Feasibility of Water Purification Technology in Rural Areas of Developing Countries

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Abstract
Water scarcity is threatening social and economic growth in rural areas of developing countries. There are potential markets for water purification technologies in these regions. The main focus of this article is to evaluate the social, economic and political feasibilities of providing water purification technologies to rural areas of developing countries. The findings of this research can serve as the basis for private investors interested in entering this market. Four representative regions were selected for the study. Economic, demographic, and environmental variables of each region were collected and analyzed along with domestic markets and political information. Rural areas of the developing world are populated with poor people unable to fulfill the basic needs for clean water and sanitation. These people represent an important group of potential users. Due to economic, social, and political risks in these areas, it is difficult to build a strong case for any business or organization focusing on immediate returns on capital investment. A plausible business strategy would be to approach the water purification market as a corporate responsibility and social investing in the short term. This would allow an organization to be well positioned once the economic ability of individuals, governments, and donor agencies are better aligned.

Keywords Water purification technology, rural areas, developing country, economic feasibility, social factors

Paper type – Research paper

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1. Introduction

There are nearly 50 countries in the world experiencing water stress or water scarcity (FAO, 2005). An area under water stress is defined as having annual water supplies below 1,700 m^3 (450,000 gal) per person. A country facing water scarcity is defined as having annual water supplies below 1,000 m^3 (260,000 gal) per person (UNEP, 2005). By the year 2025, it is anticipated another 70 countries will be added to the list. Appendix A contains a list of countries estimated to be water scarce in 2025. As part of its Millennium Development Goals, the United Nations has set aggressive targets to reduce by half the proportion of people without access to safe drinking water by 2015.

Given the importance of clean water to human health and economic growth, and the serious scarcity of water in developing countries, exploring the water purification market could be a potential business opportunity for private investors or corporations. This paper evaluates the economic feasibility of providing water purification technologies in rural areas of developing countries, along with practical considerations of social and political factors that may affect market entrance strategy. The findings of this research provide interested organizations with key information about the feasibility of entering the market. Four cases were analyzed, including Sichuan, China; Madhya Pradesh, India; Honduras, Central America; and Mozambique, Africa. Two cases representing extremes are presented in more detail. The two extreme cases included Sichuan, China, as the most feasible choice and Mozambique, Africa, as the least favorable alternative.

This paper is organized as follows. Section 2 discusses data sources used for this study. Section 3 outlines the methodology used for selecting water purification technologies. Section 4 describes the methodology for selecting representative regions for this study. Section 5 discusses

case studies for Sichuan Province, China, and Mozambique, Africa. Section 6 concludes the paper by summarizing the findings and giving suggestions to corporations that are interested in entering the water purification technology market in the researched regions. Section 7 offers suggestions for future research.

2. Data Sources

Several sources for social, economic, and governmental data were utilized to support the overall findings of this paper, including diverse medium of professional and academic journals, textbooks, special topic books, and databases[1].

Several governmental and non-governmental sources were used to identify and assemble demographic and geographic data. For example, the United Nations (UN) Department of Economic and Social Affairs Population Division was used to obtain both urban and rural population levels, densities, and growth rates. The UN population reports contain both national and regional level data along with sources of local census data, if detail is required at that scale. Energy supply, distribution, and infrastructure data for the targeted regions was gathered from the International Energy Agency (IEA), the Organization for Economic Co-operation and Development (OECD), and the World Bank.

Water resource supply, withdrawal, and use data was gathered primarily from the UN Environment Programme's (UNEP) Global Environment Outlook (GEO) Data Portal. The GEO Data Portal is a collection of data sets used by the UNEP and its partners for various environmental reports and assessments. Databases available at the UNEP include water access statistics from the World Health Organization/UNICEF and water resources/usage data from the United Nations Food and Agriculture Organization. The World Health Organization (WHO) was the source for water treatment standards. Other data sources related to water rates and willingness-to-pay levels include the World Bank, The World's Water biennial reports, individual consulting reports, and technical literature reviews of valuation surveys and methods.

[1] Some databases were available at various websites.

The UNEP GEO Data Portal offers country-specific information on: gross domestic product (GDP) per capita, illiteracy rate, and GDP annual growth rate. Literacy rates are available through United Nations Educational, Scientific, and Cultural Organization (UNESCO). The UN Statistics Division provides household size data for over 90 countries. For countries not included in the UN database, household size data is available through a variety of sources and is country-specific (e.g.: Census of India). The World Bank (2005a) has a qualitative ranking of each country's governance in the world. The following six indicators aggregated illustrate a country's governance proficiency: Voice and Accountability, Political Stability and Absence of Violence, Government Effectiveness, Regulatory Quality, Rule of Law, and Control of Corruption.

Numerous data sources were utilized for the business case studies to offer a broad perspective of the social, economic, and governmental viewpoints. The Central Intelligence Agency's (U.S. CIA, 2005) World Factbook was accessed multiple times for the economic information. Region-specific resources used frequently include websites of the Madhya Pradesh, India government and the Bureau of Statistics of Sichuan, China. Country-specific resources include websites of the National Bureau of Statistics of China and Mozambique's National Institute of Statistics.

