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Chapter 5

WATER ENGINEERING: A CHALLENGE FOR SUSTAINABLE DEVELOPMENT FOR VULNERABLE COMMUNITIES-CASE COLOMBIA

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ABSTRACT

According to estimates of IDEAM[1], Colombia has 742,705 drainage basin units, indicating the total water supply will surpass 2,000 km3/year, which corresponds to 57,000 m3/year*Hab. Despite this abundant water supply, in this country, a considerable amount of the population has no access to drinking water because of problems associated with availability (quantity, quality or accessibility), the rural population being the most affected. Currently in the country, 13.6 million people live in rural areas, of which 39.7% have no water supply system, 60% have no sanitary or sewer units and only 11% have access to treated water. The situation in 2009 was reflected by the 189,480 cases of disease and 7,900 people who died because of perinatal mortality, acute diarrheal disease, malaria, dengue, and cholera, all of which are diseases associated with water quality.Problems with the availability of water resources are associated with causes such as population growth, spatial distribution, pollution, and mismanagement of the resource associated with poor governing and implementation of policies.

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These problems make a water-rich country such as ours a failure in ensuring resource availability as a right for all the people. Although the legal structure in Colombia is one of the most important in Latin America, complementary mechanisms of action and control tend to be insufficient. For this reason, the Government, through the Decree 421/00, regulated by Resolution 151/01, has empowered organized communities constituted as non-profit legal entities, to provide public services in smaller municipalities and rural areas. This scenario requires linking different members with the objective to design innovative solutions to increase coverage of safe water. In this context, the organizational system, Ingenieros sin Fronteras - Colombia (ISFC), is established. Constituted by engineering schools (teachers and students) to work with communities and local government entities in formulating a social model which designs and implements technological solutions that are accessible and culturally appropriate. ISFC develops projects based on the CDIO approach (Conceive, Design, Implement and Operate), engineering solutions that improve the quality of life of vulnerable communities in Colombia, working together with them through collective participation.The chapter will address each of the problems mentioned by a critical analysis in light of the Millennium Development Goals and other United Nations regulations that require states to provide quality water. Additionally, it will also present a case study in a Colombian town in which ISFC, through collective participation and the CDIO methodology, improved the water quality of the population. The framework developed during this process is shown as a workable model to be replicated in other parts of Colombia, in order to propose innovative alternatives that generate sustainable development for the most vulnerable in Colombia.

1. INTRODUCTION: SHORTAGE DESPITE ABUNDANCE

The perception of most of the inhabitants of the planet regarding water is that this is an infinite resource. Even though almost the 70% of the surface of our planet is covered by water (CIA, 2010), only 3% is fresh water (FAO, 2007). This percentage is divided in a 70% in glaciers water and the remaining 30% as groundwater and superficial water associated to rivers and lakes. However, despite the small amount of water that is available (42.000 km3/year), this amount is enough to cover the demand of the 6,500 million people on the planet, that demands around 3,000 km3/year of this resource.

In Colombia, the situation is even more significant. The amount of available fresh water per person is much higher than the world average, being in the 24th place among 182 countries studied (IDEAM, 2005). This abundant amount of water is noticeable in departments like Chocó or Amazonas.

In this scenario, the logical conclusion would be that the amount of fresh water is more than enough to supply the global demand, as well as the Colombian demand. However, this amount cannot be seen so broadly. It is important to take into account three basic aspects that determine the quantity of water a specific community can have: availability[1], accessibility[2] and quality[3] (Defensoría del Pueblo, 2009).

Sadly, these three components are on a decline due to the mismanagement. The misperception of the water as an infinite resource generates a lack of concern regarding the need to preserve the resource and the ecosystems that generate it. The degree of

[1] Sustainable supply capacity based in the water quality of the basins, as well as in the regularity of the public services.

[2] Capacity to supply drinkable water for all the people without compromising their physical integrity.

[3] Physical-chemical state of the water whose concentration of polluters do not exceed the limits to avoid compromising the health of the population.

irresponsibility has reached to the extremes of endangering ecosystems like the páramo, which supplies a vast amount of water in excellent condition to numerous villages in the country.

An additional aggravating factor relatedto the lack of water conservation is the consequence in morbidity and mortality, especially in children. A bad quality of the resource on top of the lack of the resource results in millions of deaths each year because of diseases related to water, like cholera, dengue fever, diarrhea, among others. This condition is so critical in Colombia that the leading cause of death in children under 5 years old is the acute diarrheal disease.

That is why it is necessary to raise awareness of the problem in Colombia and the world, and it is vital to take improvement measures related to the resource, its conservation, and the conservation of the systems that produce it.

Variability of the water resources in Colombia

As noted above, Colombia has a large quantity of water sources that makes it known as a water-rich territory. Plentiful rivers like the Caquetá, Magdalena, Orinoco and Amazonas, as well as lakes, ponds and creeks support this reputation. For example, the Caquetá River's streamflow can reach up to to 15000 m^3/s, while the Magdalena River, the most important in Colombia due to it uses and history, reaches 7000 m^3/s (IDEAM, 2001).

Moreover, the volume of rainfall in the Colombian territory is higher than in most zones of the world. The multi-annual average is 3000 mm, a figure that represents a very important affluence to the surface runoff (IDEAM, 2009).

These two factors make possible that, when comparing regional numbers with global ones, the Andean region has a water availability per capita three times the average that in the rest of America and 6 times the world average; (IDEAM, 2005; FAO, 2010) (see table 1-1) and that Colombia has the capacity to procure 53000 m^3/year per inhabitant.

However, the variability in space and in time of the water sources and of the rainfall makes the availability of the resource limited in some zones of the country. In terms of water bodies, while in zones like the Orinoquía and the Amazonia are rich in the resource, other zones like the inter--Andean valleys and planes, the Caribbean Zone, the upper Magdalena, among others, suffer from a deficit of the resource (Marin, 2003; Defensoría del Pueblo, 2009).

To illustrate this problem with the distribution of the resource, almost 20 million Colombians (close to 45% of the population) have only 2.67% of the available water, while the 85% of the water can be used by 37% of the population (Defensoría del Pueblo, 2009). This shows Colombia as a country inhabited in the dry areas, surrounded by humid zones sparsely populated (Marín, 2003).

Regarding the climate variability, the country faces strong dry seasons with high humidity. In the floods seasons, several municipalities in Colombia are badly affected by the adverse weather, leaving numerous people homeless (v.g. 1,200,000 because of the winter of 2010) and prone to several diseases caused by the humidity and the contact with bad quality water; the water bodies and the sewer systems overflow, and the infrastructure of the country is not adequate to store the resource. Conversely, in the drought season, the people do not have available water for consumption, several municipalities have to ration the resource and the offer is not enough to satisfy the demand of the population.

Table 1-1. Fresh water availability in several regions

Region	Precipitations	IRWR	Percentage of fresh water in the world	Available per inhabitant
	km3/year	km3/year	%	m^3/year
World	112100	43002	100%	6380
Africa	20359	3931	9%	4008
Asia	26798	12393	29%	3037
Europe	16391	6548	15%	8941
Oceania	4733	892	2%	32366
America	43820	19238	45%	20928
Andes[1]	8777	5186	12%	41439

Because of this, it is important to take into account the natural regulation depending on the ecosystems and the way we take care of them.

The hydrological cycle and preserving the ecosystems

First of all, the lack of understanding of the citizens about the hydrological cycle that regulates the planet's climate and the regeneration of fresh water (ACSE, 1996) has as a consequence, among others, which is the human intervention in unique ecosystems, generating devastating impacts.

The Colombian hydrological cycle shows once again the vast amounts of water "produced" in the country. Taking into account the surface runoff, groundwater and superficial water, still and flowing water bodies, the amount of water is overwhelming. First, if we add all of the contribution of surface runoff that arrives and creates creeks, rivers, lakes, among others, the approximate total streamflow is 67000 m3/s. Another important amount is in rivers and creeks that arrive to the sea that do not have any use. Additionally, the groundwater obtained by infiltration may be equal to 70 times the amount of Colombian surface water. Finally, cienagas, lakes and still water bodies, shelters 38 million m3 (IDEAM, 2001), which is enough to sustain the whole Colombian population.

The big amount of sheltered water will not be possible without the different ecosystem types of the country. Big cienagas able to regulate the weather, unique paramos worldwide that are known as "water factories", and very special types of soils for the retention of the resource, increase its availability for the population.

Unfortunately, the privilege of having so many and so particular ecosystems that produces a big water offer, is wrongly translated as an "excess", resulting in a lack of care by the population towards this kind of natural system. Countries like Finland, Denmark, among

[1] Andes includes Bolivia, Ecuador, Venezuela and Colombia

others, value in an implicit way the ecosystems and the water, because they have such a short offer of it. Colombia does the opposite: the care and the protection of the ecosystems and water sources is minimal, despite of all the efforts of the Government; the lack of awareness of the average Colombian is so deep, that the idea of the resource being infinite is a common place in the society.

Sad examples of this situation are the paramos. Only six countries in the world have them (Colombia, Venezuela, Ecuador, Peru, Panama and Costa Rica), all of them –except Costa Rica- located over the Andes. This neo-tropical zone is affected daily by the demographic and agro-industrial growth, with a severe consequence: less available fresh water.

Table 1-2. Indicators that show the availability of the resource

Scarcity index	**Scarcity index**	**Municipalities**	**%**	**Population**	**%**
	High	21	2%	980.616	2%
	Medium High	51	5%	13.250.271	31%
	Medium	38	4%	2.624.747	6%
	Minimum	257	24%	11.713.232	28%
	Not Significant	694	65%	13.669.325	32%
Natural Regulation	**Natural Regulation**	**Municipalities**	**%**	**Population**	**%**
	Unregulated	31	3%	634.966	1%
	Very Low	107	10%	3.580.490	8%
	Low	554	50%	27.646.078	64%
	Moderate	221	20%	5.199.126	12%
	High	159	14%	4.867.791	11%
	Very High	41	4%	1.135.712	3%
Vulnerability	**Vulnerability**	**Municipalities**	**%**	**Population**	**%**
	Very High	6	1%	301.586	1%
	High	175	16%	20.036.370	47%
	Medium	568	53%	14.705.174	35%
	Low	285	27%	6.508.034	15%
	Very Low	33	3%	700.107	2%
	Minimum	1	0%	25.220	0%

In order to determine the amount of water available for the population, one must take into account the natural regulation, responsible for the capacity of an ecosystem to self-sustain the population; the scarce index, which indicates the amount of water needed by the population of a place over the amount of the water "produced" in its jurisdiction; and lastly, the vulnerability index, that combines the former two. Table 1-2 shows the level of the three indexes in the Colombian municipalities, showing a situation that, although manageable, should put us in alert regarding the care of the resource.

Accessibility of the water in Colombia

Taking into account the amount of water available for the Colombians, it is vital to take into consideration how accessible the resource is for the population. This means that the available water should be physically easy to obtain.

This takes us directly to the capacity of the water works and sewer in the country, since the infrastructure associated to these two services is the fundamental determinant to make the access to the water easy and realistic.

Based on data given by the DANE's 2005 Census, 65.1% of the countries housing are connected to a water system, while 41.2% have sewerage. Pitifully, of the 1099 municipalities of the country and 20 departmental *corregimientos* (departmental divisions), 665 have a water works coverage under 75% and 964 have less than 75% of coverage in their sewer system (Defensoría del Pueblo, 2009).

An even worst situation is seen in 110 municipalities of the country, which have coverage of less than 30% in their water works, while 440 municipalities have a covering of less than that in sewage (see Table 1-3) (DANE, 2005). This means that the population that lives in these municipalities is under a severe lack of water, and also confirms the fact that is not enough to have a large amount of water sources, but is necessary to secure its availability and accessibility to the whole population.

Table 1-3. Coverage by ranges

Total Coverage Rages	**AQUEDUCT**		**SEWERAGE**	
	Municipalities	**Average total coverage**	**Municipalities**	**Average total coverage**
0 to 15%	49	3,8%	204	5,80%
15 to 30%	60	24,2%	236	22,30%
30 to 45%	102	37,8%	216	37,20%
45 to 60%	182	53,7%	169	52,30%
60 to 75%	272	67,4%	139	67,20%
75 to 90%	327	82,3%	103	82,00%
90 to 100%	127	94,3%	52	94,20%
Total	1.119	65,1%	1119	41,20%

An aggravating factor to these figures is the access to drinking water of the child population. Nearly 3 million children have no access to the services (Defensoría del Pueblo, 2009), which leads to a very delicate public health problem that should be addressed as a priority in the country.

Quality of the water in Colombia

In parallel with the problems of distribution, the problems associated with the quality of the resource should also be contemplated; these can drastically limit the availability and accessibility of a given population to drinking water. The quality of the groundwater and superficial water is deeply at risk because of the leaking of wastewater. Since the colony andthe people have used the water bodies to transport and dump liquid and solid wastes, a practice that affects the quality of the water for the people located downstream of the disposal, it has, as a consequence, a severe deterioration of the quality of water by the affected population.

According to the resolution 2115 of 2007 (that will be mentioned in the following section), the water should have acceptable minimum of quality to be drinkable, which are not met in most of the occasions. As we can see in Figure 1-1, only 16% of the studied municipalities have water SUITABLE, an alarming 80% have water NOT SUITABLE and the remaining 4% have water NON-VIABLE (according to the Quality Water Risk Index). Ii is important to clarify that the lack of information is another common denominator in the country (Figure 1-1 has information from only 541 municipalities), which makes it even more difficult to plan possible solutions.

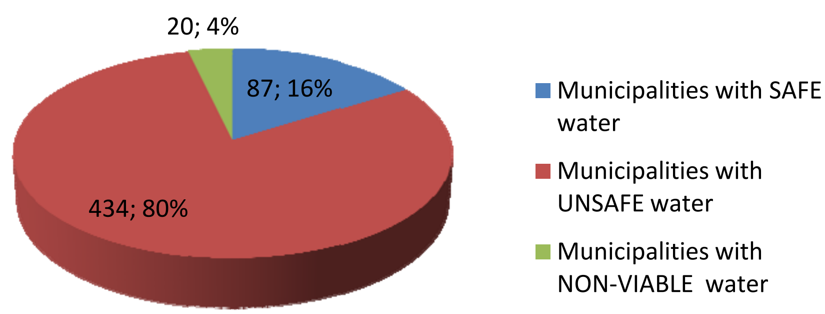

Figure 1-1. Quality of the water in the different municipalities of the country. Source: SIVICAP.

This data reflects the low quality of the water sources in Colombia, with an additional aggravating point: most of the population is crowded in very small areas, which generates a pollution pressure to the water bodies. Rivers like the Bogotá, Medellín, Orinoco and the Magdalena River have been used for centuries as receptor bodies of wastewaters, which produces a serious chain effect, where populations down the river have to consume the water from populations up the river, as we mentioned before.

