A Comparison of Water Supply Methods for Rural Ecuadorian Communities

Bruce V. Rydbeck P.E., D.WRE., M.ASCE
Director of Clean Water Projects - Vozandes Community Development
HCJB Global - Quito, Ecuador

Hugh Gillis
Consultant
Quito, Ecuador

Vozandes Community Development (VCD) responds to the need for improved rural water & sanitation in Ecuador by facilitating community projects with a focus on sustainability. The ensuing discussion on rural domestic water supply methods reflects the learning acquired during three decades of working with hundreds of rural communities. A majority of the communities are indigenous in nature but the circumstances range from high elevation Quichua communities in the Andes Mountains at close to 4000 meters to tropical Shuar and Chachi communities in the jungle at elevations near sea level. Some communities do not have road access.

The importance of sustaining water supply methods cannot be under estimated. Successful water supply methods are crucial to meeting the Millennium Development Goal (MDG) to reduce the child mortality rate by two-thirds over the ten year period ending in 2015. Water Aid studies indicate that mortalities due to water-transmitted disease can be reduced 90 to 95% by three factors: a clean water source, adequate sanitation, and improved hygiene.

Community Structure

The rural population of Ecuador is generally defined by a community structure with a high degree of loyalty and allegiance to one's community. There are about 55,000 rural communities which are predominately indigenous. Generally, rural communities build and maintain their own water system with varying levels of outside assistance.

When the Spanish conquered Ecuador in the early 1500's, many areas of the country were divided into large land parcels as *haciendas* and deeded to privileged Spanish families. The Quichua people, who are indigenous to Ecuador, became subservient labor for the *haciendas* and were considered to be part of the property. The land, together with the livestock and the indigenous people were divided in inheritances with each subsequent generation. Convenient water supplies for the indigenous labor were rarely given priority in this process. Since the indigenous people did not hold citizenship, they could not possess water rights.

In the early 1960's, an agricultural reform obligated the *hacienda* land owners to give two hectares of land to each family living on their *hacienda*. The reform also gave citizen status to the indigenous people, allowing them to obtain water rights. These families formed communities, which demonstrate a high level of commitment to each other and a willingness to work together to resolve their water needs. The agriculture reform marked a new era for rural water supply in which communities began building their own water system.

Each community water system has a community water board, called a *junta administradora de agua potable* (JAAP), charged with the operation, administration and maintenance. There are 3000 recognized community water boards, some of which oversee regional water systems. The water system operators are commonly volunteers or poorly paid part-time employees, earning an average of $20 per month, who are often unable to adequately maintain their facilities. (*El Comercio*, 2007)

The definition of the community water boards or JAAP and their legal basis provide a foundation for Ecuador's rural water systems. Communities take seriously their responsibility to administrate the water system. The deficiencies observed are generally due to the lack of government and private infrastructure to assist the rural communities with this responsibility.

Quichua women dig pipe trench for their community water system

Evaluation of Current Rural Water Systems

Sustainability is a major issue for rural community water systems throughout Ecuador. A study of existing community water systems by the Sub-secretary of Sanitary Engineering (SSA) in November 2004, found that; only 13% were sustainable, 29% had slight deterioration, 20% had significant deterioration and 38% had failed. In other words, more than half have significant problems. It is noteworthy that in another study, 42% of the communities had continuous support from some outside organization (Nolasco, 2004). The report concludes that communities with a strong relationship to an outside organization performed better in sustaining their water system.

Historical Background

Rural water supply in Ecuador continues to face the challenge of constantly changing government structures. Experience demonstrates that the communities themselves provide the most stable leadership for resolving water supply needs.

First addressed legally in 1949, rural water supply was initially considered the responsibility of the municipalities. In 1965, the Ecuadorian Institute of Sanitary Works (IEOS) was formed to take responsibility for water and sanitation services at the rural and urban level, as well as to develop regulations. However in 1966, a new law placed responsibility for water and wastewater services back on the municipalities, particularly in the urban areas, leaving IEOS solely responsible for the planning and norms. (Ordoñez, 2004) In reality, IEOS continued as the main executor of rural sanitary works for several decades. In 1992 the Law of Modernization was passed and many state institutions were downsized redefining their roles.

