Syst Pract Action Res
DOI 10.1007/s11213-010-9175-3

ORIGINAL PAPER

Participative Methodology for Local Development: The Contribution of Engineers Without Borders from Italy and Colombia: Towards the Improvement of Water Quality in Vulnerable Communities

María Catalina Ramírez · Irene Bengo · Riccardo Mereu · Astrid Ximena Bejarano R. · Juan Camilo Silva

Abstract This paper presents a systemic methodology by which engineering is put to use in vulnerable communities through applied technological research and the main results of its application. The methodology presented corresponds to one implemented and designed by two groups of Engineers without Borders in Europe and Latin America, to integrate technical know-how with local context in communities with water problems in Colombia and the Democratic Republic of Congo. The main results of this methodology are related to the improvement of the living conditions of vulnerable groups thanks to the integration of the communities' knowledge with engineering know-how, leading to autonomous communities and engineering professors and students learning from real life problems to enrich applied sciences.

Keywords Systemic participative methodology · Water engineering solutions · Ownership · Congo · Colombia · Engineers without borders

Introduction

Water is the liquid that makes life possible on our planet; it is important for the economic development of nations and essential for the carrying out of daily activities by most people. However, the reality for about one-sixth of the world population is that a lack of access to safe drinking water holds back development and causes serious gastro-intestinal diseases. As noted by the United Nations Organization in its Third Report on Water Resources, these will be the conditions for 67% of the world's population by 2030 (United Nations 2009b). The situation is critical in regions like Africa where economic growth has done so little to decrease poverty which, in turn, limits the access to safe drinking water for almost 340 million inhabitants on the continent (United Nations 2009a). It is also an area of

M. C. Ramírez (✉) · A. X. Bejarano R. · J. C. Silva
Department of Industrial Engineering, Universidad de los Andes, Cra. 1 N° 18A-10, Bogotá, Colombia
e-mail: mariaram@uniandes.edu.co

I. Bengo · R. Mereu
Department of Energy, Politecnico di Milano, Milan, Italy

Published online: 04 June 2010

concern for Latin America which accounts for 10% of the world's water resources and has 14% of the world's population, out of which 40% live in poverty with limited or no access to safe drinking water and sanitation. Out of this 40%, 26% live in South America. Based on the World Bank's projections, by 2015 the human population will have gone from 6 to 6.9 billion inhabitants reducing per capita water supply in regions with medium and low incomes (World Bank 2002). These facts show a mismatch between the world's population and the distribution of water resources, e.g. Asia, and at the same time a gap between the water resource distribution and their accessibility or management, e.g. Africa and Latin America, which is strongly associated with the sanitary, social and economic conditions of the region.

One of the United Nations' eight Millennium Development Goals by 2015 is to reduce by half the number of people without access to this resource. According to a UNDP report (UNPFA Colombia), 900 million people will need access to water and 1.3 billion will need access to basic sanitation by 2015. The reduction of diarrhea could help regain 272 million days of school attendance, especially in sub-Saharan Africa and South Asia; additionally, 3.2 million workdays could be gained for people between the ages of 15 and 59; 1.7 billion dollars which are spent treating infectious diseases transmitted by water could be saved. According to the Report on the Development of Water Resources in the World (United Nations 2009b), many countries lack the financial, legal and institutional resources to assess the state of their water resources.

There are currently three important types of problems in countries that have water issues: the lack of sources of safe water, the lack of adequate management systems for water and third, it is usually the case that these communities with unsatisfied basic needs wait for help and knowledge from others to solve their own problems. Access to basic water and sanitation facilities would save the health systems of developing countries nearly 1.6 billion dollars a year. Other interesting indicators that allow closer monitoring of the complexity of water systems show that 1.8 million children die each year due to diarrhea (5 billion cases are diagnosed each year in children in developing countries) which translates into the death of one child every 3 min. In addition, 3,600 people die each day due to malaria (of which 3,200 are children): when drainage systems are not working properly, pools of stagnant water soon become infected with malaria-carrying mosquitoes (UNDP 2006).