Therefore, it is essential to have a holistic approach to the water service: water works that distribute water of good quality, adequately treated, and sewer systems that collect the wastewater of the municipalities, which should be treated before being poured into receiving water bodies.

In terms of the treatment of drinkable water, the actions performed generally are the sanitation of water, which is an essential step to avoid several diseases. Regarding the wastewater, the situation becomes worse. Only 12% of the urban pouring effluents are treated

(SUI, 2005), and the future does not look encouraging, because there are more than 97425 pouring points identified[1], of which 43% do not have a sanitary plan.

These figures can also be compared with the levels of contamination of the most important basins of the country, which are alarming: of the 88 studied, 84 have alarming indexes of organic matter (measured as COD[2]); most of them have a pH completely unacceptable; only 7 have a good level of oxygen; and in terms of solids and conductivity, even thought the situation looks more promising, there is a lack of information (IDEAM, 2005).

Additional to the data presented, lack of treatment of wastewater and lack of control of effluents, according to the health statistics (WHO, 2010) in 2008, more than 5 million people of the countries with low income needs sewage treatment (ST), due to the use of the receptor bodies. The lowers numbers of coverage corresponded to the Oriental Mediterranean region (where only one in ten people needing ST receive it) and is higher in the American Region (where one in two people needing ST receive it).This outlook is apparently encouraging for our region, and in fact, the figures of covering of sanitation have improved and the access to improved drinking water sources is optimal. In contrast, the rural population has very low figures of covering in improved sources of sanitation and access to drinking water. Table 1-4 shows the covering percentages and the position occupied by Colombia among the 154 countries that WHO has information for.

Table 1-4. Covering of the sanitation and improved water sources in Colombia

Covering	**Urban**	**Rural**	
	% of covering	**% of covering**	**Place among 154 countries**
Improved sanitation	99%	81%	55
Improved water sources	73%	55%	73

As has been exposed, it is essential to take into account the quality when we want to determine the available water for a population, because a bad quality of the water causes multiple problems of morbidity and mortality, especially in children.

Morbidity and mortality associated with the water in Colombia

The water is the larger vector of diseases of the planet, because of its unequalled characteristics and how necessary is it to the existence of life. Diseases related with the consumation or presence of polluted water, like the infections caused by the E. coli, Salmonella, rotavirus, poliomyelitis, enteroviruses, hepatitis A, typhoid fever, cholera and malaria among others, have taken the lives of millions of people around the world.

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[1] By the Procuraduría General de la Nación and the Superintendencia de Servicios Públicos Domiciliarios

[2] Chemical Oxygen Demand.

In Colombia, the situation is not different: in 2007, 173712 cases of diseases related with the water were reported, with malaria being the most common, with 62.9% of the reported cases (see Table 1-5) (INS, 2009).

Table 1-5. Cases of diseases possibly related to the water

MORBIDITY	2006		2007	
	Num. Cases	Weight	Num. Cases	Weight
Cholera	0	0%	3	0%
Clasic dengue	33.614	23%	38.551	22%
Intoxication transmitted by Food or Water	8.562	6%	5.563	3%
Typhoid and Paratyphoid fever	615	0%	581	0%
Hepatitis A	4.212	3%	5.917	3%
Drug intoxication	1.306	1%	2.641	2%
Heavy metal poisoning	34	0%	61	0%
Methanol intoxication	47	0%	138	0%
Intoxication by other chemicals	2.107	1%	3.796	2%
Pesticide intoxication	5.219	3%	6.247	4%
Solvents intoxication	64	0%	247	0%
Leptospirosis	835	1%	630	0%
Complicated malaria	10	0%	60	0%
Falciparum malaria	30.793	21%	29.997	17%
Malariae malaria	10	0%	18	0%
Mix Malaria	1.003	1%	1.275	1%
Vivax malaria	60.745	41%	77.987	45%
Total	149.176		173.712	

In terms of mortality, the cases reported in the Colombian territory for 2007 according to the National Health Institute reached 7465, being the case with the highest incidence of perinatal mortality (see Table 1-6). It is important to highlight the relation of this kind of death with a proper coverage of a water and sewerage system, because the sanitary conditions at birth are essential for the life of the newborn.

In this manner, we can asseverate that about 80% of the diseases related with the water are due to inadequate sanitary conditions, and is quite likely that about 90% of the deaths are due to this cause.

As we can see, the availability, the accessibility and the quality of the water are essential to guarantee the health of a country. Currently, Colombia is surrounded by paradoxes: is a country rich in water, yet several zones still suffer from a lack of the resource, are prone to changing weather, face a lack of good quality water, and finally does not have a proper care of the resources and ecosystems[1].

[1] It is important to recognize that the governmental entities are working to improve the water conditions in the country.

These figures reflect the hard work that is required in order to preserve the resource and improve the quality of life of the populations, based in technically feasible, economical, financial, environmental, and social engineering solutions. The approach to these solutions should be based on the knowledge of the availability of the resource and its quality.

Table 1-6. Death cases because of diseases possibly related with the water

Morbidity	2006		2007	
	Num. Cases	Weight	Num. Cases	Weight
Maternal mortality	420	6%	415	5,56%
Perinatal mortality	6.257	84%	6.387	85,56%
Mortality by ADD 0-4 years	206	3%	20	0,27%
Dengue mortality	44	1%	205	2,75%
Mortality by ARD 0-4 years	489	7%	418	5,60%
Malaria mortality	30	0%	20	0,27%
Total	7.446		7.465	

2. Response of the Colombian Government to Water-Access Situation

The concern about environmental topics associated to the use of forests, the water and the land, became relevant in the country through the creation of the first Corporación Autónoma de Colombia (Colombian Autonomous Corporation), the 22 of October of 1954, during the government of Gustavo Rojas Pinilla. This first corporation aimed to promote the development of the Upper Cauca valley (Cauca, Valle, Caldas), due to the need to generate actions to protect the population of water-related threats in the region associated with overflows, avalanches and floods of the Cauca River and its tributaries. This first corporation, which was supported by the World Bank, the president of the Tennessee Valley Corporation and local leaders, performed environmental, civil and socioeconomical studies. With the purpose of adopting strategic measures that would guide the government investments in plans to improve the quality of life of the population both during seasons of drought and winter, following an agricultural {refer for missing text} and of management of the natural resources scope.

One of the greatest impacts that the corporation had in the country was the preparation of the Plan for Economic Development of the Water Basin of the Upper Cauca, which became a reference for the Territory Development Plans. In these plans, several topics were taken into account including those associated to water.

In parallel, the General Assembly of the United Nations in 1966 created and approved diverse covenants about socioeconomical and cultural rights, as well as civil and political rights. These covenants were included in the legislation by the Colombian Congress through the Law 74 of 1968, which recognizes, among others, that “everyone has the right to enjoy the highest possible level of physical and mental health”. This obligates the Government to take measures to ensure:

a) The reduction of the mortality, in particular, the child mortality, as well as the healthy development of the child.
b) The improvement in all aspects of the hygiene of the workplace and the environment.
c) The prevention and treatment of the epidemic, endemic, professional and other kinds of diseases and the fight against them.
d) The creation of conditions to ensure to all of the citizens receive medical attention and has access to medical services in case of emergency.

In this fashion, the door was open in Colombia for the setting of a clear regulation and management of the environmental topics, considering the impacts that these may have in the public health of a region.

Among these topics above, one of the most relevant is the topic of the water that in the developing countries is one of the topics with the largest impact in the morbidity of the population, especially for the children.

In 1968, the Instituto Nacional de Recursos Naturales (INDERENA, National Institute of Natural Resources)was created, an entity that was alive until 1994. It had a relevant role in the administrative strengthening of the management, development and protection of the natural resources and the environment. This institution was the base for the creation of the Ministry of Environment in 1993.

The Inderena had the following functions:

- Coordinate environmental corporations.
- Create awareness about the environmental problem at the communitarian level.
- Create a vision of the control and surveillance of the resources.

Sadly, the Institute had a low control capacity, it did not properly coordinate the corporations and its function was limited to surveillance, rather than management, which prevented it from accomplishing its functions. This finally caused its closure.

In 1972, and in the framework of the environmental Conference of Stockholm, the need to determine common criteria and principles that would provide the nations with patterns on how to preserve and improve the environment became relevant. There was a general call to the nations about the importance of their intervention in environmental aspects. This conference allowed them to trace global guidelines of investment for attending the environmental problems, which are condensed into the following principles:

1. The concern for the preservation of the environment.
2. The importance of preserving the natural resources for the next generations.
3. The development of policies aiming to control the growth of the population of the developing countries.
4. The free flow of information.

As a respond to the global guidelines established in Stockholm, Colombia, through the Decree Law 2811 of 1974, the Code of Renewable Natural Resources and Environmental Protection was created. This code was a global example of a remarkable environmental legislation for almost 15 years.

However, the fines imposed in the code were not updated and, after its implementation, it was evident that the ineffectiveness of the institutions responsible for its execution, as well as the lack of management and coercion capacity of the institutions. Because of this, before the promulgation of the Constitution of 1991, there was not a single organism able to control the state of the natural and environmental resources in the country; the management and environmental control were divided among several organizations, generating duplication of functions and affecting the government actions.

The Constitution of 1991 incorporates the environmental dimension as a necessary condition for the economical development in the medium and long terms, and a set of instruments were created which made possible to monitor the compliance of those rules. Furthermore, the latter rules and regulations have made it possible to specify the conceptual and legal frameworks, which allowed our country to move forward in the framework of the sustainable growth.

In the Constitution, the protection of the environment is raised to the category of collective rights and gave to the people mechanisms for overseeing its fulfillment such as popular or group actions, tutela actions and fulfillment actions.

In the framework of the new Constitution and of the United Nations Conference on Environment and Development of Rio de Janeiro in 1992, emerges the Law 99 of 1993, in which the current fundamental principles of the Colombian environmental policy are embodied. Additionally, the Sistema Nacional Ambiental is created (SINA, National Environmental System), which aims to integrate and coordinate the actions and institutions related to the environment and the natural resources. The objective is to give to the environmental management in Colombia a systemic dimension; decentralized, participative, multi-ethnic and multi-cultural.

The SINA is the set or guides, norms, activities, resources, programs and institutions that makes it possible to start up the general environmental principles in the Law 99 of 1993. Is integrated by the following components[1]:

- The general principles and guidelines contained in the National Constitution, in the Law 99 and in the environmental regulations that develops it.
- The current specific regulations that are not revoked by this law and the law that develops under this law.
- The State entities responsible of the environmental policy and action, pointed down in the law.
- The communitarian organizations and non-governmental related with the environmental problems.
- The sources and economical resources for the management and recuperation of the environment.
- The public, private or mixed entities that performs activities of information production, scientific research and technological development in the environmental field.

The principal public entities that conforms the SINA and that are directly in charge of the environmental management, may be seen in Figure 2-1.

[1] Law 99 of 1993, article 4.

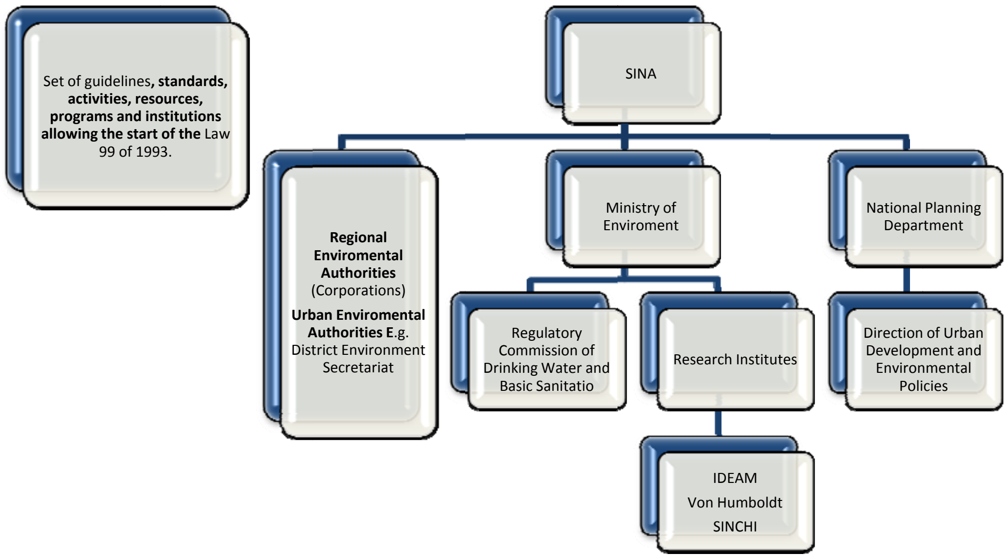

Figure 2-1: Entities that conforms the SINA.

The Law 99 of 1993 explicitly defines the objectives and functions of each of the mentioned entities, however in this chapter, we will focus on two: the Ministry of Environment and the Comisión de Regulación de Agua Potable y Saneamiento Básico (CRA, Regulatory Commission of Drinking Water and Basic Sanitation).

The Ministry of Environment becomes the governing body of the management of the environment and of the renewable natural resources. In this fashion it is in charge of promoting a relation of respect and harmony between man and nature, and to define, according to the law, the policies and regulations that will guide the recuperation, conservation, protection, ordering, management, use and exploitation of the renewable natural resources and the environment of the Nation, aiming to guarantee the sustainable development, according to the Article 2 of the Law 99 of 1993.

The main objectives of the Ministry, according to the Decree 216 of 2003, are to contribute and promote sustainable development through the formulation and adoption of the policies, plans, programs, projects and regulation related with the environment, natural renewable resources, soil use, territorial development plans, drinking water and basic sanitation and environmental sanitation, territorial and urban development, as well as the subject of integral housing.

Attached to the Ministry of Environment, the CRA is created, a special administrative unit, with administrative, technical and patrimony autonomy; its purpose is to regulate monopolies and to promote the competence in the sector, preventing abuses of dominant positions and driving the sustainability of the sector and the rendering of quality services at reasonable prices and wide covering. This purpose is achieved through the regulatory development that includes the participations of the users and the providers[1].

Inside of this legislative framework, we will proceed to enunciate a short list of laws, decrees and resolutions in force in the sector of drinking water and sanitation.

Laws

a) Law 9 de 1979. National Sanitary Code.

b) Law 99 de 1993. National Environmental System "Sistema Nacional Ambiental" –SINA-.

c) Law 100 of 1993. Social security, pension liabilities and pension bonus in public entities.

d) Law 142 of 1994. Regimen of Public Utilities.

e) Law 226 of 1996. Alienation of the State Property.

f) Law 286 of 96. About the factors of benefits and contributions, modifies the Law 142 de 1994.

g) Law 373 of 1997. Efficient and rational use of the water.

h) Law 388 of 1998. Land Use Plans.

i) Law 430 of 1998. By which the environmental prohibitive norms are dictated, referring the solid waste.

j) Law 505 of 1999. Determines competences and dates for the adoption and application of the stratification.

k) Law 549 of 1999. Coverage of pension liabilities in territorial entities.

l) Law 550 of 1999. Liabilities restructuration.

m) Law 617 of 2000. Categorization of territorial entities. Modifies the Law 136 of 1994.

n) Law 632 of 2000. Extend periods to eliminate the rate lag and announces dispositions for the ordinary cleaning.

o) Law 689 of 2001. Partially modifies the Law 142 of 1994, regarding the competences of the SPU, the AEGR and the socioeconomical stratification, among other topics.

p) Law 715 of 2001. Partially modifies the Law 142 of 1994, regarding health, education, and drinking water. Abolishes Law 60 of 1993.

q) Law 732 of 2002. Establishes new periods and terms to adopt and apply urban and rural stratifications and redefines some competences regarding the control.

