treat the water to a quality safe for human consumption.

Household versions of the BSF are frequently used to treat recontaminated municipal water supplies to safe drinking water quality. The BSF's can be operated manually or automatically even when the water supplies are delivered under very low pressure such as from the storage tanks on the tops of homes, apartments and offices.

Effect of Energy Availability
Supply of sufficient, reliable and inexpensive energy is very important to the operation of water treatment plants and distribution systems. All pumps require energy (electricity, diesel fuel, etc.) to operate. When the supply of energy is interrupted pumps stop, treatment may stop, pipe systems lose pressure and water is no longer distributed. 'Brown outs', a euphemism for electrical power stoppage, can interrupt the supply of water. Consumers, realizing that they have no other alternatives, will tolerate and continue to pay for this type of service.

Treatment plants that use either the BSF or LHPF treatment technologies require minimal amounts of energy to operate and can be designed to function during power outages without impairing treatment performance and interruption of flow of water from the treatment plant.

Distribution systems can be designed that can still deliver water, even if energy supplies are interrupted for short periods of time.

Effect of Over Subscribed Water Supply and Distribution System
As communities grow the demand for water increases and extends further from the treatment plant. The tendency is to simply extend pipelines and service to meet the new demands to the point where service to all consumers is negatively affected. In these situations a rotating service is adopted where water is available during certain periods of the day. Rotations may evolve to where water is available only on certain days of the week at certain times of the day. Ultimately, water must be delivered or the system expanded. One of the significant impacts of rotating supplies are periods where there is little or no water in the water distribution system; and, when water is finally delivered, it is dangerously contaminated and requires treatment, such as using the BSF technology, before it can be safely consumed.

Financial Sustainability
Financial sustainability implies that the water supply, treatment and distribution system is well managed and money or fees are being collected to cover the cost of all operations, maintenance, repair and the ultimate replacement of the facilities, including the treatment plant, wells, pumps and distribution system.

System management must insure that sufficient fees are collected on an <u>equitable</u> basis. There are a variety of methods to achieve this. Water meters may be installed on every consumer connection. While providing a basis for charging for water on the basis of volume consumed, installation of water meters will improve knowledge of how the system is functioning and improve system management. However, water meters are expensive to install and monitor, require periodic maintenance and are frequently tampered with. Prepayment of water supplies while guaranteeing that all water delivered is paid for, may result in a situation where many consumers are not receiving any delivered water at all – a situation that governments wish to avoid. Other methods of cost recovery include some form of flat fees for the type of service provided; for example, the number of taps served, the size of the house and property, or the amount of household storage that is used. It is very common for governments to subsidize the acquisition of water supplies, treatment and distribution.

Unsatisfied customers may refuse to pay for poor service (for example the service might not be what the law requires) and this can threaten sustainability. While refusing to pay for water may seem a suitable protest to agitate for improved service it is uncommon because even poor quality service is much better than any alternatives consumers may have. Consumers appreciate the fact that water can be delivered near their home. If they know the water is unsafe they will usually take whatever steps are necessary to produce or acquire sufficient safe water for drinking. (Many use household BSF technology.)

The most important factor contributing to financial sustainability of a community water treatment plant is the selection of the treatment technology. Certainly there are other factors that are also very important; but, if the technology selection is not appropriate, the project is certainly going to fail. The treatment technology selected must effectively treat the water, be affordable to purchase and install, and be simple and inexpensive to operate and maintain by the community it serves. Ideally, the technology should be affordable without continual subsidization – the community can afford to operate and maintain their own treatment facility once it is constructed. Incorporating some form of the BSF or LHPF technologies into the treatment system will insure that performance expectations are met at low cost.

Impact of Unmanaged Wastewater Disposal
Untreated municipal, industrial or agricultural wastewater can seriously degrade water supplies being acquired, treated and distributed for human consumption. Left unchecked indiscriminate wastewater disposal can result in water supplies degraded to where they can no longer be economically treated. The problems may be a local or regional concern but they may also become a cause for national and international conflict.

All water treatment systems, even those that use the BSF and LHPF technologies, provide the best quality water at the lowest cost when they are treating the best quality water supply.

Protection of the water source will help reduce treatment costs and minimize fees that must be levied or subsidies that may need to be provided.