In 1993, the Ministry of Urban Development and Housing (MIDUVI) assumed responsibilities for rural water & sanitation replacing IEOS. MIDUVI, in theory, reviews community water boards on an annual basis. Municipalities were identified as the organizations responsible for providing basic services for the urban and the rural areas within their jurisdiction. According to an article in *El Comercio (“Mitad, 2007*), 50% of the 219 municipalities lack potable water of adequate quantity and quality.

The current Ecuadorian government passed a new constitution, which once again reorganizes the sector and emphasizes the role of municipalities. It is unrealistic to expect that municipalities, which have been unable to solve their own water supply issues, can resolve the water supply situation for the surrounding communities.

Ground Water Sources

Rural community water systems supply their users with ground water, un-treated surface water or treated surface water. Ground water sources, which include springs, dug wells, or bored wells, can often provide coliform-free water. These water sources should be disinfected with a high chlorine dose at completion of construction and then adequately protected from contamination for subsequent use. Communities often develop around a convenient existing ground water source which can be protected or improved to provide safe drinking water. The strategy of improving an existing water source provides high levels of community acceptance and ownership.

Water rights to springs are commonly held by a particular community. In these cases it is important that the water system users be limited to the community holding the water rights to avoid conflicts between communities. Respect for political boundaries and water rights is crucial to successful water supply projects.

Spring formations vary significantly in Ecuador and are rarely confined to a single point of water production. Most commonly, springs produce water over a large area requiring a subterranean perforated pipe collection system in order to aggregate the water produced and adequately protect the spring from contamination. In cases where spring water supplies a piped distribution system, a collection tank is normally required to receive the spring water and stabilize the hydraulics. Strongly flowing springs normally do not have water quality issues requiring treatment. In the experience of Vozandes Community Development, arsenic is only an infrequent concern in Ecuador.

So called “spring boxes”, advocated in many engineering and development texts for spring capture, are impractical for the majority of spring situations except in rock formations. The difficulty of building a spring box structure in flowing water while also sealing off possible subterranean water escape routes cannot be underestimated. Installing perforated pipe collectors in a granular filter material in the water production area with a subterranean cut off wall to cut off water flow on the downstream side of the spring greatly reduces the work, investment, and risk of failure. The collector tank receiving the spring water can be built a short distance from the spring where construction is more practical. The collector tank should have a drain, overflow, sanitary cover for access and an outlet pipe. The overflow should be slightly below the spring level so that the collector pipe forms the easiest route of escape for the spring water.

The mountainous topography of Ecuador allows many rural communities to use springs located at an elevation above the community as a gravity-fed water source, thus avoiding the costs of a pumped water supply. In some cases, long feed lines are needed to pipe the water to the community. This type of gravity-fed water system experiences fewer operational issues and is therefore easier to sustain.

Dug wells can be built without heavy equipment in isolated areas. Often rural communities prefer this method of well construction over drilled wells because they can visualize where the water comes from. It is important that wells be chlorinated at the time of completion and adequately protected from contamination. Solid concrete casing or plastic casing is normally used for at least the upper 3 meters of the well. Pipe entrances to the well should be grouted, caulked or installed with sanitary well seals to avoid possible contamination routes.

Surface Water Sources

Rural water systems frequently use distant capture of surface water and in some cases provide treatment of the surface water. The discipline and cost of operating and maintaining a water treatment plant 24 hours per day - 7 days per week, most often exceeds expectations. Generally rural communities are not well prepared for the complexities which water treatment demands. Lacking laboratory facilities and adequate government surveillance or assistance, rural water treatment plants are rarely well run.

Ecuador, perhaps typical of many developing countries, suffers from significant soil erosion. Storm runoff carries a significant sediment load creating water treatment challenges. The roughing filters often used to prevent mud from entering the important downstream stages of the treatment process are difficult and time consuming to clean unless provisions are made for backwashing the rock filter media. Frequently, due to financial limitations, rural water treatment plants are built without essential elements such as flocculation, settling tanks, chlorine contact tanks or roughing filters. Invariably, the water quality suffers.