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[1] http://www.cra.gov.co/estructura.shtml#, retrieved on 10 November 2010.

Decrees

a) Decree 2811 of 1974. Natural Resources Code.

b) Decree 1594 of 1984of the Ministry of Health. Regarding the Dumping of Liquid Waste.

c) Decree 1753 of 1991. The environmental licenses theme is regulated.

d) Decree 2200 of 1993. Competences framework and methodologies in socioeconomical stratification.

e) Decree 2649 of 1993. Accounting principles.

f) Decree 2785 of 1994. Transformation and characterization of the statutory for the service providers.

g) Decree 1324 of 1995. Partial regulation of the Law 56 of 1981, in harmony with the Law 142 of 1994.

h) Decree 1429 of 1995. Citizen participation mechanisms (control speakers), in the SPD.

i) Decree 1748 of 1995. Pension bonus.

j) Decree 565 of 1996. Regulates the solidarity funds and redistribution of the income for drinking water and basic sanitation sector.

k) Regulates the cleaning service. Mostly abolished by the Decree 1723 of 2002.

l) Decree 1538 of 1996. Concepts, grounds or refusals and recognition because of the inadequate application of stratification by providers of PU.

m) Decree 2034 of 1996. Last term for the adoption of urban stratification.

n) Decree 901 of 1997. Retributive rate for pouring to the sewer.

o) Decree 1474 of 1997. About pension bonuses.

p) Decree 3102 of 1997. The article 15 of the Law 373 of 1997, related to the installation of equipment, systems and implements of low consumption of drinking water.

q) Decree 810 of 1998. Constitution of autonomous patrimonies in decentralized entities for the payment of pension bonuses and quotas.

r) Decree 1311 of 1998. Regulates the literal g of the Article 11 of the Law 373 of 1997, regarding the information of the consume –each 4 months- to the Ministry of Economical Development.

s) Decree 302 of 2000. Regulation for the services of water and sewage (Partially modified with the Decree 229 of 2002).

t) Decree 421 of 2000. Rendering of PU by authorized in minor municipalities.

u) Decree 1905 of 2000. Modifies the statutes and the functioning regulation of the Regulation Commission of Drinking Water and Basic Sanitation.

v) Decree 1987 of 2000. Regulation of the article 11 of the Law 142 of 1994, among other topics.

w) Decree 2676 of 2000. Regarding the management of hospital waste.

x) Decree 229 of 2002. Partially modifies the Decree 302 of 2000, regarding concepts of water and sewage, among other topics.

y) Decree 398 of 2002. Regulates the incise 3 of the numeral 6.4 of the Law 142 of 1994 (selections of providers).

z) Decree 849 of 2002. Regulates Law 715 regarding the certification of se SPU for the change of the reassignment of the transfers of the Nation for drinking water and basic sanitation sector.

aa) Decree 891 of 2002. Regulation of the Law 632 of 2000, regarding the exclusive service areas and the concession contracts between territorial entities and people provider of the cleaning service.

bb) Decree 941 of 2002. Regulates the constitution of the accounting and financial management of the autonomous patrimonies or of guarantee to the companies that are in charge of jubilation pensions.

cc) Decree 990 of 2002. Restructuration of the Superintendents of Public Utilities.

dd) Decree 991 of 2002. Defines the staff of the Superintendents of Public Utilities.

ee) Decree 1713 of 2002. Regulates the ordinary cleaning service, in its technical components, especially, with the exception of chapter I of the title IV, abolished the other parts of the Decree 605 of 1996.

ff) Decree 1575 of 2007 of the Ministry of Social Protection. System for the Protection and Quality Control of the Drinking Water.

Resolutions

Issued by the CRA

a) Resolution 151 of 2001. Central resolution regarding the rate regime, abolished and compiled relevant topics.

b) Resolution 9 of 1994. Update rate for 1995.

c) Resolution 12 of 1995. Criteria, characteristics indicators and model to evaluate the management and the results of the companies of water and sewerage and cleaning.

d) Resolution 8 of 1995 of the CRA (Art 3 and 24 still valid). The criteria are created and the methodology is adopted fixing that the water public utilities should determine the rates for the services.

e) Resolution 19 of 1995. Update rate for 1996.

f) Resolution 5 of 1996. Establish the methodology for the evaluation of the business viability.

g) Resolution 18 of 1996. Criteria for the approval of the PGR of the ESPD of the water system.

h) Resolution 29 of 1996. Update rate for 1997.

i) Resolution 11 of 1997. Establish rules to promote balance in the control mechanisms of the management and the results.

j) Resolution 16 of 1997. The criteria for the evaluation of the fulfillment of the first plan of management and results –PMR-, are established.

k) Resolution 17 of 1997. The conditions for the first presentation of the update PMR are established.

l) Resolution 32 of 1997. Update rate for 1998.

m) Resolution 36 of 1998. The minimum values of the rates are established for the services of water and sewerage.

n) Resolution 37 of 1998. Addition to the Resolution 16 of 1997, to determine the evaluation criteria of the fulfillment of the first PMR.

o) Resolution 54 of 1998. By which the unique paragraph of article 7 of Resolution 12 of 1995 is added and the articles second and third of the Resolution 17 of 1997 regarding the update of the PMR.

p) Resolution 60 of 1998. The conditions for the presentation and update of the PMR of 1998 are established.

q) Resolution 62 of 1998. The pointing is requested to the Direction of Public Utilities of the Ministry of Economical Development, through administrative acts, of the technical requirements that should be met by the works, equipments and processes used by the drinking water and basic sanitation public utility companies.

r) Resolution 66 of 1998. Update rate for 1999.

s) Resolution 74 of 1999. Conditions to present the PMR by the PSPD with less than 24000 users.

t) Resolution 84 of 1999. The assignment of subsidies is regulated in the payment of services of water and seweage and cleaning to the users affected by the earthquake of the 25th of January of 1999.

u) Resolution 114 of 1999. Update rate for 2000.

v) Resolution 117 of 1999. Only in paragraphs 1 and 2 of article 4 and article 16.

w) Resolution 148 of 2000. Update rate for 2001.

x) Resolution 150 of 2001. Basic consumption and maximum consumption are established according to the Law 373 of 1997.

y) Resolution 151 of 2001. Of the CRA, Integral Regulation of the Services of Water, Sewerage and Cleaning.

z) Resolution 200 of 2001. About the increases in the rate because the update will be made according to the caused inflation, when, as a minimum, there are at least 3 points certified by the Dane.

aa) Resolution 201 of 2001. The conditions for the preparation, update and evaluation of the plans and management are established.

Issued by the Ministry of Health

Resolution 541 of 1994. Regulates the load, transportation, storage and final disposal of the rubble.

Issued by the Ministry of Environment Housing and Territorial Development

a) Resolution 273 of 1997. Values and parameters to estimate the retribution rate.

b) Resolution 372 of 1998. Values and parameters to estimate the retribution rate.

c) Resolution 1096 of 2000. Technical Regulation for the Water and Basic Sanitation Sector, RAS. Modified by the Resolution 2320 of 2009.

d) Resolution 2115 of 2007 of the Ministries of Social Protection and of Environment Housing and Territorial Development. Points the characteristics, basic instruments and frequencies of the control and surveillance for drinking water quality.

Issued by the Superintendence of Public Utilities

a) Resolution 1416 of 1997. Accounting plan for providers of the sector of drinking water and basic sanitation –APSB-.

b) Resolution 1417 of 1997. Unified cost and expenses system for providers of the sector of APSB.

c) Resolution 4640 of 2000. Accounting plan for providers of public services.

d) Resolution 010541 of 2002. Formats for certification are adopted, that allows the change of destination of transferences for the sector of APSB, according to the Law 715 of 2001 and the Decree 849 of 2002.

e) Resolution 16965 of 2005 of the SPU. Establishes the regimen of inscription, updating and cancelation of the providers of public utilities in the Unique Regime of Public Providers – RUPS.

3. THE CONTEXT

As a member of the United Nations, Colombia must accept and implement the decisions that the organism makes on every subject. One of the most important subjects is water; regarding this, the General Comment No. 15 of the Committee on Economic, Social, and Cultural Rights describes the fundamental factors of the human right to water[1]:

1. Availability of drinking water
2. Accessibility to the drinking water
3. Quality of water

In this way, the universal right of every human being to access the water resource without any reservations and everything this implies is established (Defensoría del Pueblo, 2006).

Even though the Covenant is signed by the United Nations, including the National Government, it would not have much significance if the *magna carta* of our country, the 1991 Political Constitution, didn't demand also that all levels of government in the national territory guarantee the compliance of these global postulates, and forbids at all costs that they go unfulfilled.

For the issue of quality of water, several dispositions and rules have been established worldwide in order to adjust all the procedures concerning this subject and set the tone for every country that wishes to improve its levels of water quality, given the huge importance of this subject and the significative influence and impact it has on the world population, especially for children under five.

For this reason, the Colombian Government, through the Ministry of Social Protection and the Ministry of Environment, Housing, and Territorial Development, issued the resolution 2115 of June 22nd, 2007, which establishes "characteristics, basic instruments and frequencies of the supervision and control system for the quality of water for human consumption" (Ministerio de la Protección Social, 2007). These characteristics were divided in the following components:

- Physical Characteristics
- Chemical Characteristics
- Microbiological Characteristics

These three characteristics blend in a grand index named the Index of Risk of Quality of the Water for Human Consumption (Spanish acronym, I.R.C.A.), which shows the level of hazard to which a human being is exposed each time he/she drinks water.

[1] (Defensoría del Pueblo, 2009)

This index must be reported by every municipality of the country, identifying each risk point of the water, and uniting all of these analysis in a measure of the risk of water.

Table 3-1. Risk scores assigned to each characteristic analyzed for IRCA measuring

Characteristic	Risk score
Apparent Color	6
Turbidity	15
pH	1,5
Free residual chlorine	15
Total alkalinity	1
Calcium	1
Phosphates	1
Manganese	1
Molybdenum	1
Magnesium	1
Zinc	1
Total hardness	1
Sulfates	1
Total iron	1,5
Chlorides	1
Nitrates	1
Nitrites	3
Aluminum (Al)	3
Fluorides	1
COT	3
Total coliforms	15
Escherichia Coli	25
Total sum of assigned scores	100

Source: (Defensoría del Pueblo, 2006)

Hence, it is important to assign the risk scores to every sample analyzed, in order to determine the IRCA percentage of the respective analysis, as it is shown in the following formula:

$$(\%IRCA)\frac{\sum Risk\ score\ assigned\ to\ each\ unacceptable\ characteristic}{\sum Risk\ score\ assigned\ to\ all\ the\ analyzed\ characteristics} * 100$$

Formula 3-1. IRCA percentage of each sample (Ministerio de la Protección Social, 2007)

Using the IRCA scores obtained from each sample, the monthly index is analyzed using the following formula:

$$(\%IRCA)\frac{\sum IRCA\ percentage\ obtained\ in\ each\ sample\ took\ in\ the\ month}{\sum Total\ number\ of\ samples\ analyzed\ in\ the\ month} * 100$$

Formula 3-2. Monthly IRCA Percentage (social M. d., 2010)

Through the analysis of the samples reported throughout the country, and the enforcement of the Decree 1575 of 2007, the following reports were generated:

Table 3-2. Risk Index of the Quality of the Water for Human Consumption (I.R.C.A.) by department and/or district

	IRCA Average		
Department	**2007**	**2008**	**2009**
AMAZONAS	25,5%	25,4%	23,9%
ANTIOQUIA	7,8%	4,4%	4,8%
ARAUCA	17,0%	13,3%	1,7%
ARCHIPIÉLAGO DE SAN ANDRES Y PROVIDENCIA Y SANTA CATALINA	11,4%	5,6%	6,4%
ATLÁNTICO	6,7%	5,1%	5,5%
BOGOTÁ	0,1%	8,6%	16,4%
BOLÍVAR	28,4%	44,4%	34,7%
BOYACÁ	21,5%	30,1%	30,4%
CALDAS	11,3%	47,9%	58,5%
CAQUETÁ	28,6%	27,2%	23,7%
CASANARE	37,2%	22,7%	33,1%
CAUCA	30,7%	28,5%	24,4%
CESAR	31,9%	32,0%	22,0%
CÓRDOBA	41,1%	14,7%	18,5%
CUNDINAMARCA	11,1%	7,7%	8,5%
GUAINÍA	52,2%	44,8%	53,7%
GUAVIARE	100,0%	68,9%	51,6%
HUILA	12,5%	28,0%	24,8%
LA GUAJIRA	21,5%	31,8%	15,6%
MAGDALENA	46,5%	24,5%	35,3%
META	38,0%	40,4%	43,5%
NARIÑO	36,6%	35,6%	37,2%

Table 3-2. (Continued)

NORTE DE SANTANDER	14,4%	17,1%	11,9%
PUTUMAYO	47,6%	41,7%	49,8%
QUINDIO	14,1%	0,3%	0,2%
RISARALDA	29,4%	25,7%	26,8%
SANTANDER	20,7%	19,4%	18,0%
SUCRE	23,6%	22,0%	20,4%
TOLIMA	33,9%	32,9%	33,1%
VALLE DEL CAUCA	17,7%	17,9%	20,6%
VAUPÉS	100,0%	92,2%	-
VICHADA	33,5%	30,5%	34,1%

Source: National Health Institute, (Instituto Nacional de Salud, 2009)

Despite the evident difficulties of the country, the National Government has invested around 1,360 billion pesos in 2009 in different projects related to improving the coverage and quality of water. Most of these resources are assigned to the Departmental Plans for Water (PDA), which are instruments used by the ministries for assigning resources to the departments, without taking into consideration the needs of each department and without making an equitable distribution according to the requirements of each region. (Ministerio Ambiente, Vivienda y Desarrollo Territorial, 2010).

This becomes very relevant when analyzing the impact of these plans in departments such as Cundinamarca, whose urban area shows remarkable satisfactory numbers, with a coverage of the aqueduct, sewer and sanitation systems of around 95%, a figure that differs considerably from the one of the rural area, where the coverage of water works is 58.7%, sewer is 19.6% and there is no coverage in sanitation. The severity of this situation increases since the rural sector is the worst poverty and violence-ridden area of Colombia. The shocking figures evidence a conjuncture that establishes a significant priority in the accomplishment of projects in these areas destined to fulfill the need of these areas for basic elements, which are essential for the development of any human being.