3. Methodology for Selecting Water Purification Technologies

For water purification technologies, the disinfection contribution, primary use, affordability, and appropriateness of each technology were analyzed as a basis for selection. Four criteria established for technologies were: 1) disinfection capability to remove or inactivate microbiological contaminants for safe drinking water; 2) primarily applied to domestic use; (3) affordable to the user; and (4) appropriate for cultural and social conditions.

Based on the above selection criteria and the technology information, the most appropriate technologies were:

- Hand pumps

- Media filtration (sand filtration)
- Reverse osmosis (RO)
- Chemical disinfection (chlorine bleach)
- Ultraviolet radiation (UV)
- Flocculation/coagulation plus sedimentation (or filtration).

These represent the least costly alternatives, and in some cases, require no technology or energy/power.

3.1 Specification of Community Size for Evaluation of Water Purification Systems

For the selected technologies, a community with a population of 1,000 people was selected as a representative size based on the fact that a reasonable estimate of the common population of the communities and neighborhoods in the selected countries or regions was 500 to 800 people.

4. Methodology for Selecting Representative Regions

Four representative regions were initially selected for the study. Economic, demographic, and environmental variables of each region were collected and analyzed along with domestic markets and political information. To ensure a broad representation of markets on a global scale, it was decided to select a province within China, a province within India, a country in Africa, and a country in Central or South America as the four representative regions. Criteria for selecting the four regions are provided below.

4.1 Selection of Regions of Study

The criteria for selecting representative regions were defined by ten key variables (i.e., GDP was counted as one variable). These included demographic, economic, political, and water resource related variables used to assess a region's suitability for this study. The ten variables and the data associated with each variable are summarized in Table I for the four selected regions. Demographic, economic, and water resource related variables are self-explanatory. Political

variables include political stability[2] and government effectiveness[3]. Demographic variables include literacy rates to account for ease of information transfer pertaining to the business and technology of water purification systems.

"Take in Table I"

The political stability and the government effectiveness are thought to be critical attributes for a firm to make a decision regarding the selection of a particular country for investment. The World Bank (2005a) conducted a study to rank these two attributes (among others) of nearly every country in the world. Madhya Pradesh and Sichuan's rankings for political stability and government effectiveness are for all of India and China, respectively. Therefore, for these two target regions, the values may not accurately represent the provincial political stability and government effectiveness. However, China and Mozambique represent the two countries most politically stable and with the highest government effectiveness of the four target regions. While India has an effective government, its political stability ranks lower than the fiftieth percentile. Honduras' rankings fall below the fiftieth percentile as well. Diversity with respect to government effectiveness and political stability exists among the four target regions through the spread of rankings.

When choosing the four target regions, literacy rates were considered to account for ease of information transfer pertaining to the business and technology of water purification systems. All four countries have literacy rates at 54% or greater, with Mozambique's literacy rate near 54% (World Bank, 2005d). These literacy rates indicate the potential for educating technology operators and business entrepreneurs.

[2] Political stability is defined as one of six dimensions of the Governance Indicators combining several indicators that measure perceptions of the likelihood that the government in power will be destabilized or overthrown by possibly unconstitutional and/or violent means, including domestic violence and terrorism (World Bank, 2005d).

[3] Government effectiveness is defined as one of six dimensions of the Governance Indicators combining responses on the quality of public service provision, the quality of the bureaucracy, the competence of civil servants, the independence of the civil service from political pressures, and the credibility of the government's commitment to policies (World Bank, 2005d).

Western China is much less developed than eastern China. Twelve western provinces account for 75% of the total area and 28% of total population, but only 19.2% of total GDP of the entire country in 2002 (SATC, 2002). Northwest China is dominated by desert, and therefore, water resources are scarce. Northwestern provinces are sometimes afflicted with separatism and terrorism threats from central Asia. Southwest China consists of 5 provinces, as listed in Table II. Tibet was immediately eliminated as a province for the study due to the harsh environment and prohibitive transportation cost. Sichuan was the best selection due to its large rural population and relatively high income per capita.

"Take in Table II"

North Africa was immediately discounted because of water resource scarcity. Then, any country afflicted with wars and turmoil was disregarded due to the extreme barriers that would place on emerging business and technology. These countries were Sierra Leone, Liberia, Cote d'lvoire, Central African Republic, Sudan, Eritrea, Ethiopia, Somalia, Uganda, Burundi, Congo-Brazzaville, Congo, and Angola (Guest, 2004). The candidates for this project were eleven central and southern African countries with relatively peaceful environments, as listed in Table III. Mozambique stood out among the remaining candidates with its high percentile ranking of political stability and relatively large population.

"Take in Table III"

Madhya Pradesh, a province in India with a lower population percentage classified as rural, was selected to further diversify the targeted sites of the project. However, the overall population needed to be large enough to accommodate profitability of a water purification technology. Madhya Pradesh has a total population of more than sixty million with nearly 25% rural.

Besides the ten key variables, geographic location is another criterion used in selecting target regions. The regions of study were selected based on geographic diversity. For example, Honduras and Mozambique are coastal nations, but Madhya Pradesh and Sichuan are land locked.

Also, states in northeast India were avoided because of close proximity to China. Madhya Pradesh is located in the center of India and is representative of India with many of the states with large populations in the same region having similar water access issues.