Rural communities do not receive technical assistance or surveillance of their water systems from the provincial or national government. As a result, the water quality suffers due to poor operational practices. Not infrequently, poorly operated treatment plants end up being bypassed altogether, thus providing the users with untreated surface water.

Disinfection

MIDUVI, the government agency overseeing rural water supplies, strongly encourages disinfection by chlorination to ensure the microbiological quality of the water. In spite of this, disinfection is rarely sustained by rural communities due to low public acceptance of chlorinated water. Chlorine is often perceived by rural users as a chemical to be avoided. In the absence of laboratory testing, the rural population uses taste and odor as important indicators of water quality. Therefore rural users are less likely to ingest chlorinated water because of the chemical taste. Since water-borne pathogens are not detectable by odor or taste, when users reject the chlorinated community water supply, they are likely to drink water from less secure water sources. Therefore, it is essential to be aware of the public acceptance level of chlorinated water.

A second issue in the use of chlorine is the cost of either liquid or granulated chlorine. Rural communities cannot take advantage of the reduced cost of bulk purchases normally available to municipalities. Some NGO's, such as CARE, have dealt with this issue by installing electrolysis devices which produce chlorine solution from salt. This cost effective method can only be used in areas where there is a continuous electrical supply.

Facilities for drip dosing of liquid chlorine solution are normally provided in government built water systems, but are rarely used long-term. Almost all rural water systems stop chlorinating shortly after the assisting institutions withdraw. It is impractical for rural communities using the rudimentary drip chlorination method to dose a variable water supply flow rate with the precision necessary to consistently kill pathogens and at the same time maintain levels of chlorine low enough for public acceptance.

MIDUVI, the Ecuadorian agency responsible for rural water supplies, is experimenting in the use of a Venturi regulated chlorine dose controlled by the water flow. Vozandes Community Development is also embarking on a pilot project using normal electrically powered chlorine metering pumps for a water system which serves about 500 homes in the semi-urban Quichua community of Carabuela. The pilot project results should help determine if adequate levels of chlorine disinfection can be maintained to kill the necessary pathogens while also maintaining public acceptance.

The SODIS method of using ultra-violet solar disinfection is a practical method, which does not impart taste or odor to the water. There is little if any cost since plastic (PET or polyethylene terephthalate) bottles are readily available. Water filled bottles laid out in direct sunlight disinfect within hours. Ecuador's equatorial location makes this methodology particularly effective. Only 2 to 5% of the water supply is normally ingested or about 2 liters/person/day. This method allows the users to focus disinfection efforts on this critical portion of the water rather than disinfecting the entire water supply. The plastic water bottles used for disinfection remain sealed protecting the drinking water for long periods of time until the water is consumed.

Disinfection is not as crucial for ground water sources since protected ground water sources normally do not contain pathogens. Even in more developed countries such as the U.S., small water systems supplied by ground water do not always require disinfection. For this reason, VCD normally uses protected ground water sources for the water supply and recommends the SODIS method to provide an additional confidence level in the drinking water. Although not all the users are likely to implement the solar disinfection, the protected ground water source normally represents several orders of magnitude reduction in pathogen levels over the previous community water sources, thus improving health.

Peguche Spring Contamination Incident

A significant water supply contamination incident occurred in the Peguche water system in late April 2009. A new concrete sewer collector pipe was installed several meters away from the spring capture and water pump station which supplies water to about 800 homes for a number of communities in northern Ecuador. The contractor did not implement adequate precautions to protect the water source and allowed sewage to flow liberally in the area. As a result, more than 1000 people became sick with gastro intestinal infections according to community estimates, and 50 people hospitalized.

An inspection of the two spring capture structures revealed several relatively unprotected breather pipes and access openings close to ground level. Most of the openings could be eliminated to better secure the springs. The use of ductile iron or plastic pressure pipe for the sewer line in the vicinity of the spring would be advisable. In response to the incident, Peguche used tanker transported water from a local municipality for a month and began chlorinating the water supply using the drip method.

This episode underlines the importance of sustainable water quality and adequate spring protection. Rural areas like Peguche, which transition into becoming peri-urban, face unique challenges in adapting their infrastructure to the increased demands and changes of population growth. Although springs form a reliable water source, protection and disinfection of the water supply become increasing important as land development occurs in the vicinity of the spring.