The Ministry of Environment generates the regulation required for developing the departmental plans for water, which are the instrument used by the territorial entities to manage the resources for complying with the needs and requirements exposed in the PDA, making the resources destination much more effective.

That regulation was entitled Decree 3200, of August 29th 2008, and it intends to provide a legal tool that contemplates all of the elements that a PDA should have, and, thus, execute the projects referred to. Initially, this seems to be a very useful tool, but the civilians, including the citizens of the populations directly interested, are not taken into account in the Decree, and therefore, their voice hasn't been heard.

This is evidenced in the regulation when it establishes that the stakeholders required for the development of the PDAs are:

1. The Department.
2. The Municipalities and/or Districts.
3. The Ministry of Environment, Housing and Territorial Development- MAVDT.
4. The National Planning Department - DNP.
5. The environmental authorities with jurisdiction in the municipalities located in the territory of the department.

(Ministerio Ambiente, Vivienda y Desarrollo Territorial, 2010)

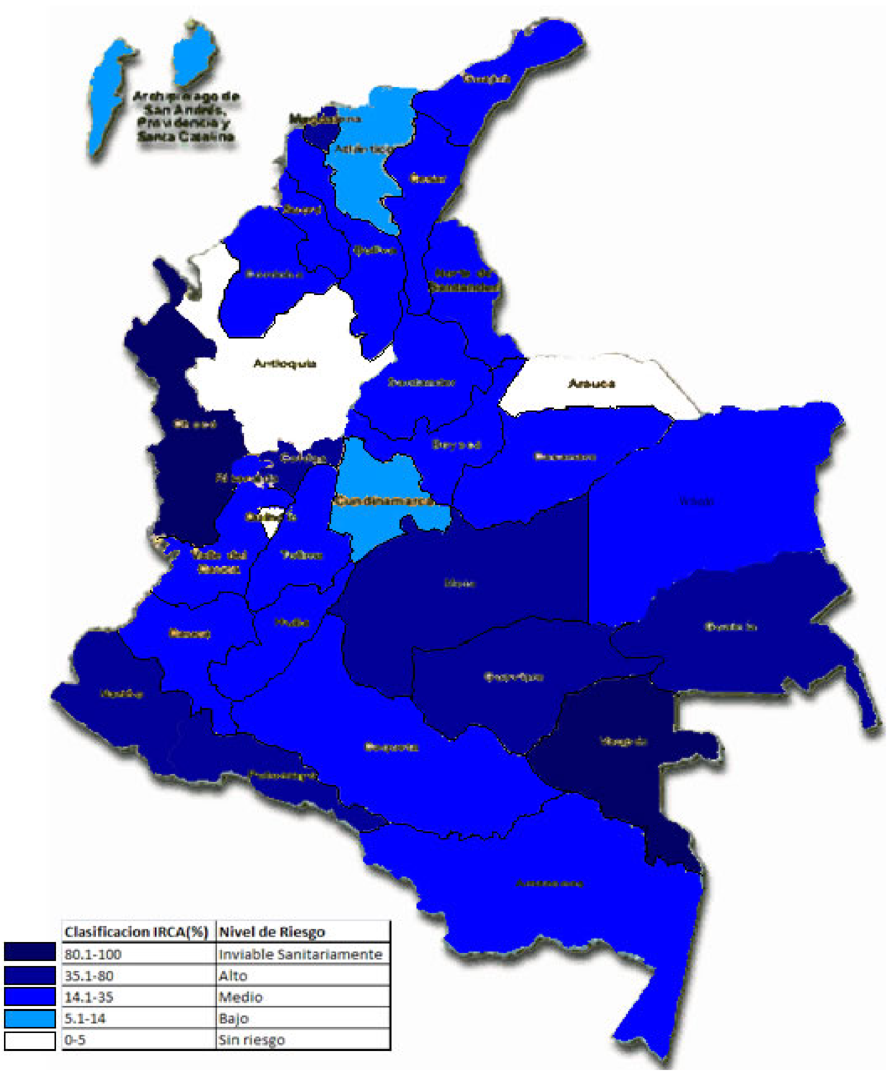

Figure 3-1. Risk Map; Inviable Sanitariamente = Not Viable; Alto = High; Medio = Medium; Bajo = Low; Sin riesgo = No risk.

Source: National Health Institute (Instituto Nacional de Salud, 2009).

4. PARTICIPATORY METHODOLOGY FOR WATER ENGINEERING

Given the situation explained above, it is possible to assert that the organizational mechanisms ordinarily used have not managed to design water management solutions for a considerable amount of vulnerable communities. Next, we will present some alternative models that have helped in the past and may help in the future to find appropriate local solutions.

This section introduces the proposal for an organizational model based in the OCDIO (Observe, Conceive, Design, Implement, and Operate) intervention methodology and the PAR (Participatory Action Research) participation methodology. This model contains a proposal of joint work of the universities, the communities, and the local governmental stakeholders, which has been conceived and headed by the organization Ingenieros sin Fronteras Colombia (ISF Colombia).

The Ingenieros sin Fronteras group proposes to analyze the management and innovation associated to the water subject as an engineering project. Consequently, there are several challenges to be faced from the engineering perspective, such as:

- How should the problem situations associated to a particular subject be defined? How should a technological solution be defined so as to tend to the real needs of the water users?
- How could the balance between a solution that is technologically innovative and the appropriation of that technology by the community be guaranteed?

In order to approach these challenges, the first step is to define the problem situation. Engineers are used to solving “structured” problems, that is, problems with single solutions, algorithmic methodologies and precise results. In this order of ideas, the water matter is related to questions such as:

- How to design an appropriate technology in order to improve the quality of water, within a specific context?
- What are the restrictions that have to be considered in the design?
- What are the technical variables that have to be considered?

We could define the questions that will let us propose a technically structured engineering solution that applies a simple or complex algorithm. However, considering that the context facing the engineer presents difficulties related to the social order, poverty, inequity, among others, the question should be more complex:

- How to guarantee that the solution takes into account the real needs of the community?
- How to guarantee that the proposed solution will help in improving the quality of life in the poverty and inequity context in which it takes place?
- How to generate an engineering solution that promotes autonomy in the community?
- How to guarantee that the solution does not bring along other types of problems?

For these questions, there are not pre-defined algorithms. Therefore, it is necessary to consider solutions based on effective organizations design. For understanding the problem situation, there are four characteristics to be taken into consideration (Aldana y Reyes, 2004):

– *The problem situations are transdisciplinary;* this means that the source of the problem goes beyond the methodologies of a discipline or a single group of disciplines. Of course, the quality of water issue can be approached through simulation models, lab tests, etc., but also is valuable to find out which systems, and in which way, have contributed or not to the improvement of the quality of water; why no solutions have been reached yet; which variables guarantee the cultural appropriateness of a technical solution; among other aspects. The main point is that the solution can come from different disciplines and with different terms. For example, an environmentalist may define the problem in terms of the lack of conscience of the inhabitants regarding water sources contamination; an administrator may refer to the lack of leadership or communication between the community and the local entities, and so on. There are not more or less valid answers, rather they are all pertinent.

– *The formulation and description of the problem situation depends both on who originates it and who observes it;* this means that the solution must be a construction in which several actors participate or are represented. In the quality of water, matter is pertinent to identify the view points of the different stakeholders (researchers, managers, students, community), clients (community, researchers), potential suppliers (of information, of technology, of resources), intervenors (other members of the community, local and national law makers). Once again, all of their view points are pertinent, and should be taken into account.

– *The problem situations are derived from the relations between the different stakeholders;* this means that it is through the analysis of these relations that the situation will become clearer. In the context of quality of water for vulnerable communities, the relevant relations include those of the community/community leaders/local government, health, and education entities/researchers. Therefore, it is fundamental to identify and understand all of the relevant stakeholders (that is, all those who affect or are affected by the problem situation) and their relationships, in order to properly approach specific subjects such as negotiation processes with local entities, current and future diseases, lack of education and awareness, among others.

– *The comprehension of a problem situation should be understood as a system;* this means that the solution should be designed from an integral and inclusive perspective. The quality of water situation should be looked at from a systemic point of view, rather than an analytical one. That is to say that the solution shouldn't be approached or conceived in an independent way, from a single perspective.

What would happen then, if we reduce the proposals and solutions to just the spheres of technical design? Or what would happen if we reduce the proposals and solutions to just the spheres of organizational design?

The first case is a technically viable engineering proposal, assuming that the technical design fulfills the necessary requirements. The zone in which Ingenieros sin Fronteras has undertaken water related projects, there are aqueducts built with correct technical specifications, but are abandoned due to a poor management or improper use.

The second case is a viable management proposal, assuming that all those involved in the solution are interested and willing. But a strategic alliance between the local entities and the community for solving technical problems is not enough to guarantee technically viable long-term solutions. This usually does not go further than the group of people solving a specific immediate problem, or even worse, the solution solves one specific problem, but generates a different one.

These challenges are related to proposals of the "Organizational Diagnosis and Design" research line. In this framework, we present below the proposal that seeks to guide engineering projects related to water management (and, of course, for similar fields).

The OCDIO- PAR Model

The proposed integrated model is based on Figure 4-1 and is described below:

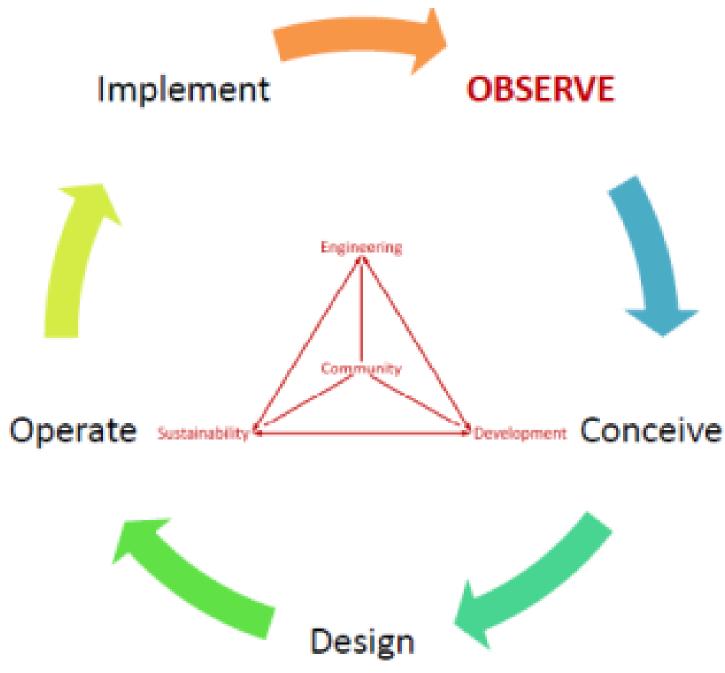

Figure 4-1: OCDIO – PAR Model; Based on Lucena et al. (2010).

Taking into account the aforementioned premises, it is intended that the proposal for managing water-related problem situations takes into account not only experts of different engineering fields (industrial, chemical, environmental, etc.), but also different interested parties of the community (users, local government entities, local health entities, local education entities, etc.). Even though the work focus is the community itself (as can be seen in the pyramid on Figure 3), in the process of developing the project there is constant feedback between the community and the engineers (looking for a permanent and systemic learning model). For this, the synergy between the community's lore regarding water and the new engineering techniques proposed is essential. In this way, two key factors would be guaranteed: development and sustainability.

It is intended, then, that both the engineers and the community play a main role, based on the steps proposed by the PAR methodology (Bodorkós et al., 2009):

1. Generate communication and information capacity between the community and the engineers.
2. Generate decision-making processes where the points of view of both the community and the engineers are taken into account.
3. Promote the active participation of individuals in the process: the community provides labor, resources, local knowledge and feedback, and the team of engineers provides technical knowledge and research facilities.
4. Increase interactive participation so that local communities are involved at all phases of project design.
5. Promote self-development.
6. Develop knowledge through the interaction and feedback between the community and the engineers.

Taking into account the previously presented systemic framework, it is necessary to define a teamwork methodology. For this, the CDIO framework is presented. In traditional engineering education, it was not explicitly necessary to strengthen the competences that enable the future professional to face, in an innovative and flexible manner, the complex problems of society. Taking into account what was said by Deutsch (1968) and Shaw (1976), and being aware that engineering know-how must be translated into real life situations, students and teachers have begun working on direct application cases called CDIO (Conceive, Design, Implement and Operate) engineering projects.

The students and teachers approach the problem by interviewing the people involved, exchanging ideas with experts and researchers and exploring knowledge on the subject at hand. Once the observation process is finished, the group conceives the formulation, contextualization and a possible solution to the observed reality together with the community. This conception requires a great deal of creativity and innovation to offer technology that meets the community's needs. After an evaluation stage, the process moves on to the preliminary design phase of the prototype and a proposal for implementing the technology in order to improve water conditions in the community. Subsequently, assistance from teachers is intensified and the development of the project is deepened. Thus, the design is carried out with greater precision regarding the prototype, the implementation is clearer and the project is finally put into operation. During the process, the efficiency of the filtering prototype is monitored and adjusted periodically through lab tests and community visits. The group and the community regularly evaluates the experience and learning generated during the project's design and evaluation, in order to improve the cooperation model and the methodology hoping to replicate the project in other areas of the country which also present drinking water problems and unsatisfied basic needs.

In that sense, the group used a combination between the traditional engineering projects development context and a participation methodology which guarantees that the different inputs of everyone interested in the situation will be considered.

5. CASE STUDY : GUAYABAL DE SIQUIMA, COLUMBIA

Problem situation

<u>Technical diagnosis of the water consumed in the Torres district</u>

The water supply system of the Torres district is fed by a 30000 L (30 cubic meters) tank made of reinforced concrete, which is supplied by a little spring located approximately 5 meters above the tank. Figures 5-1 and 5-2 show the spring and the tank.

Figure 5-1. Spring (Up)

Figure 5-2. 30.000 L. Concrete Tank (Down)

A volumetric analysis was made in order to establish the average flow rate of the spring (0.291 L/s). Likewise, measurements of turbidity and conductivity were conducted; the results are shown below:

Table 5-1. Turbidity

#MEASUREMENT	*TURBIDITY (NTU)		
1	12.3	13.9	14.1
2	10.2	10.2	10.6
3	10.8	9.2	9.14
4	10.5	9.94	9.15
5	10.1	11.1	
6	9.85		

Source: Authors' calculations

*Approximately, three measurements per each sample were taken.