From the preliminary data analysis, the following four regions were targeted for this study based on the ten selected variables:

- Honduras, Central America
- Mozambique, Africa
- Madhya Pradesh Province, India
- Sichuan Province, China

National data for China and India was used in some parts of this study when provincial data was not available. The two regions to be discussed in more detail in this paper include: a Chinese province, Sichuan, China, and a Sub-Saharan Africa country, Mozambique.

4.1.1 Water Stress or Scarcity

Aside from the water resource related variables listed in Table I, water stress is also an important consideration in selecting representative regions. As shown in Appendix A, based on the earlier definition of water stress and scarcity, the four regions/countries chosen for analysis cover a wide range of water resource availability and consumption, with many facing water stress or scarcity conditions in the coming years. For example, many regions in China and India currently face water stress conditions. By 2025, Mozambique, India, and several provinces in China will be under water stress, with some Indian states facing water scarcity conditions (UNEP, 2005b). Honduras, however, has abundant water supplies and is not expected to suffer water supply shortages within the coming decades (UNEP, 2005b). Moreover, the four selected regions cover a wide range of annual domestic water consumption patterns, with Mozambique (4 m^3/capita or 1,060 gal/capita) and Madhya Pradesh (51 m^3/capita or 13,500 gal/capita) being the extremes. All four regions also face challenges in providing clean water. Urban and rural areas with access to improved water supplies vary greatly between the selected regions.

In Table I, the definition of "improved" water is based on the assumption that one technology is better for health than another, implying that "improved" water and sanitation designate safe water and sanitation. Although defining access as "improved" or "not improved" simplifies the meaning, there are contradictions to every situation. For example, in some locations an unprotected household well may provide a better supply of water, both in terms of quantity and quality of water, than a household connection, which may be subject to intermittence and poor water quality. It is argued in the 2003 joint report by twenty-three UN agencies, Water for People, Water for Life, that methodology should be further developed so that progress can be assessed by measuring the number of people with access to "safe and sufficient" water and "safe and convenient" sanitation that meets basic welfare and hygiene needs (Water for People, 2004). The issue is not whether people have access to water and provision for sanitation, but whether the water supplies are safe, sufficient for their needs, and easily accessed at a price they can afford. It is also essential that there is a quality provision for sanitation that eliminates contact with human excreta and wastewater by making available toilets that are convenient, clean, easily accessed and affordable by all.

5. Case Studies

The case studies section provides information on the two extreme cases: Sichuan Province, China and Mozambique, Africa. Sichuan Province, China is the most feasible possibility for introduction and implementation of water purification technologies. Mozambique, Africa represents the other end of the spectrum as the least feasible opportunity.

The level of detail and analysis varies based on the availability of information for the two regions examined in the case studies. General information includes the economic background, rural water supply and demand, water purification technology customers, water treatment technology market, and barriers and risks to entry. Additional information, based on data availability, includes private investment, international organizations and NGO investment, and rural water supply project financing practices.

5.1 Introduction to the Case Studies

5.1.1 Background in Water Privatization

In the early 1990's there was a shift in international development toward allowing transnational corporations to play a role in providing water and sanitation to the developing world. The belief was that individual countries could no longer meet their people's needs due to inefficiency and corruption. As a result, international development agencies, such as the World Bank, pushed for water management by the private sector. Although this seemed like an ideal solution, transnational corporations have struggled with privatization because they find difficulty in generating profits in the sale of services to the poor. This leads to communities accusing corporations of favoring projects for the wealthy (Robbins, 2003).

In recent years, private organizations have begun to consider both financial benefits and social responsibility in their attempts to meet the water needs of the poor. In January of 2002, J.F. Talbot, chief of SAUR International, the fourth largest water company in the world, informed the World Bank that water could not be delivered to the poor. Talbot stated that "the scale of the need far out reaches the financial risk taking capacities of the private sector" (Hall, 2002).

At the same time it is still apparent in many developing countries that the majority of poor villages and urban slums are not yet served by piped water systems. Water sources available to the poor are polluted rivers, lakes, and shallow hand dug wells. To avoid these sources, some are dependent on street vendors that cost more over time than paying fees for piped water (an unaffordable investment). In addition, middle class consumers in many countries pay subsidized rates, becoming a burden to government and preventing the expansion of infrastructure to the poor (Siregar, 2003). It is conditions such as these that motivate organizations like the World Bank to push for privatization of the water market.

5.1.2 Role of International Organizations and Non-Governmental Organizations

Although international governmental and non-governmental organizations (NGOs) play a significant role in activities in rural areas of developing countries of the world, it is not certain

that they will be customers for water purification technology. Based on research of current NGOs' practices, it can be concluded that some organizations are helping to install purification technology; the technology promoted is usually what is considered "appropriate technology." Accordingly, technology must be "culturally and economically appropriate" so it can be operated and maintained by local people.

The NGOs are not in the business of promoting or marketing technology. Companies need to properly evaluate the environment and the market and not expect to implement technology that is not appropriate (i.e., no power or fuel source available). This is not suggesting that the NGOs do not work with private investors. It is stating that NGOs will in some cases work with private investors to evaluate what technology may be "culturally and economically appropriate" in a given setting.