Impact of Environmental Degradation
Environmental degradation of a water supply can occur as a result of deforestation of the watershed contributing the water supply, establishment of human habitation (including squatter communities) without adequate wastewater or surface runoff management, inadequate management of industrial and agricultural activities and inadequate management of solid wastes. Deforestation may result in the loss of supply.

The inevitable result of environmental degradation is the deterioration of the quality of the water supply to the extent that it may no longer be economical to treat it to a satisfactory quality, (similar to the impacts of unmanaged wastewater disposal).

Implementation of environmental management programs to prevent or restore the effects of environmental degradation of the water supply will help reduce treatment costs and minimize fees that must be levied or subsidies that may need to be provided.

Lack of Resources
Many small communities have limited resources to build, operate and maintain community scale water treatment and distribution systems.

Small scale, centrally located water treatment systems can be used to exclusively provide safe drinking water – with or without distribution systems. These ‘drinking water stations’ can successfully introduce more complex water treatment technologies and be sustainable while providing the community safe drinking water for a fraction of the cost they are already willing to pay for alternative supplies such as bottled water or even pop. Several variations of this approach have been developed using the BSF technology in urban and rural communities in Bangladesh. These types of treatment systems can be tailored to provide only safe drinking water or all water required, subject to the availability of a suitable supply and financial resources. Treatment plants may be scaled to serve any size community.

Peri-Urban, Slum or 'Squatter' Communities

Peri-urban communities often develop next to established, legal urban development or boundaries as a result of the migration of the poor rural population to the cities. Some other names given these settlements are slums, 'squatter communities' or 'informal communities'. These communities occupy land they don't own. If land, public or privately owned, appears unoccupied an attempt may be made to 'colonize' it. This process can be one or two households at a time or by a 'developer' who organizes a swift appropriation and occupation. Once established these communities are very difficult to remove and seem to perpetuate, gradually improving, become valuable and may be occupied by successive generations of 'owners'. They are a unique form of urban development that can be difficult to distinguish from the 'official' part of the cities. As difficult the living conditions in the squatter communities may be, they are considered much better than the living conditions experienced in the country. Migration from within formal urban communities to squatter communities may be necessitated as a result of financial crisis. The problem is worldwide.

A number of solutions are being tried to stop development of informal communities and remove those that have been formed. Concerned governments attempt to eliminate the social malaise that causes the desperate actions. Some will also implement organized relocations to well planned and serviced areas. Many countries support social housing programs for the less affluent; and, while helpful, these programs do not solve the problem because the people simply have no money. Attempts made to improve economic conditions in the country to discourage migration to urban centers have not been successful. In some situations where truly accessible social housing is provided the rate of migration and demand exceeds supply and the informal communities continue to grow.

Water supply in squatter communities is a major problem. Households will install shallow wells if possible; but, this water is contaminated with waterborne pathogens and other substances. If the opportunity is available they will simply take the water they need from the local water utility (as they will electricity). Specialists can be hired to perform the task. If the communities 'steal' their water supplies they can place enormous extra demands on the established water utility without contributing to the capital cost for developing the supplies and treatment plant or compensating for any operation and maintenance. Attempts to remove illegal connections can result in violent and life threatening confrontations. Even if the illegal connections are removed they are quickly reestablished. Citizens in some communities lament that the water service in squatter communities is better than the service they pay for.

The squatter communities do not have adequate sanitation facilities or any form of storm water management. The social condition within the squatter communities is often desperate and dangerous. Civil society may simply not exist.

There is an understandable reluctance on the part of municipal governments to acknowledge the legitimacy of the squatter communities and provide them with services they often desperately need. The problem is much broader and larger than any city is capable of managing themselves.

The provision of safe drinking water to inhabitants of squatter communities appears impossible but there are solutions. The residents of squatter communities do have some wealth and discretionary income despite the fact that they constitute the poorer and poorest segment of society. These people do understand that 'bad' water makes them sick. It is common for them to use a very large fraction of their limited income to obtain safe drinking water or to provide medical treatment for their family when needed. It is simply a matter of finding a legitimate and sustainable way to give them the opportunity to acquire the appropriate and affordable technology and services they want and are willing to pay for.

It is unlikely that the required support will come from the government because the people in squatter communities are occupying land illegally and governments will not do anything to legitimize this behavior. Affordable community scale water treatment systems that are owned and operated by cooperating members of the community or by entrepreneurs may be able to provide sufficient safe drinking water if the technologies are inexpensive, effective and simple to operate such as the BSF or LHPF. If the community scale solutions cannot be implemented household BSF technology is still available and affordable to those that wish to use it and profitable to the businesses that wish to make it available.