Table 5-2. Conductivity

#MEASUREMENT	CONDUCTIVITY (us/cm):	O.D.(mg/l)	T(°C)
1	353	6.69	20.4
2	355	6.7	20.2
AVERAGE	**354**	**6.695**	**20.3**
	PH:	**7**	

Source: Authors' calculations

In order to establish the microbiological conditions of the water in the Torres district, different microbiological tests were conducted. The samples were taken on May 6th, 2008, at the spring, the tank and Mr. *Adán'*s house. The results are shown below:

Table 5-3. Microbiological analysis results–"Las Torres" district

		Spring	Tank	House
06/05/2008	Reference Test Lot	Good		
	Coliforms	220	Countless	1580
	E. Coli	-	40	-

Source: Authors' calculations.

Social and economical diagnosis of the district

The following is the profile of the social and economical conditions of the community of Torres district. The profile was based on the group observations and a survey conducted with 11 families of the community of San Felipe, a sector near the Torres district. Both sectors share the same socioeconomic profile.

In their initial observations of the group, they found a settlement of families who are dedicated to being day laborers in the large crops of the area, or to making *panela* (unrefined whole cane sugar). This last job is done in a sugar mill built archaically in the community; and the *panela* sale is done in the nearby towns. The sale of this panel was held in nearby towns. However, it should be noted that neither the day's wages nor the sale of *panela* are an economical source that provides sufficient and adequate income for the families.

The following are the conclusions of the survey:

- The families in these districts belong to the strata 1 and 2 and have a low economic capacity according to the Department of National Planning.
- The community is composed mostly of the women (55% of the population). The main age range of the population is between 30 and 60 years old.
- 63% of the population live in nuclear families (both parents and their children).
- Regarding the necessities perceived by the community, 38% of the population said that the most urgent necessity is related to the water resources in the community, since due to the bad quality of the water, there have been diseases outbreaks among the population. On the

other hand, 18% feel that the most pressing necessities are related to work and transportation, and in lower percentages, to health and housing.

- 72.73% of the families live in houses; the rest of them live in houses with a plot of land, which they use for agricultural activities. The main construction materials are blocks, bricks, tiles and, in lesser proportions, wood. In the majority of cases, the floors are made of mud. 90% of the families said they felt comfortable in their current house.

Regarding the economic conditions, the study identified that in relation to family income, 63.64% of the population subsists on a monthly income of less than 120 thousand pesos. The main source of income is the agricultural work, followed by the daily wages, which do not exceed 15 thousand pesos, this situation evidences the community's high degree of vulnerability.

Regarding public services, the families consider that the most expensive one is the electricity (45.45%), followed by gas (27.7%), which is supplied through cylinders because there is no pipeline system; the water service is perceived as the less expensive (9.09%), also this service is regarded as the most relevant and the one that requires an urgent improvement on supply and quality.

Since the analysis showed the community's concern regarding the drinkable water, and 82% of the water resource comes from water works which may not comply with the necessary water treatment conditions, some questions were asked to the families regarding the condition of the water. The results show that 54.55% consider that the water is crystal clear, and 45.45% perceive it cloudy, which makes for a good overall perception of water quality by the population.

Figures 5-3: Torres community.

Students and teachers involved:

From the University Corporation Minuto de Dios participated the teachers Camilo Torres (Civil Engineering) and Juan Fernando Pacheco (vice chancellor), and the students Diego Grisales and Julián Castañeda (Civil Engineering).

From Los Andes University, teachers Catalina Ramírez (Industrial Engineering), Jaime Plazas, Andrea Maldonado, Diana Calvo (Environmental Engineering) y Felipe Muñoz (Chemical Engineering); and the students Miguel González, Paula González, María Paula Valderrama, Juan Camilo Silva (Industrial Engineering), María Fernanda Díaz, David Zuñiga, Oscar Vaca (Industrial Engineering), Nathalia Torres (Chemical Engineering) participated.

Planning of the project

OCDIO methodology:

In order to plan the Project, the Observe, Conceive and Design phases of the OCDIO methodology were carried out. Here is a summary of the work developed:

Observe:

During the observation and initial conceive phase of the project, first-hand information about the main characteristics (economic, political, socio-cultural and geographical) of the community was collected, through visits and cooperation with an employee of the UMATA[1]. With this information, and its discussion and validation with the members of the community (see PAR methodology), the team of engineers was able to begin the design of sustainable solutions based on the population's needs, characteristics and input. For example, later in the design phase, the filter was designed taking into account the general characteristics of the homes and the habits of its inhabitants, so that it could meet their water-related needs and be placed in an appropriate location which would facilitate its use. (Ramirez et al., 2010)

Conceive:

In order to conceive a project that could be supported by the actors involved, the interests of the main stakeholders were taken into account: EWB-Colombia, community members and their community and political leaders, the UMATA employee and the district's aqueduct. During the development of the project, active participation of the stakeholders was promoted, particularly of the district's inhabitants, by conducting surveys and interviews to understand their problems and needs, training workshops to help them appropriate the technology and encouraging their collaboration in the adaptation of land for the installation of the filters in order to help develop a sense of ownership. This learning process between EWB-Col and the community has allowed the group to adjust the initial proposal based on the community's feedback, resulting in a more appropriate and productive solution. (Ramirez et al., 2010)

The analysis begins with the identification of the problem. EWB-Colombia and the population identified the problem associated with the quality of water used for human

[1] UMATA: Unidad Municipal de Asistencia Técnica Agropecuaria - Municipal Unit for Agricultural Technical Assistance.

consumption. Then, the stakeholders were identified: the inhabitants of the community, EWB-Colombia, Universidad de los Andes, Universidad Minuto de Dios, the directors and employees of the district's water worksand the mayor of Guayabal de Síquima. After this, EWB Colombia aimed to the involvement of stakeholders through various activities organized by the group, which included questionnaires about basic sanitation and hygiene practices among other subjects, training workshops on the use and operation of the filter and education on basic hygiene practices.

All of this work was achieved with the support of data collection, which was carried out during visits and interviews with people with previous experience working within the community, allowing the group to revise initial assumptions and adjust the proposals based on the interaction with the community. The visits were scheduled according to the daily activities of the inhabitants and taking into account special dates (market days, political activities, holidays, etc.) to avoid any inconvenience. The debate and discussion within the community revealed different positions among stakeholders regarding the management of water resources and their availability and generated an opportunity to build consensus within the population, as well as between it and EWB-Col regarding the scope of the project, its aims and technical details. (Ramirez et al., 2010)

Design

Two strategies were identified for the management of water resources in the project; basic education on hygiene practices for disease prevention and community training in the management of slow sand filters and their installation in family homes. The group sought to establish close links with key local authorities in an effort to enlist their support and collaboration, obtaining good results from the collaboration with the Mayor and the UMATA. This strategy has been important in developing the project. (Ramirez et al., 2010)

The group evaluated different types of filtration technologies in a search for those which are best-suited to the characteristics and conditions of the community. The evaluation was made taking into consideration the cost, ease of construction and procurement of materials and ease of maintenance. The aim throughout the project was to ensure that the technology chosen would be sustainable in the long-term and that the community might appropriate it and eventually no longer need help from the engineering group. After the evaluation process, the group decided to use slow sand filters due to their low cost, ease of use and installation, and good results in the removal of micro-organisms. (Ramirez et al., 2010)

PAR Methodology:

Concerned by the bad quality of life in Colombian rural communities, EWB-Col looked for a suitable community to develop a participative project to improve the quality of water. In this process, the communities were selected preliminarily, and afterwards, the Torres district was chosen. After some initial visits, intended to confirm the socioeconomic vulnerability and the existence of water related problems, ISF proposed to the community to work together, and received a positive response by the community. Since the beginning, the community had an active participation in the project's development. As a matter of fact, the community leader who had been running the water works helped the engineers team to understand the main problems related to water in the community, and personally introduced the ISF team to each family. (Ramirez et al., 2010)

The selection of the technology and design of methodologies were the result of a dialogue with the community, based on an understanding of their needs and concerns. Likewise, the work with the community was structured and developed based on its major socioeconomic and cultural characteristics, seeking to ensure compatibility between the lifestyle of the local population and the project to promote long-term sustainability and appropriation of the technology by its inhabitants. This is how the PAR methodology was implemented. (Ramirez et al., 2010)

The financing of the project is an interesting example of the application of the participative methodology. In this case, the group of engineers funds the research required to develop the technologies and implement them, usually with support from their corresponding educational institutions, interested in the academic results and learning opportunities for students. The other stakeholders make a financial contribution of some sort to the development of the project. The local population, for example, commits to building the necessary infrastructure for the installation of the technical solutions; and the local authorities provide the resources required to guarantee the sustainability of the project (allocation of municipal resources, for instance). It is very important that the community help finance the project by providing their work and skills in order to promote a sense of ownership and empowerment. (Ramirez et al., 2010)

Implementation of the project

<u>Technical proposal for intervention</u>

As mentioned above, during the design phase of the project, the group evaluated different technological alternatives for implementing a system that improved the quality of water in the Torres district. This evaluation concluded in the selection of the sand filter as the most suitable alternative for implementation. Below, this technology is explained, as well as the design process for adapting this technology to the specific conditions of the district, the filter construction process with its associated costs, and the results of the lab tests for the technology.

1. *Slow sand filters*

Sand filtering has proven to be an effective method for improving the quality of raw water, mainly due to its simplicity and low cost. Nevertheless, experience has shown that a proper design and a diligent maintenance program are indispensable requirements for its operation.

In a slow sand filter, the water percolates slowly through its pores. During this process the biological and physical quality of the water improves considerably due to a group of biological, chemical and physical processes. The functioning mechanism of these filters emulates the purifying process that takes place in nature, in which the rain water penetrates through the soil and, little by little, forms underground deposits of water known as aquifers. Sand filters are commonly used due to its efficiency in reducing water turbidity. Moreover, with a proper design and operation, it can be considered an effective disinfection system. The formation of a biological layer on the sand surface, works as a barrier that prevents pathogens from getting through, because the biological film composed by microorganisms consumes, absorbs and filters the pathogens of raw water.

2. Slow sand filter design for the Torres district

Since the filter design is the first main stage for the success in water treatment, it was important to come up with several possible designs, and afterwards selecting the most suitable for this case. In that order of ideas, two filters with different configurations in their filtering bed were proposed. Both designs would be contained in 40 gallons plastic barrels. Figures 5-3 and 5-4 sketch each filter's configuration.

Figures 5-4 and 5-5. Left: Fine sand, coarse sand and gravel filter. Right: Fine sand and gravel filter.

Table 5-4 displays the characteristics each stratum should have for functioning properly.

Table 5-4. Granulometric properties of the strata

Material	E (mm)	U
Fine sand	0,3 – 0,45	≤ 2
Coarse sand	0,7 – 1,2	≤ 2
Gravel	20	-

Source: Author's calculations.

Each filter should keep a constant hydraulic head of 5cm, as shown on Figures 5-4 and 5-5. In order to achieve this, a floating valve that regulated water entrance was designed. A 5cm free zone at the top of the filter was kept in order to ensure the survival of the microorganisms present on the top of the bed.

Additionally, the filtered water collecting was located on the bottom of the container, and had a fish spine configuration, made with PVC pipes and accessories of ½", bored with 5 mm openings. Finally, the water would be taken from a pipe to a garden faucet, which the user would use whenever he wants treated water. The optimal height of the garden faucet would be established in the lab, so as to maximize the flow and provide comfort for the user. Figure 5-6 shows the filtered water draining system.

Figure 5-6. Filter's draining system.

3. *Materials acquisition*

The materials were purchased in stores specialized in PVC articles and stores of materials for construction. The cost of each material is presented in Tables 5-5 and 5-6.

Table 5-5. Costs for filter of fine sand and gravel

FILTER FINE SAND - GRAVEL			
	Unitary Value	**Quantity**	**Total Value**
Tube 1/2"	$ 1.333,33	2	$ 2.666,66
Tee	$ 400,00	6	$ 2.400,00
Cap	$ 300,00	8	$ 2.400,00
Elbow	$ 400,00	2	$ 800,00
Floater	$ 16.000,00	1	$ 16.000,00
Flanche	$ 5.500,00	2	$ 11.000,00
Welding	$ 7.000,00	1	$ 7.000,00
Cleaner	$ 3.000,00	1	$ 3.000,00
Female coupling	$ 300,00	2	$ 600,00
Male coupling	$ 300,00	2	$ 600,00
Tap	$ 5.000,00	1	$ 5.000,00
Teflon	$ 600,00	1	$ 600,00
Tank	$ 35.000,00	1	$ 35.000,00
Fine Sand	$ 12.500,00	2	$ 25.000,00
Coarse Sand	$ 12.500,00	1	$ 12.500,00
Gravel	$ 12.500,00	1	$ 12.500,00
		Total	$ 137.066,66

Table 5-6. Costs for filter of fine sand, coarse sand and gravel

FILTER COARSE SAND - COARSE SAND - GRAVEL			
	Unitary Value	**Quantity**	**Total Value**
Tube 1/2"	$ 1.333,33	2	$ 2.666,66
Tee	$ 400,00	6	$ 2.400,00
Cap	$ 300,00	8	$ 2.400,00
Elbow	$ 400,00	2	$ 800,00
Floater	$ 16.000,00	1	$ 16.000,00
Flanche	$ 5.500,00	2	$ 11.000,00
Welding	$ 7.000,00	1	$ 7.000,00
Cleaner	$ 3.000,00	1	$ 3.000,00
Female coupling	$ 300,00	2	$ 600,00
Male coupling	$ 300,00	2	$ 600,00
Tap	$ 5.000,00	1	$ 5.000,00
Teflon	$ 600,00	1	$ 600,00
Tank	$ 35.000,00	1	$ 35.000,00
Fine Sand	$ 12.500,00	3	$ 37.500,00
Gravel	$ 12.500,00	1	$ 12.500,00
		Total	$ 137.066,66

The fine sand, the coarse sand and the gravel were bought in 50 Kg sacks each.

4. *Construction of sand filters*

The first step in the construction of the filters was the drilling of the entrance and exit openings for each barrel, with a ½” hole saw. The figures 5-7 and 5-8 illustrate the procedure.

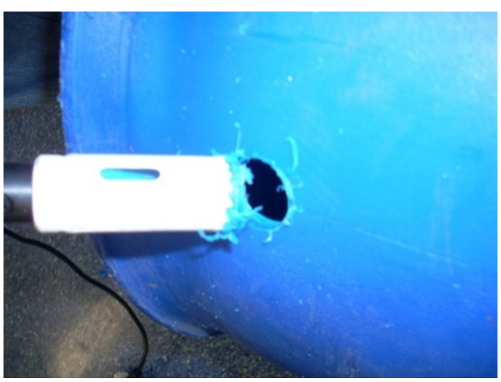

Figure 5-7. Entrance opening drilling Figure 5-8. Exit opening drilling.

Afterwards, the draining system was built. Initially the fish spine design only had parallel pipes; however, due to the low flow obtained in the faucet, more pipes were included and the number of orifices was considerably increased. The new and definitive design is shown on Figure 5-9.