Also, many organizations focus resources on providing water and sanitation education (and not technology) to local communities for families to understand the benefits of using clean water and the interaction between clean water, sanitation, and improved health. Significant investments in water technology focus on providing accessibility to water for those in need. Examples of this include hand digging or mechanical drilling a well, installing a hand pump, and constructing rainwater catchments and water storage tanks. The water is consumed in an untreated form, or subsequently boiled or treated with chlorine.

5.1.3 Potential Customers and Water Market

Generally, it is difficult to collect customer information in rural areas of each region for several reasons. First, the demand for sanitation and water supply has been weak because the perceived benefits of the purification technologies are outweighed by the investments needed to receive and sustain it (Deverill et. al., 2002). Second, people in remote areas are hard to reach by organizations. Because it is difficult to identify end users, this research assumes that the customers would be communities, international organizations, or NGOs. These are the organizations willing to purchase the technology and deliver clean water to the end users.

A precise estimate of the size of the water purification market is not always possible. This analysis instead used information assembled from previous studies to develop broad estimates (Meng, 2004; WaterAid, 2003a; Water and Sanitation Program, 2002). The results of these earlier studies show there is a low willingness for rural populations to embrace new water supply technologies (WaterAid, 2003a). These represent immature markets for water purification technologies that need significant development.

5.2 Regional Analysis Sichuan, China

5.2.1 Economic background

"Sichuan, located in southwestern China, is an agricultural province. Sichuan has the third largest population among all provinces in the country. Its rural population accounts for 80% of its total population. Boosted by the National Western Development Plan launched by the Chinese government a few years ago, Sichuan's economy is growing at a rapid pace with an average growth rate of 10.15% during 2000 to 2003 (BSS, 2003)," compared to a national average of 8.25% during the same period (The World Bank Group, 2005c). The growth rate is an average for both urban and rural areas. The rural growth rate is much lower than the average. This rate was not reported in statistics used for this study. Table IV provides a summary of Sichuan's key economic indicators.

"Take in Table IV"

To stimulate domestic and foreign investment, China has been maintaining very low interest rates (lower than most countries) since 1998 (U.S. Department of State, 2005a). The inflation rate has been successfully controlled between 0.7~4% in 2000~2004 (IMF, 2004). The exchange rate of Chinese Yuan to US dollar has been constant around 8.3 Yuan per US dollar for more than one decade, as a result of government manipulation. Recently, the government has expressed its intention to relax control over the exchange rate (The Economist, 2005), but it is difficult to forecast future fluctuations.

5.2.2 Rural area water supply and demand

Most rural residents obtain water directly from rainwater, surface water, and shallow wells. Water consumption per capita is estimated to be 80.55 liters per day (NBSC, 2003). Province specific data is lacking to determine the percentage of residents who have access to improved water sources, but the nationwide percentage is 68% of the rural population (WHO, 2005), which is used throughout this study to estimate Sichuan's rural population with improved access to water supply. At the national level, the Chinese government has set a high priority for increasing rural access to improved, conveniently located water. The government encourages investment of this kind to help reduce poverty and improve health and living standards in rural China.

One factor impacting Sichuan's water supply is the construction of the world's largest water dam, the Three Gorges Project (which was started in 1994 and completed in 2006, ahead of schedule), in Hubei (a neighboring downstream province of Sichuan) (IRN, 2006). As a result of the many concerns regarding the possible pollution to the water supply of Sichuan, many treatment facilities are expected to be built in near future.

5.2.3 Private investment

Most water supply infrastructure is state-owned and state-operated. Since China joined the World Trade Organization (WTO) in 2002, the central government has been gradually introducing more market-driven practices. The government is also slowly lowering barriers to market entry to allow private investment and international investment. For example, the consortium of Vivendi (France) and Marubeni Company (Japan), a foreign owned water group, has recently been granted the right to operate the Sixth Water Plant in Chengdu (the capital city of Sichuan) (U.S. DOC, 2005). The number of private investors and international investors is still small. Their presence has been regarded as positive to the development of the water supply sector. The local government and rural residents are continuing to welcome their investment.

5.2.4 International organizations and NGOs involvement

Since the 1980s, China's rural water supply projects have obtained financial support from various international organizations, including the World Bank, United Nations Development Program (UNDP), the United Nations Children's Fund (UNICEF), and the World Health Organization (WHO), etc (Meng et. al., 2004). The World Bank is the major contributor among these organizations, and has financed a total of $US137 million in loans for four water supply projects since the 1980s. Table V presents a brief summary of the four projects. Sichuan was one of the beneficiary provinces in the first project (CRWS).

"Take in Table V"

The Chinese government encourages NGOs to support rural water supply projects. For example, from 2000 to 2004 one major Chinese NGO, the All-China Women Federation, has raised approximately $US18 million to support rural water supply projects in western provinces (Meng et. al., 2004).