Regional Water Supply, Treatment and Distribution Systems
Several communities may share a water source and the cost of a single water treatment plant if they can be served by a pipeline that delivers water to a single point in each of the communities being served. Treatment plants can be more expensive and sophisticated but still be affordable in these circumstances.

Delivered or Trucked Supplies
Water is often delivered from the source or water treatment plant to the consumers. This type of supply is intended to reach those consumers who do not have access to the pipe distribution system, or, water supplies of any kind. The water may be delivered by large water trucks, rickshaw, horse, donkey, oxen, wagon, wheel barrow or bucket. The delivered water is more expensive and less convenient than piped water and there is a very real danger of contamination during the delivery process and subsequent storage and dispensing by the consumer. Household water treatment, such as the BSF technology, is required to provide safe drinking water.

Bottled Water and Drinking Water Stations
Bottled water is usually associated with the sale of purified water in small volume plastic bottles and larger twenty liter bottles. Provision of bottled water has become very common and is usually the domain of the private sector. The water is very expensive when compared to municipal water and there is considerable suspicion that the bottled

water sold in developing countries has never been treated to safe drinking water standards or is simply the same, untreated, contaminated, water from the community water distribution system. Newspapers in major cities frequently carry articles reporting the quality or lack of quality of local bottled water supplies.

Water for drinking my also be provided in small plastic bags or pouches. The equipment required to package the water in plastic bags is very inexpensive; and, the water supplied is definitely more suspect in terms of its quality. The pouches typically contain less than one-half litre of water and the empty bags are often just thrown to the side of the road. The plastic bags are not only unsightly. They can plug storm drains and sewers and cause serious flooding. Some countries have banned the practice of selling water in plastic pouches.

A few communities allow public access to the water at the treatment plant itself or at the deep well as it is being pumped into the distribution system. The water is sold for a negligible price provided the customers bring their own containers. The only difficulty is that the water treatment plant or well may be a great distance from where most of the people, who could benefit from this service, live.

As previously discussed it is reasonable to consider the construction of small local treatment plants for the sole purpose of producing inexpensive, safe, drinking water and making it available to the local community for a small profit. The price of the water would be much lower than bottled water and the service could form the basis of a viable small business.

Role of Household Water Treatment Systems in the Community Setting
Household water treatment systems are used to treat delivered but unsafe municipal water to a quality that is safe for human consumption. Consumers would also like biologically safe water for food preparation, kitchen hygiene including the cleaning of all cooking and eating utensils, surfaces where food is prepared and served and personal hygiene when preparing or eating food. They may also wish to have sufficient water for bathing if the untreated water is known to cause skin, eye and other infections.

A household water treatment system must be compatible with the characteristics (flow rate and pressure) of the water supply to the home. As previously noted water from municipal distribution systems is often supplied at very low pressure when it is supplied at all. Most of the point-of-use or point-of-entry (household) filtration systems used in developed countries cannot operate under these conditions. Unless provision is made to boost pressure and flow rates, household water treatment in developing countries must be manual. It is still common to find households using gravity type filters to remove particulate matter, followed by boiling the water to disinfect it and then cooling it prior to drinking. BioSand Water Filter technologies can produce large volumes of biologically safe water using the typical low pressure water supplies commonly found. The BSF technology can be manually or automatically operated. Household BSF treatment systems are available to provide safe drinking water from a faucet supply or treat all water used by the household and dispense it in any manner they chose.

Water Treatment for Apartments, Offices, Businesses and Subdivisions

Water treatment systems, similar to automated or semi-automated BSF or LHPF household water treatment systems, but much larger capacity, can be used to treat existing municipal water supplies (or any other water supplies) to a safe water condition for use by all residents in entire apartment buildings, office complexes, businesses and even whole residential or business subdivisions of large urban communities.

Technological Advances

The technologies that are used to supply, treat and distribute water are constantly being improved. New technologies are being developed on a regular basis. Many innovations are specifically designed for use in developed countries, where the prospects for commercial success appear to be greatest. Often these 'new' technologies find their way into the developing country environment with unfortunate, predictable results – they fail when the intended consumers implements them as instructed. Notable exceptions are the BSF and LHPF treatment technologies, which have been specifically designed for use in these environments..