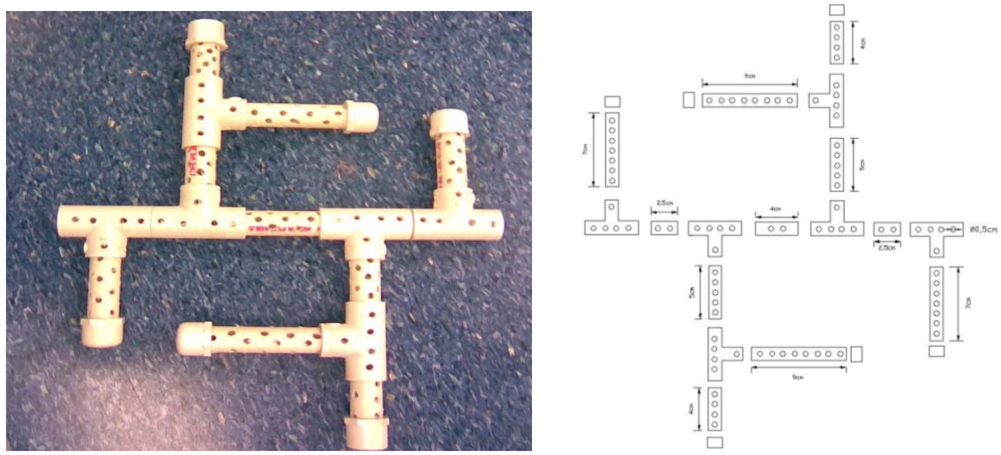

Figure 5-9. Draining system.

Later, the pipe that takes the water to faucet was installed and the heights of each stratum were marked, before pouring the sand. This procedure can be seen on Figures 5-10 and 5-11.

Figure 5-10. Garden faucet installation Figure 5-11. Demarcation of each stratum height.

Next, the materials of the filtering bed were washed. This is very important because it can condition the success or failure of the treatment. Washing the sand and gravel is fundamental because these materials are mixed with many impurities that may produce odor, flavor, and color problems in the flow. For washing the finest materials, it is necessary to use buckets with capacities above 10 liters. The sand is poured in the bucket until it is half full, afterwards water is added –not necessarily drinking water- and the whole content is manually stirred for approximately two minutes, making sure that the bottom sand gets washed as well. Then the content is left to rest for 2 to 3 minutes, so the sand sediments and the impurities remain in the water. After that, the water is emptied slowly, making sure that the sand doesn't get out. This procedure must be repeated several times until the water doesn't present so much turbidity after being stirred. A good indicator of the cleanliness is the foam present. If after the sand has been washed there is still foam present in the water, it is necessary to repeat the process until it disappears.

Finally, the floating valve is graduated so it closes when the water is 5 cm over the filtering bed. The procedure is shown in Figure 5-12.

Figure 5-12. Floating valve installation.

Table 5-7. Physical analysis results

		Before				After				
	Date / Hour	Turbidity (NTU)	pH (.)	Conduct. (µs/cm³)	True Color (UPC)	Filters	Turbdity (NTU)	pH (.)	Conduct. (µs/cm³)	True Color (UPC)
1	15/04/2008	12,8	9,37	59	10	1	7,99	4,61	135,5	7
	10:50 a.m.					2	7,86	6,14	84,1	7
2	16/04/2008	9,42	7,81	76,7	7	1	4,47	7,35	89,5	10
	11:00 a.m.					2	11,8	7,41	90,2	7
3	21/04/2008	16,3	8,11	56,1	10	1	7,33	7,99	100,3	7
	11:00 a.m.					2	5,96	7,03	109,3	5
4	24/04/2008	12,7	6,8	75,4	10	1	4,03	6,35	99,4	5
	10:50 a.m.					2	3,49	6,37	110,6	7
5	25/04/2008	17,9	8,23	94,7	10	1	6,25	8,26	94,8	10
	11:00 a.m.					2	8,23	8,72	112,9	10
6	28/04/2008	12,4	8,96	92,6	10	1	3,22	8,71	98,9	7
	11:30 a.m.					2	4,58	8,64	105,1	7
7	07/05/2008	16,8	8,75	75,8	10	1	2,06	8,22	107,3	7
	10:00 a.m.					2	3,47	8,21	103,8	7
8	30/04/2008	17,5	8,56	85,8	10	1	4,08	8,32	101,5	7
	01:00 p.m.					2	0,66	8,35	99,7	7

5. Start up and technical tests

For the start up of the two filters, drinkable water was added regularly throughout one day, in order to “purge” the filters. This is done with the purpose of eliminating the finer particles of the bed until a stabilization point is reached, in which the turbidity of the flow is below 10 NTU. For the fine sand, coarse sand, and gravel filter, 162 L of water were required to obtain the aforementioned turbidity reduction. Every technical test pilot was done using water of the San Francisco River, collected in Bogota’s 1st street.

Thus, measurements of pH, turbidity, true color and conductivity for raw water –from the San Francisco River- were taken, as well as for the flows of both filters, three times a week for 3 weeks. The results are presented on Table 5-7.

The filter of fine sand and gravel was named filter 1, and the fine sand, coarse sand, and gravel filter was named filter 2. Additionally, Table 5-8 presents the reduction percentages of physical parameters for both filters.

Table 5-8. Reduction percentages

% Remotion				
Filters	Turbidity %	pH %	Conductivity %	True Color %
1	37,578	50,800	-56,458	30
2	38,594	34,472	-29,845	30
1	52,548	5,890	-14,302	-30
2	-25,265	5,122	-14,967	0
1	55,031	1,480	-44,068	30
2	63,436	13,317	-48,673	50
1	68,268	6,618	-24,145	50
2	72,520	6,324	-31,826	30
1	65,084	-0,365	-0,105	0
2	54,022	-5,954	-16,120	0
1	74,032	2,790	-6,370	30
2	63,065	3,571	-11,893	30
1	87,738	6,057	-29,357	30
2	79,345	6,171	-29,975	30
1	76,686	2,804	-15,468	30
2	84,800	2,453	-13,942	30
1	87,738	6,057	-29,357	30
2	79,345	6,171	-26,975	30

Similarly, several flow measures were taken on the output of both filters. For this, a 500ml test tube and a stopwatch were used to measure the flow rate. Likewise, the hydraulic losses were registered using a piezometer installed previously. Table 5-9 shows the flow rate and hydraulic losses results for both filters.

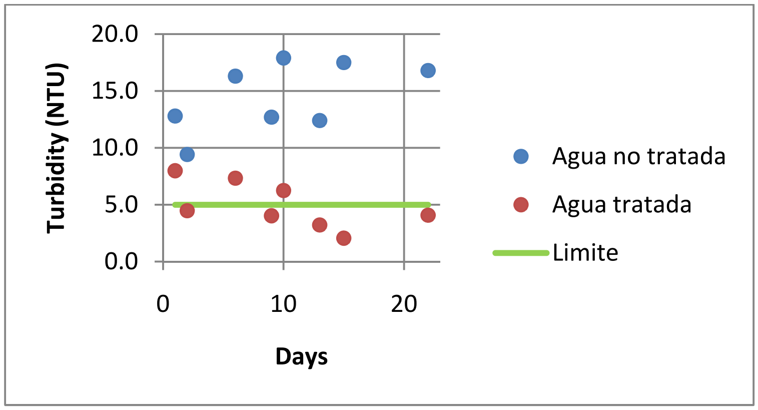

Figure 5-13. Hydraulic analysis results – Fine sand and gravel filter: Turbidity.

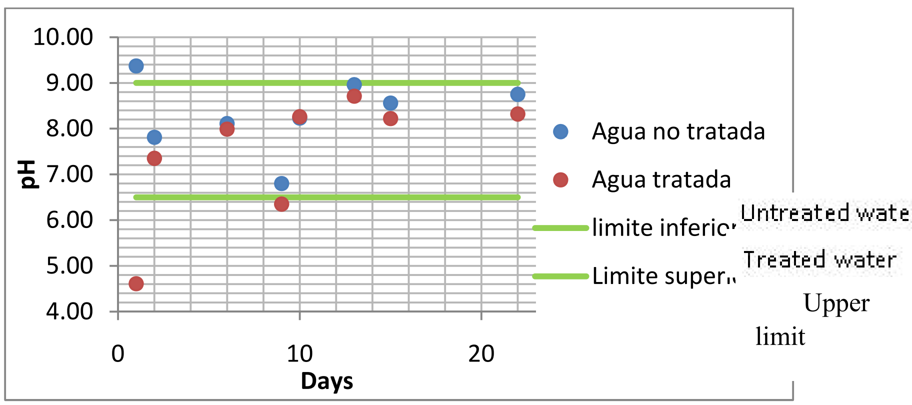

Figure 5-14. Hydraulic analysis results – Fine sand and gravel filter: pH.

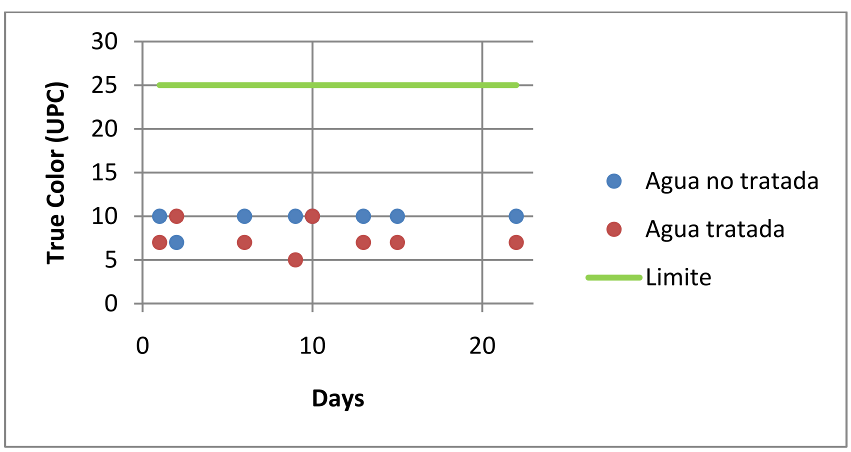

Figure 5-15. Hydraulic analysis results – Fine sand and gravel filter: True Color.

Table 5-9. Hydraulic analysis results – Fine sand, coarse sand, and gravel filter

		Filter 1					T average	Q obtained	Q	Looses
	Date	**t1**	**t2**	**t3**	**t4**	**t5**	(s)	(l/s)	(l/h)	hf-open (cm)
Monday	14/04/ 2008	29,53	27,72	28,99	27,81	25,1 4	27,84	0,0179611	64,6598 18	18
Tuesday	15/04/ 2008	26,11	25,3	24,45	27,7		25,89	0,0193125	69,5249 13	23
Wednes-day	16/04/ 2008	25,65	24,29	24,36			24,77	0,0201884	72,6783 31	29
Thurs-day	17/04/ 2008	24,31	23,71	23,55	23,24		23,7	0,0210948	75,9413 56	32
Friday	18/04/ 2008	23,22	24,99	25,123			24,44	0,0204546	73,6366 98	
Monday	21/04/ 2008	22,75	23,1	22,86			22,90	0,0218309	78,591 180	22
Tuesday	22/04/ 2008									
Wednes-day	23/04/ 2008	25,22	24,32	26,12			25,22	0,0198255	71,3719 27	31
Thurs-day	24/04/ 2008	23,48	22,91	23,1			23,2	0,0215858	77,7090 23	27
Friday	25/04/ 2008	24,76	25,4	24,53			24,9	0,0200830	72,2988 35	
Monday	28/04/ 2008	10,98	11,12	11,12			11,05	0,0452489	162,895 928	25
Tuesday	29/04/ 2008	23,11	21,88	22,3			22,5	0,0222222	80,0000 00	27
Wednes-day	30/04/ 2008	23,45	24,54	24,34			24,11	0,0207383	74,6578 18	22
Holiday	01/05/ 2008									

*Data taken with 250 ml test tube

		Filter 2					T average	Q obtained	Q	Looses
	Date	**t1**	**t2**	**t3**	**t4**	**t5**	(s)	(l/s)	(l/h)	hf-open (cm)
Monday	14/04/20 08	12	14	13,8	13,7	13, 6	13,42	0,0372578	134,12816 7	27
Tuesday	15/04/20 08	13,12	14,42	12,19			13,243	0,0377548	135,91744 3	21
Wednes day	16/04/20 08	14,16	13,81	14,52			14,15	0,0353357	127,20848 1	25
Thurs-day	17/04/20 08	13,36	13,99	14,54	14,66		14,14	0,0353669	127,32095 5	32
Friday	18/04/20 08	14,93	13,39	13,25			13,857	0,0360837	129,90137 1	30
Monday	21/04/20 08	14,74	14,82	14,8			14,78	0,0338295	121,78619 8	23
Tuesday	22/04/20 08									
Wedne-sday	23/04/20 08	14,99	13,83	13,3			14,040	0,0356125	128,20512 8	25

Table 5-9. (Continued)

Thurs-day	24/04/2008	13,22	13,58	13,3			13,4	0,0374065	134,663342	23
Friday	25/04/2008	14,73	15,19	15,36			15,09	0,0331272	119,257951	29
Monday	28/04/2008	7,24	7,09	7,1			7,17	0,0697837	251,221214	21
Tuesday	29/04/2008	14,14	14,91	14,5			14,53	0,0344116	123,881624	23
Wednesday	30/04/2008	14,49	13,86	14,57			14,307	0,0349487	125,815471	19
Holiday	01/05/2008									

*Data taken with 250 ml test tube

Finally, Table 5-10 presents the results of the microbiologic tests performed once a week per three weeks. These analyses were made to the raw water of the San Francisco River, as well as to the water treated by each filter.

Table 5-10. Microbiological analysis results

	Date / hour		Ex	Filter 1	Filter 2
1	15/04/2008	Reference Test Lot	Good		
		Coliforms	220		
	10:00 a.m.	E. Coli	1200		
2	24/04/2008	Reference Test Lot	Good		
		Coliforms	25600	Countless	4400
	11:30 a.m.	E. Coli	23500	23000	200
3	09/05/2008	Reference Test Lot	Good		
		Coliforms	600	2100	0
	10:44 a.m.	E. Coli	300	0	0

Development of the organizational intervention proposal

After the first visits, a meeting with the community was arranged, looking to identify who was interested in working in the design and surveillance of the systems for improving the quality of water. Thus, groups with engineers and people from the community were formed in order to establish the characteristics of the filters that were going to be used. The group began a pilot project in which four families cooperated.

Approximately every fifteen days, the EWB team visited the community and met with the people. Through these meetings, the team was able to determine that the filter was useful for all the homes which were to take part in the pilot project. For each home, a committee was established, formed by the owner of the house who provided the details of the installation and a couple of students who provided technical support, and its task was to determine the specific characteristics of the filter and the installation. The knowledge gained by the students through this process was shared each week with the rest of the team during meetings. It is worth pointing out that the characteristics of the filter were the same for all of the homes but each committee determined the optimal conditions for installation based on the preferences of the homeowner, the characteristics of the landscape and the house. The experience with this group of people was used to verify the acceptability of the technology, identify problems in its use (technical and cultural), measure improvements in water quality and make adjustments to the participatory methodology to improve cooperation and make better use of the community's local knowledge.