5.2.5 Rural water supply project financing practices

In China, partial user-financing for rural water supply projects has been in place for many years and has been mostly successful. Funding of a project comes from various sources, including contributions from different levels of government, bank loans, and end users. In a typical World Bank supported project, the Bank provides 50% of the capital through credit/loan (Water and Sanitation Program, 2002). The different levels of government finance 25%, with the end users contributing the remaining 25% in the form of cash or labor hours. The end users are also responsible for the Bank debt payback and the operating/maintenance cost through payment of water tariffs, which are regulated by local governments. Taking all this information into consideration, the users finance 75% of the investment cost (Water and Sanitation Program, 2002). For economically disadvantaged villages that cannot afford this share, it is expected that other players (governmental and/or non governmental organizations) would provide stronger support.

5.2.6 Water purification technology customers & market

Past rural water supply projects were mainly funded by governments, international organizations, and NGOs. These could be the potential customers for the water purification technologies. With the opening of the water supply market, private investors could also be potential customers. Province specific data is lacking to determine the size of the market of water purification technologies in Sichuan. The total size of the market in China is enormous and provides a significant opportunity. It is reasonable to estimate that Sichuan, the province with the third largest population in China, has a significant portion of this vast market. Most of the market demand is covered by local production, but the import market is promising. According to the US Commercial Service, China's market for imported water treatment equipment is about $US2 billion per year (U.S. DOC, 2005). Table VI summarizes the market size data.

"Take in Table VI"

5.3 Regional Analysis Mozambique

5.3.1 Economic background

Although it has experienced high GDP growth in recent years, Mozambique is one of the poorest countries in the world. The 7.25% growth rate is one of the highest in Africa, but poverty still remains pervasive in rural areas. Per capita income in rural Mozambique averages $US65/year, while the median is only $US30/year (Walter et. al. 2004). The high GDP growth rate is observed because the scale of Mozambique's economy is small and is not an indicator of an economic boom. Table VII provides a summary of the key economic indicators in Mozambique.

"Take in Table VII"

The inflation rate is high but has been steadily decreasing in recent years, from 16.8% to 12.9% in 2002~2004 (IMF, 2004). Mozambique has a small capital market of ten commercial banks. Taking out a loan is usually difficult and expensive because of high interest rates (U.S. Department of State, 2005b). The foreign exchange rate of Mozambique meticais to US dollar is stable around 23,700 meticais per US dollar in recent years (U.S. CIA, 2005).

Lack of clean water is a serious problem in Mozambique. Improving water quality and increasing access to safe water, in both urban and rural areas, are among the Government's poverty reduction strategies. Government efforts have yet to reach rural areas. Even in cities, the water price sometimes is so high that not all city residents can afford access. The Mozambican government initialized a "Poverty Reduction Strategy Paper (PARPA)" in 2001, which set the water sector as a priority (SDC, 2003). Under this strategy, there are two main goals in improving the country's water supply: (1) establish an integrated water resource management system; and (2) build sanitized water supplies for all areas. Given the limited resources and the current government efficiency, there is still a long way to go before the goals can be achieved.

5.3.2 Rural area water supply and demand

Twenty-four percent of the rural population has access to improved water sources (WHO, 2005). Shallow wells and hand pumps are the only means of obtaining water in rural areas.

5.3.2 Private investment

The Mozambique government has consistently failed to provide affordable and sustainable clean water for its rural population because of government's limited capacity and authority. The government is now encouraging the participation of the private sector (including international investors) in the construction of improved water sources. A core element of their strategy is the policy of public asset privatization, as indicated by the Enhanced Structural Adjustment Facility Paper (ESAF), another strategic document approved by the government recently (Zandamela, 2001). Because most water supply facilities are public assets, this policy offers many opportunities for foreign investors who can provide cheap and sustainable water supply technologies.

Two private sector participants are known for this study. Aguas de Mozambique (AdeM) (World Bank, 2004), a consortium of SAUR International, IPE Aguas de Portugal and a group of five local investors, has undertaken a 15-year lease contract to improve urban water systems in five cities in Mozambique since 1999 (WaterAid, 2003a). AdeM's operation has been turbulent

and unsuccessful. AdeM's involvement is limited to urban areas only. A Mozambican private institution called EPAR implements water sanitation systems mainly in rural areas (WaterAid, 2003a). EPAR receives financial and technical support from both the Mozambican government and Oxfam Belgium, a major European NGO.

A recent sample study conducted by WaterAid (WaterAid, 2003a), a major water resource related NGO based in the UK, shows that private sector participation has barely tackled any water supply difficulties in Mozambique due to the long-lasting major problems in capacity building, community participation, finance and institution reform. The study cautions private investors' involvement in water supply projects in Mozambique. Extreme poverty, poor governance, inactive citizenry, and lack of responsible partners are among the concerns cited by the study.

5.3.4 International organizations and NGOs involvement

Water supply projects in Mozambique predominantly depend on the involvement of international organizations and NGOs around the world. Refer to Appendix B for the major participants and their projects in recent years.

5.3.5 Rural water supply project financing practices

Government financed projects require water consumers pay 2-10% of the capital cost of a water facility (Breslin, 2002). The remainder comes from the government's budget. For each dollar the government invests, 90 cents are expected to come from foreign aid (WaterAid, 2003b). While heavily relying on foreign aid itself, the government has faced sharp criticism for making its poor citizens pay their share of 2-10% (Breslin, 2002). In addition, NGO financed projects sometimes provide water consumers a range of options to contribute to the capital cost. For example, they can contribute maize (corn, a major crop in Mozambique) or in-kind labor instead of cash.