Peguche pump station and adjacent spring collector

Pumping

Pumped water systems must have reliably installed pumping equipment in order to be sustaining. Electric water pumps need;

- Proper pump sizing and selection
- Adequate cooling consideration
- Voltage and over current protection
- Low level cut-off switch
- Lightning protection

- Adequate electrical grounding
- A backup pump in case of pump failure or during pump repairs

Commonly some of these aspects are missing or not taken into account in rural areas. The urgency of building a rural water system can prejudice good judgment. Additionally, submersible pumps need to be installed with sanitary seals where the pipe passes to the exterior environment to properly protect the water source from contamination. Submersible pumps installed in cisterns should be placed in a flow sleeve to promote the water flow necessary to cool the pump motor.

Distribution Piping & Structures

Older rural water distribution systems used polyethylene (PE) pipe with internal sleeve connectors to make joints between 100-meter lengths and fittings. Steel banding clamps were used to secure the joints. This type of joint begins leaking at low pressures particularly in the larger diameters. The issue is further complicated by the mountainous terrain of many communities necessarily dictating the use of higher pressures. These older leaking distribution systems made it difficult to keep the water distribution system pressurized and to conserve valuable water supplies.

Rural water systems built since 1990, generally use PVC bell & spigot pipe which became more available at that time. PVC pipe is more economical than PE but must be buried at an adequate depth to be properly protected. PVC pipe is more fragile than PE, but withstands higher pressures and has more secure joints.

The mountainous conditions in the central highlands of Ecuador pose significant challenges due to the extreme variations in elevation and require careful topographic survey to do the design necessary. Commonly, feed-lines to transport the water from its source to the principal reservoir of the water system are built with unnecessary pressure breaking structures that add maintenance concerns and allow unnecessary susceptibility to contamination. Feed-lines can often be built without control valves and operate with open channel flow conditions making pressure breaking structures unnecessary. The hydraulic gradient for the range of flow conditions expected should be calculated to optimize pipe diameters and locate vacuum relief valves, air evacuation valves and water storage structures.

The following are important design practices for rural water distribution systems.

- Bell & spigot PVC pipe should be buried at a sufficient depth (normally 1.2 m) or otherwise protected from damage.
- Pipe bends and tees should be adequately secured to prevent displacement when under pressure.
- Above ground pipe should be threadable pipe or other appropriate grade to afford good protection.
- All distribution piping should be sized to provide adequate flow at times of peak use with nominal losses.
- All water storage and pressure breaking tanks should be built as sanitary structures with covered top, a sanitary access cover, drain, valved outlet and overflow.

Sustainable Administration & Maintenance

The government study of rural water systems indicates that the continuing maintenance and administration of a water system is equally important in attaining successful sustainability as the proper design and construction. In the past, good operational practices were difficult because of the rustic nature of rural water systems. Limited shifts of this mind set can help communities provide better water service to users and reduced maintenance.

Water systems should be designed and operated to provide water to all house connections or water spigots 24 hours per day – 7 days per week. This practice eliminates the need for users to store water in open containers which are impractical to protect from contamination. In order to keep constant water pressure in all parts of the distribution piping, the system requires water meters for each user. A reasonable value for the water must be determined to charge the user for the number of cubic meters used each month rather than charging a flat monthly fee. Metering combined with an appropriate rate structure encourages water conservation and allows the community to share costs equitably.

Normally, Vozandes Community Development helps the community establish a budget for the first two years of operation by projecting the volumetric water use and the operating costs for the same period of time. The projected costs are simply divided by the expected water use in order to establish a value for the water. Communities are encouraged to use this income stream to equip themselves with the necessary plumbing tools and supplies during the first two years of operation.

Typical metered spigot on concrete pedestal

Community Development Methods

Successful community water system projects require the users or beneficiaries to participate in the decision-making process and to contribute resources for the construction. The World Bank uses the Demand Response Approach (DRA) which keys on these two factors. These two factors treat seriously the reality that a high level of community ownership of the design and completed water system is necessary for the long-term success of the project.