Later, 10 additional families got involved in the project after having verified the effectiveness of the filters and their cultural suitability. Parallel to this process, other activities like training workshops were developed, in order to look for a high degree of sense of ownership in the community and an independent and autonomous management of technology which is vital to ensuring sustainability and the potential for replication in the future.

<u>Systemic intervention proposal:</u>

The systemic focus used in the project entailed a coordinated work between the technical and the organizational aspects of the project, as mentioned above. Additionally, the systemic focus facilitated the approach to other social and cultural aspects that affect the development of the project, but are not always taken into consideration. One of these aspects is the involvement of other *stakeholders*.

Work with stakeholders:

Aside from working with the community, EWB Colombia also worked together with the mayor and an employee from the UMATA to try and establish a relationship of trust with the community's inhabitants from the beginning. Working together with the mayor has improved the probability of effective outcomes of the participatory methodology used. Thanks to the mayor, the EWB group and the local population who have been working together have had the chance to show their findings to the political leaders representing each of the districts attached to the municipality. This has created a positive "tension" which has increased the number of people interested in making a contribution with their local knowledge and participating in creating better living conditions for their communities. Testimonials such as that of the mayor are presented: "I was able to go and look at the functioning of the filters and we are definitely very happy because we found that. thanks to the collective work, water was improved and is fit for human consumption. What we liked best is that this is a professional job, well done (1), which benefits us and also enables us to keep the filters working". Moreover Leonel Riaño, community leader says that "... All the work of implementing the filters was very good, the community was actively involved and we learned several things about the composition of the filters and their maintenance. The learning process has been fundamental for students in order to actively participate in the design of other proposals". (Ramirez et al., 2010)

In this process, the help from other stakeholders such as the community leaders, the mayor and the UMATA employee has been crucial for the success in organizing the community. The group has had to be careful in dealing with politicians, as they might try to claim some of the results of the project as their own in order to obtain support from the community and portray a more positive and proactive image. Communication with the community and the politicians has been crucial in this process, the group has been very careful not to promise more than it can deliver and not to make commitments it can't keep. (Ramirez et al., 2010)

Results of the project

<u>Results of the filters in the field</u>

In order to make a pilot test of the filters, four families were chosen and the filters were constructed along with them, with the objective studying the impact of these filters on the microbiological quality of the water consumed by these families.

The following tables sum up the results of the microbiological tests performed before and after installing the filters.

Table 5-11. Monitoring of the first four installed filters

<table>
<tr><th colspan="6">July 18th, 2008</th></tr>
<tr><th>Parameter</th><th>Units</th><th>Problem water</th><th>Carlos</th><th>Dionel</th><th>Don Jorge</th></tr>
<tr><td>E. Coli</td><td>UFC/100m/L</td><td>7</td><td>0</td><td>2</td><td>2</td></tr>
<tr><td>Total Coliforms</td><td>UFC/100m/L</td><td>Uncountable</td><td>Uncountable</td><td>Uncountable</td><td>Uncountable</td></tr>
<tr><td>Color</td><td>U. PT/CO</td><td>< 5</td><td>< 5</td><td>< 5</td><td>< 5</td></tr>
<tr><td>Conductivity</td><td>µmho/cm-25</td><td>61</td><td>139,6</td><td>103</td><td>127,8</td></tr>
<tr><td>Turbidity</td><td>N.T.U.</td><td>0,626</td><td>0,602</td><td>1,97</td><td>1,21</td></tr>
</table>

<table>
<tr><th colspan="7">October 9th, 2008</th></tr>
<tr><th>Parameter</th><th>Units</th><th>Fountain</th><th>Adan</th><th>Dionel</th><th>Jorge</th><th>Carlos</th></tr>
<tr><td>E. Coli</td><td>UFC/100mL</td><td>0</td><td>0</td><td>0</td><td>2</td><td>1</td></tr>
<tr><td>Total Coliforms</td><td>UFC/100mL</td><td>10300</td><td>61</td><td>57</td><td>Uncountable</td><td>55</td></tr>
</table>

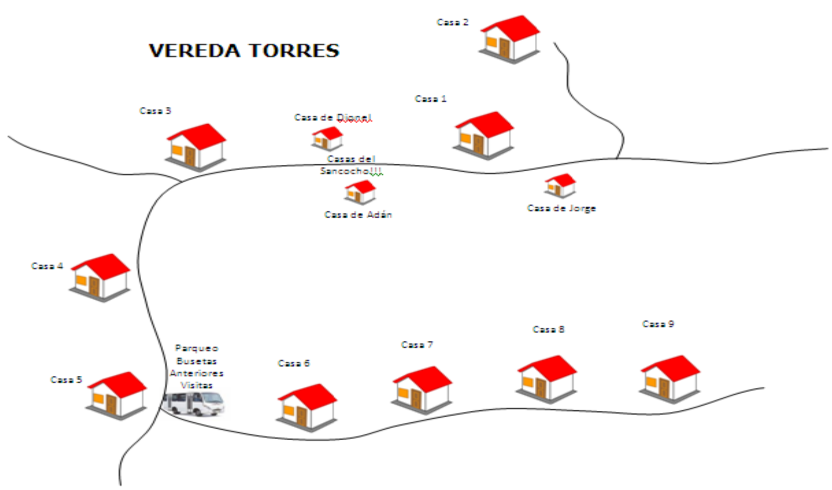

Figure 5-16. Torres district map.

Technical monitoring of the filters

Table 5-12. Filters Monitoring – "Las Torres" District

HOUSE	CONSTANT SUPPLY OF WATER		FILTER INTERNAL STATE					STATE OF WATER UPON LEAVING THE FILTER			
	YES	NO	ODOR	FLAVOR	COLOR	FAT	OTHERS	ODOR	FLAVOR	COLOR	OTHERS
House 1	X		No	no	no	no	no	no	no	no	no
House 2		X	No	yes	no	yes	no	no	yes	no	no
House 3	X		No	no	no	no	no	no	no	no	no
House 4	X		No	no	no	no	no	no	no	no	no
House 5	X		No	no	no	yes	no	no	no	no	no
House 6		X	No	no	no	no	no	NA	NA	NA	NA
House 7	X		No	no	no	no	no	no	no	no	no
House 8		X	Yes	yes	yes	yes	no	yes	yes	yes	no
House 9	X		No	no	no	no	no	no	no	no	no
House 10 (Dionel)	X		No	no	no	no	no	no	no	no	no
House 11 (Adan)	X		No	no	no	no	no	no	no	no	no
House 12 (Jorge)	X		Could not be observed					no	no	no	no
House 13 (Carlos)	X		No	no	no	no	no	no	no	no	no

HOUSE	AVERAGE FLOW	BIOLOGICAL LAYER		FILTER MATERIALS CONDITIONS			FILTER PERCEPTION	
		YES	NO	GOOD	BAD	DRIPPING	GOOD	BAD
House 1	NA		x	X		yes	X	
House 2	NA		x	X				
House 3	0,059	X		X		no	X	
House 4	0,082	X		X		no		X
House 5	0,058	X		X			x	
House 6	NA		x	X				
House 7	0,06		x	X			x	
House 8	0,058	X		X				X
House 9	NA	X		X		no	NA	NA
House 10 (Dionel)	0,051	X		x		no	x	
House 11 (Adán)	0,032	X		x			x	
House 12 (Jorge)	NA			x			x	
House 13 (Carlos)	0,044	X		x			x	

The filters were made again for houses 2 and 8.

Table 5-13. Results of monitoring the filters one year after installation

House	Filter conditions	The user followed the instructions	Condition of the treated water
1	Good	YES	Good
2	Regular	NO	Has flavor
3	Very good	YES	Very good
4	Does not work	NO	-
5	Very good	YES	Good
6	Does not work	NO	-
7	Very good	YES	Good
8	Bad	NO	Has odor flavor
9	Very good	YES	Good
10	Very good	YES	Very good
11	Very good	YES	Very good
12	Very good	YES	Very good
13	Good	YES	Good

Perception of the community

In order to measure the people's perception of the project, as well as to inquire about the eventual participation of phase 1 beneficiaries in the second phase of replication in another district of the municipality, some EWB members went to Torres district to interview some families. Below, there's a summary of those interviews, which were carried out two years after the beginning of the project.

Interview # 1: Jorge and Luisa (House 1)

Luisa told us that she is very grateful for having the filter in her home. According to her, this is instrument has contributed greatly to improving the quality of life of her family, because they no longer suffer frequently from gastrointestinal diseases. In addition, she did not have any negative comments regarding the project; quite the opposite, she remarked the advantages that the installment of the filter in her home has generated.

Luisa told us that her and her husband would be willing to collaborate. She said that, even though she may not have the abilities to train other people on the construction of a filter, her husband might, since he has attended all training processes. If there is a new training process, she would be willing to help by teaching people from other communities how to use the filter and for what purpose. Her collaboration would consist of her testimony to the community so that others may implement these filters.

Interview # 2: Gloria Arévalo (House 3)

Until 2 months ago, Gloria used her filter normally, but since then the instrument began to deteriorate and stopped working. The deterioration of the filter occurred because she had never done any maintenance to it; because, despite having been instructed on how to do it, she forgot to perform the maintenance.

Gloria is willing to train her neighbors in the implementation of the filter, and to offer her testimony regarding its use and the benefits it has brought to her home.

Interview # 3: José Antonio and Leyla Monroy (House 7)

Leyla told us that currently she uses the filter on a daily basis. At home, the filter looks clean, impeccable and organized. Just like with Luisa, her husband is the most involved with the project, but she is the one who has been doing the maintenance to the filter, and has been more involved than her husband in the practical matters. Leyla was involved in the installation process, and recalls certain aspects of its construction.

Leyla was doing the maintenance process to the filter every 2 months with chlorine. The Engineer Julian commended her for taking care of the filter, but explained to her that maintenance is required only every 6 months and should be done without using chlorine, because this compound could leave traces in the water, and there will be the risk of ingesting chlorine residuals.

Leyla said she did not have much time to train people on how to implement the filter. She could not commit, but would be willing to give her testimony to other neighbors, to encourage them to participate by telling them the uses and benefits the filter has brought to her home.

Ingenieros sin Fronteras Colombia learning:

This case of applied research generates two types of knowledge:

On one hand, how to develop viable solutions for local water-related problems. The ISF learned how to develop viable solutions for local problems associated with the management of water; the group also learned that the use of simple and cheap technologies may make a difference in problems of marginalized communities.; and it also learned how to develop a research process about these technologies, aiming to do improvements that will make adaptation easier to different geographical and social contexts.

On the other hand, how to conceive a human group composed by communities and universities aiming to generate suitable and sustainable solutions. The second kind of learning is a profound learning addressing how to develop an organizational model which includes the Universities and the rural Communities for the solution of problems related with the water players that are not always taken into account in the formulation of these kinds of solutions. Is important to highlight how a team work relation was developed, where all the community members, like the students and professors, are active agents in the development of the process. This relation not only contrasts with the paternalistic relationships that emerge in similar projects, but it also generates spaces for the empowering of the community, as well for the learning and research by the students.

6. MOCHUELO CASE, CIUDAD BOLIVAR, BOGOTA

After completing the project in Guayabal of Síquima, ISF-COL managed to generate internal learning, by identifying aspects to improve and making adjustments to their intervention methods, from a technical and social point of view, and as researchers.

Keeping the interest to identify mechanisms of the development of the communities in the rural zones, a process of research has begun with the objective of identifying places close to Bogotá where is easy to monitor and to develop activities continuously so we can guarantee a better execution of the project. In consequence, we manage to establish that the locality of Ciudad Bolívar was a place with a high potential because of the low quality of life there and using our expertise we could improve it with our intervention, particularly leveraging in simple technologies, sustainable and culturally viable; framed in a research context, applied engineering and the linking of students and professors of ISF-COL.

In this way, we established the making of a pilot project as fundamental, where the understanding of the technology by the community will be evaluated, and in turn, we evaluate our intervention and team work with the community; the objective behind the pilot was to guarantee in the future a well planned project with clear objectives, goals and work methodologies.

Taking into account that ISF-COL works under the PAR methodology, within the framework of the OCDIO and the systemic approach, in the next pages, each of the steps of the methodology are explained as applied to the Mochuelo case, Ciudad Bolívar, Bogotá.

Planning

According to Campo et al., the locality of Ciudad Bolívar located in Bogotá, is the biggest locality (22.920 hectares), with almost 93% of the population living in the two lowest socioeconomic strata, 53.3% of the population of the locality is under 25 years old and in general, have a low index of quality of life.

Taking into account these conditions, and while we were doing the research about the viability of the project in the zone, we strategically decided to strengthen the relation between ISF-COL and the Centro de Estudios en Vivienda Saludable (CENVIS), organization with a huge credibility and experience in the locality, particularly in the Mochuelo neighborhood.

Previous studies by the CENVIS, showed that the community of Mochuelo presents strong rural characteristics and severe problems because of its proximity to the landfill of Doña Juana (waste collection center of Bogotá) and the lack of water works and sewage; however, they remark that it is a community committed to participating actively in any activity that may improve their quality o life.

In consequence, the Mochuelo community adjusts to our objectives and was selected for a new project, in which it was clear that the work with the community was going to be developed by the ISF-COL, which required strengthening of the intervention team including social workers.

Figure 6-1. Mochuelo.

Identification

The analysis starts with the identification of the problem (Phase 1), however the CENVIS had previously identified some gastrointestinal problems in the community, due to the consumption of bad quality water, they also identified that the water arrives through hosepipes that are not properly maintained. And according to the surveys made by the CENVIS, the families manifest distrust regarding the water because of its color, smell and particularly, the turbidity that sometimes it presents.

Because this phase is supported through OBSERVATION, which takes into account the characteristics of the systemic thinking it was decided to link part of the project with the activities that would take place in the Second International Seminar of Ingenieros sin Fronteras, where students of all the engineering careers, social workers, biologists, and other assistants to the seminary made diagnostics of the zone and the community from their field of knowledge. Highlighting in their final papers the positions and characteristics of the problematic situation, based on the opinions of the families of the community, the community leaders, the communitarian organizations and of organizations already working in the zone, like CENVIS.

With the input of the top-rated diagnostics from each discipline, experts and professors that support the work of ISF, it was established that the priority in the zone was the improvement of the quality of the water, together with education aimed to changing the hygienic habits and life styles focused on the development of a healthy housing.