5.3.6 Water purification technology customers & market

The Mozambican government, international organizations, and NGOs are potential customers for the technologies identified in this study. EPAR and AdeM are potential private sector customers.

Water supply/treatment technologies used in rural Mozambique are predominantly hand-dug wells and hand pumps. Hand pumps have proven to be extremely difficult to maintain. More than 35% of hand pumps across the whole country are dysfunctional (WaterAid, 2003a, 2003b). Protected springs and rainwater harvesting are also used occasionally (Breslin, 2003). There is insufficient information available to determine market share for these technologies.

5.4 Profitability uncertainties due to high risks

Common risks and barriers associated with investment into the water purification technology industry in the four selected regions are listed below:

1. *Government Corruption.* A major concern is the pervasive corruption in government. Bribery and "under the table" deals are common practice in doing business in these regions. This may add unforeseeable expenditures to initial investment.
2. *Affordability.* A risk specific to rural area water supply projects is that poor villagers usually cannot afford treated water. A vast amount of the rural population in these developing countries is still struggling to obtain basic living necessities. According to a WHO estimate, a household should spend 3.5% of its income for basic water supply (Walker et. al., 1999). Based on this estimate, investors should not expect to finance any significant part of the project through water tariffs. Investors should also be aware that the revenue generated is likely to be inconsistent and unsustainable.
3. *Uncertainty of capital recovery.* The same problem leads to difficulties in capital recovery for any investors. Investors must capitalize on the non-cash contribution of the poor communities, as well as the social benefits, to justify their investment.

   Additionally, each region/country has specific risks, as discussed below:

5.4.1 Sichuan, China

1. *Water Tariff Regulations.* The biggest risk comes from the water tariff regulation by the government. In poor areas government intervention in setting water prices is

common. The variation of water prices is a major factor to be considered by any investor (U.S. DOC, 2005).

2. *Import Regulations.* If a water supply project requires imported technologies and equipment, then China's constantly changing import regulations pose a threat to investors. Identical technologies and equipment may be subjected to different levies at different times and ports. This uncertainty complicates the investors' cost control.

5.4.2 Mozambique, Africa

1. *Low literacy level and hygiene education.* The low literacy rate and hygiene education among rural residents undermine public awareness of the importance of clean water. As a consequence, rural residents have a low willingness to accept more advanced water treatment technologies (WaterAid, 2003a). This is a common phenomenon in Africa.
2. *State Owned Facilities.* Water supply infrastructure is traditionally owned and operated by the state. The worker union in the state-owned facilities strongly opposes private sector participation in any utility services in the country (Zandamela, 2001).
3. *Insufficient Statistical Data.* Due to the constrained capacity and authority of the Mozambican government, statistical data needed by investors is insufficient. Even the available statistics are usually unreliable (WaterAid, 2003b).

5.5 Investment Feasibility

Overall, based on the set of qualitative variables used in this study to evaluate and analyze the business case for water purification technology in rural areas of developing countries, it is difficult to build a strong case for any business or organization focusing on immediate returns on capital investment.

If a private investor is willing to take on business risk to pursue a market, Sichuan, China may represent a potential opportunity for limited water purification technologies. Sichuan has the largest population density and rural population percentage among the four regions studied. This

could be a sign of possible market and demand growth for technologies. Sichuan's economy is growing at a pace as fast as the national economy of China. Rural household income is likely to increase with the growth of the economy and lead to increased willingness to pay for improved water supply. Moreover, the Chinese government has implemented favorable policies to encourage foreign investment, focusing on poverty reduction and living condition improvement in Western China. For example, a 5-year tax break is available in Sichuan because of the National West Development Plan (SATC, 2001; SATC, 2002). Based on these facts, Sichuan, China could be the most favorable potential market for water purification technologies among the four regions.

On the other hand, it is not recommended to pursue business opportunities in Mozambique. Most water consumers in rural Mozambique are relying on unstable income sources. It is not unusual for people to fail to pay for water, no matter how low the water tariff would be. In many cases water consumers have to pay the water tariff with crops due to shortage of cash. This indicates a very unstable cash flow and unsustainable revenue source for the operation (Zandamela, 2001). The same problem leads to difficulties in capital recovery for any investors. Investors must capitalize on the non-cash contribution of the poor communities, as well as the social benefits to justify their investment (WaterAid, 2003a). The inability to pay for improved water associated with the low literacy rate and the lack of hygiene education among rural residents leads to low acceptance of advanced technologies. Another critical factor is the lack of reliable statistical data for investors to make a well-informed business decision. There are also other factors that would prevent a company from operating successfully in Mozambique, such as corruption, state-owned facilities preventing private business entry, etc. Considering these risks, it is unlikely pursuing business opportunities for water purification technology in Mozambique will be economically feasible.

6. Conclusions & Recommendations

Rural areas of the world are populated with poor people unable to fulfill the basic needs for clean water and sanitation. Although this represents an important group of potential users, the

population density in rural developing countries may be difficult to quantify, small in number, and difficult to reach. Because of these critical issues, markets for rural areas of developing countries may not represent economically feasible regions to implement water purification technologies. The development effort should focus on generating demand for clean water by changing the social and cultural norms that currently prevent inhabitants of rural areas of developing countries from understanding the necessity of clean water.