Political and Bureaucratic Responsibilities

Ownership of community water supplies, treatment plants and distribution systems is normally the community; village, town, city, municipality, state or country. Water is usually viewed as a publicly owned resource and should benefit all and there are laws that are used to define and manage access and use of water resources.

Politicians and associated government bureaucracies are usually responsible for funding and arranging for the acquisition of water supplies, provision of appropriate treatment facilities and development of systems to distribute the water to the community. In many circumstances they do not appear to be very successful in performing these tasks; but, the truth is that the politicians and bureaucracies are probably doing as good as they can with the limited resources and tools at their disposal. There is very little incentive for politicians to provide inadequate water supplies to the people they are responsible for, particularly if the politician wishes to remain in a position of power. There may be some incentive for minor bureaucrats to engage in questionable practices; but, they could not survive long either unless the water needs of the community were generally being met. It can be concluded that politicians and responsible government agencies really are trying their best with the limited resources at their disposal. What they need is technology that allows them to do their job as required and expected. As indicated throughout this paper, the use of the BSF and LHPF treatment technologies can likely make this possible.

Privatization

Privatization of publicly owned water treatment and distribution facilities consists of giving or selling the facilities to a private company in return for a negotiated level of service and fee that would be charged for this service. Privatization was encouraged by International financial institutions (IFI's) considering it the only way to preserve and possibly expand failing water utilities. Privatization of community water utilities has met with mixed success in developing countries (mostly failure) and remains controversial. Obviously, privatization itself does not eliminate the root problems and the companies that are brave enough to take over the failed water supply, treatment and distribution systems are faced with the same issues as the previous owners, management issues withstanding. IFI's are frustrated with providing a seemingly unending series of loans or grants to maintain public utilities; however, the focus on mismanagement and corruption will not resolve the problems.

Effects of Global Warming

The 'wild card' in the discussion of the provision of adequate supplies of safe water to communities in developing countries is the impact of global warming. It is conceivable that water supplies will degrade in terms of availability of water and its quality. While communities in more developed areas of the world may be able to respond to these changes in a timely fashion, those effected communities in developing countries might not. It has taken many of these communities several decades to accumulate what infrastructure they have. Dramatic changes in either water supply or quality may result in societal collapse. It is essential that water treatment capability exist (such as those which use the BSF and LHPF technologies) that can rapidly, effectively and economically respond or adapt to the changing and unpredictable circumstances.

Right to Safe Water

Access to reliable, adequate, appropriately treated and affordable water (for a variety of purposes including drinking), contributes significantly to the well-being of all individuals, communities and countries. The right to safe drinking water has been endorsed by the United Nations and is extensively reported by several of its agencies. The focus is on the rural poor but the comments are equally valid for urban and peri-urban communities as well.

The Millennium Development Goals were published by the United Nations Millennium Summit in September 2000. Within the Millennium Development Goals is included the provision of safe drinking water.

General Comment 15 on the right to water, adopted November 2002 by the United Nations Committee on Economic, Social and Cultural Rights sets the criteria for the full enjoyment of the right to water.

The publication Right to Water, by the World Health Organization, 2003 cites the responsibilities of the various stakeholders and the list includes; governments (all levels, private sector, local and international nongovernmental organizations, United Nations, international financial institutions, the World Trade Organization, national and multi-national private service providers, the research community and the citizens of the world.

The recently published United Nations Human Development Report 2006, Beyond Scarcity: Power, Poverty and the Global Water Crisis underline the significance of the provision of water to everyone in our global community.

Final Comments

Despite the best efforts of governments, elements of the private sector, agencies (national and international), and NGO's, successful implementation of community water treatment and distribution systems for the production and delivery of safe drinking water, as it pertains to developing countries, has remained an unsatisfied objective.

Solutions lie in thoughtful integration of a thorough understanding of the technical, financial and management challenges facing communities in developing countries with knowledge of and respect for the culture of the consumers being served. Appropriate solutions continue to be developed using the BSF and LHPF treatment technologies and will be described in papers published on the web site: www.manzwaterinfo.ca .

Both the BSF and LHPF technologies are patent protected.

The BSF technology is commercially available through the Canadian company, Pure Filtered Water Ltd. of Calgary, Alberta, Canada.

The LHPF technology is commercially available through the Canadian company, Oasis Filter Ltd. of Calgary, Alberta, Canada.