As a technical component in the identification of the problem, physical-chemical tests were conducted on the quality of the water in the sector of Mochuelo. Specifically, the places and results of the sampling were:

- Point 1=Close to the water source

PH	CONDUCTIVITY (us/cm)	T(°C)	ALKALINITY (mg/l CaCO3)
6,41	51,1	16,8	21
6,38	52,5	16,8	22
5,83	52,5	16,8	

FECAL COLIFORMS (NMP/100ml)	TOTAL COLIFORMS (NMP/100ml)	APPARENT COLOR U.Pt co	TOTAL HARDNESS (mg/l CaCO3)
15	15	4	24
1100	1100	4	27

GYA(mg/l)	IRON(mg/l-Fe)	OD	TURBIDITY (NTU)
<3,6	0,09	3	2,32
<3,6	0,18	3,1	6,65

- Before the grit chamber

PH	CONDUCTIVITY (us/cm)	T(°C)	OD
5,69	48,2	14,8	6,2
5,84	48,7	14,8	6,3
5,52	48,6	14,7	

- In the grit chamber

PH	CONDUCTIVITY (us/cm)	T(°C)	ALKALINITY (mg/l CaCO3)
7	46,9	14,4	15
6,6	47,3	14,3	15
6,8	47,6	14,2	

FECAL COLIFORMS (NMP/100ml)	TOTAL COLIFORMS (NMP/100ml)	APPARENT COLOR U.Pt co	TOTAL HARDNESS (mg/l CaCO3)
23	240	15	35
43	75	15	23,4

GYA(mg/l)	IRON(mg/l-Fe)	OD	TURBIDITY (NTU)
"10,5"	0,17	6,6	8,81
12,7	2,86	6,5	9,2

- House 1

PH	CONDUCTIVITY (us/cm)	T(°C)	ALKALINITY (mg/l CaCO3)
6,58	48,9	16,4	14
6,55	49,9	16	14
6,42	49,5	16,5	

FECAL COLIFORMS (NMP/100ml)	TOTAL COLIFORMS (NMP/100ml)	APPARENT COLOR U.Pt co	TOTAL HARDNESS (mg/l CaCO3)
<3	<3	20	25
<3	<3	15	20

GYA(mg/l)	IRON(mg/l-Fe)	TURBIDITY (NTU)
<3,6	0,15	6,27
"5,7"	0,15	5,93

- House 2

PH	CONDUCTIVITY (us/cm)	T(°C)	ALKALINITY (mg/l CaCO3)
6,45	48,6	16,4	14
6,34	49,7	15,4	14
6,38	50	15,6	

FECAL COLIFORMS (NMP/100ml)	TOTAL COLIFORMS (NMP/100ml)	APPARENT COLOR U.Pt co	TOTAL HARDNESS (mg/l CaCO3)
<3	43	15	34
<3	<3	20	22

GYA(mg/l)	IRON(mg/l-Fe)	TURBIDITY (NTU)
"5,3"	0,25	6,75
<3,6	0,22	8,63

- House 3

PH	CONDUCTIVITY (us/cm)	T(°C)	ALKALINITY (mg/l CaCO3)
6,4	49,5	15,6	15
6,39	49,8	15,2	14
6,25	50,1	15,1	

FECAL COLIFORMS (NMP/100ml)	TOTAL COLIFORMS (NMP/100ml)	APPARENT COLOR U.Pt co	TOTAL HARDNESS (mg/l CaCO3)
<3	20	15	22
<3	43	20	20

GYA(mg/l)	IRON(mg/l-Fe)	TURBIDITY (NTU)
<3,6	0,62	5,45
"5,2"	0,25	8,18

- House 4

PH	CONDUCTIVITY (us/cm)	T(°C)	ALKALINITY (mg/l CaCO3)
6,54	49,5	15,9	15
6,55	50,3	15,6	
6,56	50,5	15,4	

FECAL COLIFORMS (NMP/100ml)	TOTAL COLIFORMS (NMP/100ml)	APPARENT COLOR U.Pt co	TOTAL HARDNESS (mg/l CaCO3)
75	43*10^2	20	28
150	93*10^2		

GYA(mg/l)	IRON(mg/l-Fe)	TURBIDITY (NTU)
<3,6	0,41	9,86

According to the results, the water of the Mochuelo is not in the optimal conditions for human consumption. In most of the sampling points microorganisms were found, which may negatively affect the health in an infectious manner (fecal coliforms) and the turbidity is above the maximum allowed by the WHO (World Health Organization), which is 5 NTU for drinking water. In consequence, the results allow us to technically measure the problem regarding the quality of the water in Mochuelo; these results will be taken into account in the formulation phase where the best technology will be chosen for the context in study.

As was explained before in this stage of the PAR methodology, learning was generated by ISF-COL and the community while the project is adjusted through the continuous interaction with the community. So in phase 2, the relevant stakeholders in the solution of the problematic situation are the inhabitants of the community, CENVIS, ISF-COL, Los Andes University and the University Corporation Minuto de Dios. The phase 3 consists in involving all of the people interested in the activities organized by ISFCOL (with training sessions and working sessions), allowing us to identify the level of comprehension of the community of the content of each training and the building of technology.

The relations among the interested people allowed us to understand the local interests (Phase 4), continuously expressing topics related to the quality of the water, solid waste, smell and health. In the same way, in most of the interviews and meetings, it was highlighted that the improving of the quality of the water will be the main priority, and after improving the habits and health topics will start the improvements in other problems.

Finally, in Phase 5, the importance and influence of the people involved in the development of the project is analyzed, that, for the case of the ISF-COL, would be the engine of the work. The community should be committed in all of the processes, the CENVIS will support the project with information and the creation of the initial relations between us and the community, the universities will allow the use of the laboratories and facilities to perform the applied research in a proper way.

Formulation

Starting from the identifications of the problem and in concordance with the living conditions and the socioeconomic characteristics of Mochuelo, ISF-COL evaluated several types of technologies that improve the quality of the water. To make this decision, the team used its own decision model, which takes into account the technology cost, ease of the manufacturing, impact of the technology, ease to monitor, complexity, sustainability and knowledge generation. Consequently, the technology selected was the Slow Sand Filter, particularly Version 2 that was adapted to Mochuelo, making it dismountable and facilitating its maintenance because the families in the zone are constantly upgrading and adapting their houses.

For this moment of the pilot project when the real comprehension of the filters and apprehension will be measured, 4 families were selected, taking into account their previous commitment with CENVIS programs, the leadership skills in the community and the potential of being replicator agents of the knowledge were also taken into account.

Two strategies were identified for the improvement of the living quality conditions regarding the water: the conductions of trainings addressing the basic sanitation, good hygiene practices and the importance, use and management of the filtering technologies; and as a second strategy, the training addressing the manufacturing and installation of the slow sand filters version 2.

However, aiming to keep the development of the project in a systemic way and according our experience in Guayabal, the trainings were a good strategy to accomplish this, but were not enough to empower and actively link the community, because of this, it was necessary to think in improvements. In this way, we established that it was fundamental to evaluate the comprehension of the trainings, assuming that the families, knowing that they will be evaluated, were going to be more committed with the topics of the trainings and, in consequence, with the project.

In summary, for this stage of formulation of the pilot project, it was established that the participation of the community was going to be developed in the following activities:

- Active participation in trainings
- Participation in evaluation processes
- Adaptation of the place for the installation of the filter
- Manufacturing of the filter

However, we had all the time in mind that the pilot project will allow us to identify new strategies of participation in line with the characteristics of the population, which will be applied in the robust execution of the project.

We were hoping to integrate most of the team of ISF-COL, professors, students and those volunteers that start to integrate the team with those trainings and the installations of the filters.

Regarding the technical component, it was established as necessary the performing of physical-chemical tests after the installation of the filters, which allowed us to validate the proper selection of the technology and its evaluation according to the characteristics of the Mochuelo.

Finally, in this stage, we established that to obtain and adequately use and maintain the filter, the day of the installation we will give a user's manual, one printed and one that will be posted to the filter with the objective of being constantly visible, helping the community to ensure a proper use of the technology; we also established that after the installation of the filter, there will be surprise visits with the objective of checking the state and understanding of the filter.

Funding

After the identification phase and having as a motivation, getting funding for the execution of the project in the Mochuelo; undergraduate students linked to ISF-COL and advised by the leader professors of our group, assumed the challenge to participate in a calling which awarded the communitarian innovation in topics related with the water.

The students' team with industrial, civil and chemical engineers was the winner of the prize "Mejor Solución Comunitaria", after being evaluated by representatives of the OAS, IBD, YABT, PepsiCo and the Peruvian Government.

This recognition and the resources allocated to the prize, allowed us to make the project in the Mochuelo reality. However, the new resources were not enough so Los Andes University and the Universitary Corporation Minuto de Dios, members of ISF-COL; gave resources for the necessary research in the project and especially for the performing of lab tests and people for each training session.

Implementation

Before the training sessions, the 4 selected families received information regarding the project, highlighting the criteria addressing why they were in the pilot project.

There were 4 training sessions in total, the first 3 addressed subjects related with self-esteem, personal hygiene, the water as a need and a right, the housing as a living space and its influence in the family dynamic, the proper use of water and the characteristics of a water of good quality. The fourth training session was special because the families had to manufacture a small scale filter, making a special emphasis in materials, maintenance and care.

As an aspect to highlight, in training session 1 and aiming to formalize the commitment of ISFCOL and the families in the project, an agreement was signed (ISF + Community), highlighting the fulfillment of the conditions for each training session.

It is noteworthy to highlight that these training sessions had a systemic approach, which aimed to develop the capacity of the participants to identify a problem from a sustained knowledge point of view, and do not expect that technicians or engineers had the last word in the identification of the problems. In this way, in the training sessions, we delivered tools for the families to evaluate the pros and cons of improving their habits and the right use of technology.

Valuation and Feedback

In the first training session, the main achievements were: the interest of the adults in the subjects related with self-esteem, the participation in the discussion related with the subjects of daily life, the interest and support by the students and the greeting by the assistants because of the interest shown presenting this project in the zone.

However, we identified that the assistance of Saturdays is complicated because some people have to work and is not possible for all the family to assist, and the child distracts the parents, so we need to improve the strategies to integrate the child.

To continue strengthening the self-Esteem subject, in the second training session, we took, as a core subject, the “Self-image”, making a special emphasis that is a relevant aspect, because it allows highlighting the qualities and the skills of each of the family members. A practical exercise was performed where the participants should write their principles skills on a wall, highlighting those that may give good to the whole community, generating in this way a discussion and reflection space where the assistants identified their strengths. After this exercise, the announces on the wall were presented to the whole audience, allowing that the group to recognize the group because of its qualities and skills, arriving at the conclusion that each of the announcements presented were important because they highlight the positive aspects of each person.

Finishing the subject of self-image, we continue with the subject of the space in the housing, highlighting the house as a vital space, because on top of being constructed with solid matters to avoid risks and accidents, it is necessary to keep the proper hygiene conditions, allowing in this way an optimal environment. At the same time, it generates an adequate space for the familiar harmony. Each of the participants gave an opinion regarding the best habitat conditions, taking into account aspects like the control of the crowding, improvement of the housing and the prioritizing of spaces.

In the third training session we used a video where the consequences of the consume of bad quality were shown, after explaining the basic recommendations to guarantee good quality water, the families expressed that the third training session was really useful and that is something that may be broadcast to the community, because it does not address personal issues and is based on studies and knowledge.

The training session 4 was the most didactic, because the families were guided in the manufacturing of a small scale sand filter, achieving that the families understand the operation of each of the components and the whole filter. Equally, they managed to learn the basic care and the adequate maintenance of the technology.

Regarding the results of the influence and interaction among actors involved in the project, it is important to highlight that the students registered as volunteers after noticing the commitment of the families, had assumed with commitment the development of each of the assigned tasks. Because of the absence of one of the families, it was necessary to separate it from the pilot project and give it the possibility to bind with commitment in the second phase where the project will be run in a robust way.

Analyzing the results of this pilot phase, we identify the need to reduce the training in subjects related to self-image and we commit ourselves to strengthen the skills in the care and proper management of water. We are also going to include a new training session about the motivation of the technological replication; the idea behind these training sessions is to deliver tools that will allow the replication processes in the community to start and the real communitarian development.

We also determined that the training is going to be framed in a class, which is going to develop theoretical subjects and other practicals like the manufacturing of the filter. In the end of the process, we will give diplomas that certify the knowledge acquired in each of the sessions. In conclusion, by the end of the project, the families would have built their own filter and will be certified.

Finally, with the objective of strengthening the commitment with the community, a part of the funding of the project should be carried by the families, but this will be a small amount, a symbolic amount but will make the distinction that the real development is achieved by the community leveraging in the knowledge transmitted by ISF-COL.

CONCLUSION

As we have seen, the availability, the accessibility and the quality of the water are essential to guarantee the health of a country. Colombia, right now, is surrounded by paradoxes: it is a country rich in water, yet still several zones suffer from a lack of the resource, face a lack of good quality water, and finally, doesn't have a proper care of the resources and ecosystems. The government has carried considerable effort to solve this problem, but its main flaw is that the projects proposed by the regulations don't take into account the citizens, which, in most cases, results in bad outcomes. This happens because it is not possible to intervene effectively on the needs of the civil population, if they haven't been acknowledged.

This chapter proposes a mechanism that Observes, Conceives, Designs, Implements and Operates engineering solutions that aim to improve the quality of life of vulnerable communities in Colombia, by integrating universities and rural communities using participatory methodologies. The model has been proved to be successful in the Guayabal de Siquima study case, and evidence from the Mochuelo case shows that the model can be replicated and escalated in several other vulnerable communities in Colombia, and probably, in other places in the world.

The benefits of dialogue between universities and rural communities are:

1) We can exchange the engineering knowledge and know-how in the design and installation of water filtering technologies that respond to the economical and social characteristics of local rural communities

2) We can discuss the ecologically sustainable and culturally appropriate water solutions

3) We can establish a long term relationship between the communities and universities in order to develop filtering technologies and implementation processes that respond to local needs.

Each day, safe water for human consumption is becoming scarcer due to pollution, deforestation and climate change among other reasons. Unclean water spreads diseases such as cholera and diarrhea, which will affect millions of people per year. Unsafe water poses a serious threat to people's health, spreading diseases that could be prevented through financially and ecologically sustainable means. As concerned college students, we wish to make a difference by improving the availability and quality of drinking water in marginal rural communities through our work and effort.

The purpose of the project is to improve the availability and quality of drinking water in Colombian rural communities, through the joint design and implementation of water filtering technologies that respond to each country's unique water conditions, to reduce the proportion of the population without sustainable access to safe drinking water by providing the tools and technical know-how required to build, use and maintain water filters and allowing them to carry out an active role in their community's improvement and growth which will hopefully result in a long term sustainable project.

The development of the project proposal was an arduous engineering process that has required a great deal of cooperation and effort from both groups and from the team as a whole. The work and communication between universities and communities allowed the team to write a better proposal, which reflected different points of view, methodologies and ideas. During the course of the development process, the students, teachers and communities have grown close, developing a strong friendship which will help the future growth and development of the project.

In the end, we wish to provide clean and safe water to those who do not have access to it, hoping that many people will benefit from our project.

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