As part of its Millennium Development Goals the United Nations has set two aggressive goals which apply directly to the future of the water purification market.

- *By 2015, reduce by half the proportion of people without access to safe drinking water.*
- *Target for 2015: Halve the proportion of people living on less than a dollar a day and those who suffer from hunger.*

These goals were set at a September 2000 conference and have been approved by the world community (UNDP, 2005). It is for these reasons that a plausible business strategy may be to approach water purification as a corporate responsibility and social investing in the short term, which will allow one's organization to be positioned well once the economic ability of individuals, governments, and donor agencies are better aligned. As one individual from the NGO CARE stated during this research, taking the time now to learn about people and culture and develop appropriate business models without the pressure of making a profit will provide a competitive advantage when the market for water purification technology evolves over the next decade.

6. Future Research

Population density is typically low in rural areas of developing countries and could be one of the larger impediments to growth in new or expanded markets for technology. Urban regions of the developing world may represent a larger potential market based on population trends and density. In fact, urbanization is one of the critical global trends shaping the future. For example, by 2025, it is estimated that two-thirds of the world's people will live in cities. In contrast, only one-third of

the world's population was urban 35 years ago. In addition, more than 150,000 people are being added to urban populations in developing countries every day. Poorer people can be located in urban regions, and in some developing nations, may represent a large share of the potential consumers and end-users for growth in these regions.

Because country, province/state and region specific data was used in the current study, key indicators represent possible barriers to urban areas in these same countries, provinces/states, and regions. Future studies should focus on different countries and/or regions within these countries.

If accurate information regarding market size potential is desired, a longer time-frame of 18-24 months may be required to gather information. A caveat is that even with more market research, the conclusions may remain the same.

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Appendix A: Countries Estimated to be Water Scarce in 2025 (Seckler et al., 1999)

Countries that face absolute water scarcity are recognized as category 1 and they will not be able to meet water needs in the year 2025. Countries that must more than double their efforts to meet 2025 water needs, but will not have the financial resources available to develop these water supplies, face economic water scarcity and are recognized as category 2. Countries that must increase water development between 25 and 100% to meet 2025 needs but have financial resources to do so are considered category 3. Countries that will have to increase water development modestly overall on average by only 5% to keep up with the 2025 needs are considered category 4.

Category 1 (absolute water scarcity)	Category 2 (economic water scarcity)	Category 3	Category 4
Afghanistan	Angola	Albania	Argentina
Egypt	Benin	Algeria	Austria
Iran	Botswana	Australia	Bangladesh
Iraq	Burkina Faso	Belize	Belgium
Israel	Burundi	Bolivia	Bulgaria
Jordan	Cameroon	Brazil	Canada
Kuwait	Chad	Cambodia	(China)*
Libya	Congo	Central African Republic	Costa Rica
Oman	Cote d'Ivoire	Chile	Cuba
Pakistan	Ethiopia	Columbia	Denmark
Saudi Arabia	Gabon	El Salvador	Dominican Republic
Singapore	Ghana	Gambia	Ecuador
South Africa	Guinea-Bissau	Guatemala	Finland
Syria	Haiti	Guinea	France
Tunisia	Lesotho	Honduras	Germany
United Arab Emirates	Liberia	Indonesia	Greece
Yemen	Mozambique	Kenya	Guyana
(China)*	Niger	Lebanon	Hungary
(India)*	Nigeria	Madagascar	(India)*
	Paraguay	Malaysia	Italy
	Somalia	Mali	Jamaica
	Sudan	Mauritania	Japan
	Uganda	Morocco	Mexico
	Zaire	Myanmar	Netherlands
		Namibia	North Korea
		Nepal	Norway
		New Zealand	Panama
		Nicaragua	Philippines
		Peru	Poland
		Senegal	Portugal
		Tanzania	Romania
		Turkey	South Korea
		Venezuela	Spain
		Zambia	Sri Lanka
		Zimbabwe	Surinam
			Sweden
			Switzerland
			Thailand
			UK
			Uruguay
			USA
			Vietnam

*These countries have severe regional water scarcity. A portion of their populations (381 million people in China in 1990 and 280 million people in India in 1990) are in Category 1. The rest of their populations are in Category 4.

Appendix B: Major International and Non-Governmental Organizations in Mozambique

International Organizations	
The Netherlands	Major donor since the late 1970's budget 3.5 million Euro per year.
The World Bank	Supported two projects.
Switzerland	Mainly focusing on rural water supply, training, institutional building and human resource development, budget $US3.5 million per year.
The African Development Bank	Planning rural water supply projects for Niassa and Nampula provinces.
The European Union	Active with some technical assistance, watershed commissions and development and in a future sanitation project for Beira.
UNICEF	Provide institutional support, participant in a rural water project in Zambezia province.
Canada	Funds a rural water supply project in Inhambane province, implemented by Cowater, a Canadian firm.
Japan	Funds a rural water supply project in Zambezia province implemented by a Japanese NGO.
NGOs	
WaterAid	Active in rural Niassa and rural Zambezia provinces.
CARE	Active in rural Inhambane province.
World Vision	Active in rural Nampula province.
Helvetas	Active in rural Maputo province and Cabo Delgado.
MSF	Active in urban Maputo.
AusAid	Funds World Vision project.
Ireland Aid	Active in Niassa province.