The projects facilitated by Vozandes Community Development (VCD) normally require that the community provide all local materials, the manual labor to build the water system, and room & board in the community for the skilled staff who supervise the construction. VCD provides the water system design and facilitates funding requests to government agencies and potential donors for the pipe and other building materials needed. The community participation in the resources and decision making process assures a sense of project ownership and a long-term commitment to maintain the water system for years to come.

Development agencies often place an exorbitant concern on the water quality and little concern on accessibility; whereas, rural communities normally place greater concern on water accessibility. For this reason, water treatment methods which are difficult to maintain, costly or burdensome for the community are often abandoned. Communities normally prefer to invest their time and resources on the distribution system rather than on water treatment. The simplicity of ground water sources takes this community motivation to into account.

Conclusions

Ground water sources normally represent the most secure and sustaining water sources for rural Ecuadorian communities. The water supply must be protected from contamination from the source to the user. Chlorine disinfection is rarely sustaining in the rural sector. Disinfection is of lesser importance for protected ground water sources except in the case of urban or peri-urban communities.

Well designed water systems with metered water use at each home are necessary to assure sustainability. Successful administration of the water system must include equitable sharing of costs and proactive maintenance. Ecuador maintains clear definition for the sustaining community leadership necessary for this role by the community water board or *junta administradora de agua potable*.

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Bibliography

Borja, Juan Fernando. (Feb 2007). La capacitación: un instrumento para la sostenibilidad de los sistemas de agua potable. *Agua Yaku*. CIASE Comité Interinstitucional del Sector de Agua Y Saneamiento del Ecuador. Quito, Ecuador.

Chávez, Leopoldo, et al (1988). *Normas de Diseño Para Sistemas de Agua Potable y Eliminación de Residuos Líquidos: Poblaciones con más de Mil Habitantes*. Instituto Ecuatoriano de Obras Sanitarias, Quito, Ecuador.

En la mitad de los 219 cantones no se consume agua potable (2007, Feb. 6) *El Comercio,* Quito, Ecuador, p.16.

Estévez, Roberto. (Feb. 2007). La Segunda Fase del Programa de Agua y Saneamiento para Comunidades Rurales de pequeños Municipios – PRAGUAS. *Agua Yaku.* CIASE Comité Interinstitucional del Sector de Agua Y Saneamiento del Ecuador, Quito, Ecuador

Fernández, Javier M. et al. (2000) Proyecto Sistemas Comunitarios de Agua y Saneamiento: Evaluación participativa de 8 sistemas de agua potable y saneamiento en las Provincias de Azuay y Loja del Ecuador. CARE and Cinara, Quito, Ecuador

Isch, Edgar L. y Gentes, Ingo. (2006). *Agua y Servicios Ambientales: Visiones criticas desde los Andes*. Abya –Yala, Quito, Ecuador

Ordóñez Martínez, Fabián. (2004) Ecuador Análisis del Sector Agua Potable y Saneamiento. Corporación Andina de Fomento. Informes Sectoriales de Infraestructura, Año 2 n9, Quito, Ecuador

La Motta Diaz, Enrique. (1987) *Sistemas de Abastecimiento de Agua Potable y Eliminación de Excretas para Poblaciones con Menos de Mil Habitantes*. IEOS (UNORMIL), Quito, Ecuador.

Nolasco and Assoc. Inc. (2004) *Estudio Sobre Sostenibilidad de Servicios de Agua y Saneamiento Rural en Ecuador*. Programa de Agua y Saneamiento (PAS), Banco Mundial.

Solis, Fernado, et al. (2006) *Estudio de Sostenibilidad de los Sistemas de Agua Potable Rural.* CARE and CAMAREN. Quito, Ecuador.

Terán, Juan Fernando. (2005) *La sequedad del ajuste: Implicaciones de la gobernanza global del agua para la seguridad humana en Ecuador.* Centro Andino de Estudios Internacionales. Quito, Ecuador.

Zurita, Jorge et al (2003). *Política Nacional de Agua y Saneamiento*. Ministerio de Desarrollo Urbano y Vivienda. Quito, Ecuador.

34 365 concesiones de agua, registradas en todo el país (2007, Feb. 7) *El Comercio.* Quito, Ecuador, p.16.