Table I: Key Variable Data for the Four Regions

Variables	Units	Honduras	Mozambique	Madhya Pradesh, India	Sichuan, China
GDP per capita	$US	1026 (2004)	233 (2004)	603 (2004) *	697 (2002)
Gross Domestic Product - Annual Growth Rate	%	4.79	1.6	4.33	10.15
Political Stability	% ranking	38.4	63.8	22.2*	51.4*
Government Effectiveness	% ranking	27.3	42.8	54.1*	63.4*
Total Population	thousands	7257	19495	60385	86730
Percentage Rural	%	53.6	62	73.33	82
Literacy Rate	% population over age 15	76.2	53.5	64.11	86.45
Average Household Size	# persons	5.4	4.1	5*	4*
Water Use per capita	m^3/yr	133	36	635*	80.55 **
% of urban population with access to improved water***	%	99	76	>85	92*
% of rural population with access to improved water***	%	82	24	100	68*

* National data, not province/state specific at this time.

** Rural water use; urban water use is 153.38.

*** The definition of "improved" water is based on the assumption that one technology is better for health than none at all, implying that "improved" water and sanitation designate safe water and sanitation.

[a]Sources of Data in Table I: Ping 2005, IMF 2005, Office of the Registrar General- India 2001, DDWS 2005, Government of Madhya Pradesh 2003a-b, NBSC 2003, UNESCO 2005, UNEP 2005, UNESA 2004, The World Bank Group 2005a-d, U.S. CIA 2005, BSS 2003, Dev 2004

Table II: Key Variables of the Southwest Provinces of China.

Province	The Amount of Water Supply (billion km^3)	Rural Population (thousands)	GDP per capita ($US)	Income per capita (Rural) ($US)
Guangxi	237.259	40,642	615	243
Guizhou	111.757	31,934	373	180
Sichuan	206.616	69,049	679	255
Tibet	424.349	2,201	730	177
Yunnan	230.887	34,898	622	194

Source: NBSC (2003)

Table III: Key Variables of the Candidate Countries in Africa.

Country	Renewable Water Resources (km^3)	Population (thousands)	GDP per capital ($US)	Political Stability (%)
Botswana	2.90	1,801	3968	71.4
Cameron	273.00	16,564	702	37.3
Kenya	20.20	32,849	320	21.6
Madagascar	337.00	18,409	209	53.3
Malawi	16.14	12,572	142	54.6
Mozambique	99.00	19,495	222	63.8
Namibia	6.16	2,032	2230	60
Nigeria	221.00	130,236	273	10.3
Tanzania	82.00	36,588	201	35.7
Zambia	80.20	11,043	404	44.3
Zimbabwe	14.10	12,963	528	8.6

Sources: UNEP (2005a), UNESA (2004), The World Bank Group (2005d)

Table IV: Sichuan Economic Indicators

Economic Indicators	Sichuan	China
Population (2002)	86 Million[1]	1,285 Million[1]
Urban (2002)	17Million[1]	502 Million[1]
Rural (2002)	69 Million[1]	782 Million[1]
GDP (2002) ($US)	59 Billion[1]	1,266 Trillion[1]
Per Capita Net Income (2002) (Rural) ($US)	255[1]	299[1]
GDP average annul growth rate (2000-2003)	10.15%[2]	8.25 %[3]

Source:

1. NBSC, 2003
2. BSS, 2003
3. The World Bank Group, 2005c

Table V: Rural Water Supply and Sanitation Program in China supported by the World Bank.

Name of Project	No. of Province	No. of Counties	No. of Beneficiaries Million people	Implementation Period		WB Credit/Loan (M$)
				Start	*Complete*	
CRWS	5	25	5.93	1985	1991	10.46 (C)
CRWSS	6	75	9.06	1992	1998	11.00 (C)
NRWS	5	40	4.60	1997	2003	70.00 (C)
FRWSS	4	27	3.08	1999	2005	30.00 (C)
						16.00 (L)
Total	20	167	22.67			137.46

Source: The World Bank Group, 2002

Table VI: Estimated Size of the Water and Wastewater Technologies Market in China, 1999. (millions of $US)

Technology	Local Production	Imports	Total Market Size
Water treatment and supply	1,506	646	2,152
Wastewater treatment	1,191	1,273	3,184
Total	3,417	1,919	5,336

Source: U.S. DOC, 2005

Table VII: Mozambique Economic Indicators.

Economic Indicators	Mozambique
Population (2005)	19.50 Million[1]
Urban (2005)	7.40 Million[1]
Rural (2005)	12.10 Million[1]
GDP (2003) ($US)	4.3 Billion[2]
Per Capita Net Income (2002) (Rural) ($US)	65[3]
GDP average annul growth rate (2002-2003)	7.25%[4]

Source:
1. UNESA, 2004
2. IMF, 2004
3. Walter et. al., 2004
4. The World Bank Group, 2005b