The Systemic Methodology: Emerging Solutions from Communities and Engineers

Literature Review

The scenario presented above shows that it is relevant to inquire about the role of science in society and the part played by Non-Governmental Organizations (NGOs) and Universities in the promotion and development of sustainable development initiatives creating synergy between the community and the professionals, especially in the rural regions where they have influence (Bodorkós and Pataki 2009). In this framework of institutional social responsibility within regions (Bodorkós and Pataki 2009), there is a concern to design projects and strategies that aim to improve the quality of life of the most vulnerable population, in this case through the improvement of the quality of water for human consumption. Some of the questions regarding the role of science have been answered by engineering, which, through the implementation of different types of technologies and methodologies, has contributed in some regions of the world in the improvement of water quality. Regarding the choice of technology, which is related to factors such as the type of source, collection, treatment, storage and distribution (Brikké and Bredero 2003), some projects have made use of POU (*point of use)* type technologies such as SODIS, also known as Solar Disinfection (Moser and Mosler 2008), sand filters or clay filters with silver coating, micro filtration membranes, or more chemical alternatives such as the use of chlorine for the disinfection of water in homes. On the other hand, literature points out that the intervention methodology usually used in projects in vulnerable rural communities with water problems is based on Participatory Action Research (PAR); in this process the community participates in the evaluation of their problem and the implementation of the projects with the help of the institution in charge of carrying out the research. In general, this method is appropriate for work with rural communities because it: (1) promotes the emergence of sustainable solutions, (2) generates a progressive change in the community, (3) increases community participation, (4) generates consensus regarding the objectives and planning of activities in the community, and the roles and responsibilities of the stakeholders, (5) results in the implementation of more productive technologies for each community's specific characteristics, (6) facilitates *feedback* and adjustments regarding the proposals and (7) generates long-term commitment. On the other hand, it is interesting because it allows engineers and engineering students and teachers to apply their knowledge in real problems with the hope of obtaining real and satisfying results, and more specifically it allows them to: (1) work jointly with communities as part of their social responsibility programs, (2) address real problems, search for real solutions and learn from local knowledge and (3) generate inclusive teaching and research processes generating new knowledge in the different disciplines which benefits all those involved (Bodorkós and Pataki 2009; Schaap and Nandi 2005; Martin and Sherington 1996; Frölich et al. 2001). Nyong and Kanaroglou (1999) presents a case-study in northeast Nigeria, in the village of Katarko, where the objective was to develop an integrated management system of water resources taking into account not just the technical aspects but also the socio-demographic and cultural patterns which might impact on water usage in the community. Moser and Mosler (2008) also utilize PAR in the implementation of SODIS technologies in Bolivia; Prokopy (2005) makes use of the method to evaluate the impact in communities participating in water projects in India and Bodorkós and Pataki (2009) integrate research based on the community and knowledge of academia to promote sustainable development in the rural regions of Hungary. A case-study closely related to those treated in this paper is the evaluation of water sources in the Colombian Andean zone through PAR with the participation of local groups of young people (Roa García and Brown 2009). These projects were successful in the implementation of technologies or water management systems from the community's point of view and were capable of responding with solutions adjusted to the users. PAR has been applied since the 1980s in North American universities with good results regarding the interaction generated between education in the classroom and interaction with communities (Bodorkós and Pataki 2009). The methodology has gained a wide acceptance in the implementation of water-related projects, especially in those carried out in developing areas such as Africa and Latin American countries such as Bolivia and El Salvador, in which good results have been obtained due to the ownership generated in the community (Prokopy 2005) through the gradual participation in projects in which the inhabitants acquire the skills necessary to operate the systems over time (Frölich et al. 2001). Each group participates with its own knowledge, creating synergies towards the improvement of the living conditions of communities without access to safe water, thanks to the combination of the local knowledge of with the technological innovation developments of engineering teachers and students.

It is worth pointing out that the results obtained from the implementation of this methodology can vary from case to case, and they are not always those expected by the community, the group of engineers or both. PAR provides general guidelines for the implementation of water related projects in rural communities and to be effective, modifications must be made according to local context. It does not guarantee success; it simply improves the chances of success by actively involving the community in the identification of the problem, the solution and the implementation processes. As in most intervention methodologies for communities, there are several arguments against, such as there being little evidence to state that the relationship generated by PAR has positive effects, that the community has too much power in the decision-making process, or that it imposes a large burden on communities who won't know how to respond. Still, Prokopy's results in his 2005 research suggest that at least in developing countries, work should be carried out through the application of this methodology. In this way the proposed technical solutions can hopefully be effective and replicated by local communities working towards the achievement of real independent development.

Participative Methodology

These projects are based on a systemic participative methodology. The sustainability of these projects depends on the way in which they are integrated in the local cultural and social context, environmental and economic conditions, institutions and available technologies. For this reason, starting from an analysis of the concepts of autonomy and development, the purpose of this type of engineering project is to make the community autonomous, self-organized and independent. In projects managed by engineers, Technology and Innovation alone are not sufficient to guarantee success; they must be driven by human factors and coupled with the principle of participation and direct community involvement so that they may constitute a more proper set of instruments and values to address the challenge for global development and human promotion. The proposed participative methodology is based on the seven steps of PAR, previously mentioned.

The community plays an active role in the decision-making process guided by an institution in such a way that commitment is generated, allowing the local population to gain awareness of the problems and to facilitate the decision-making process by increasing knowledge and experience. The community's willingness to tackle water related problems, although important, is not enough to appropriately address the problem as they may lack resources and technical know-how that could help identify and design more appropriate solutions given their context. This is where the group of engineers comes into play, by working jointly with the community and combining their experience and knowledge with the group's research skills and resources in order to design the best possible solution and work together in its implementation, hopefully achieving substantial improvements in the quality of their life.

Regardless of the choice of participation methods, the identification and participation of all those involved (stakeholders) is essential. To address and solve conflicts arising from changes in the context, they must be identified during the initial stages of the process, in order to initiate adequate negotiations, consult stakeholders and devise a constructive plan. The discussion topics depend on the type and scope of the project, but in principle, they are related to the involvement of institutions at different levels, associations, technicians and experts, various types of public associations (neighborhood committees; social, religious or ethnic groups; NGOs, environmental organizations, territory-linked institutions, etc.) and individuals. A key role in the participation process is that of the "facilitator" (formal or informal leader) whose function is to facilitate communication between the parties involved. The facilitators' role is limited to explaining the scope of the debate and guaranteeing that it will not be polarized or monopolized, giving an opportunity to all parties involved to express their points of view and understand one another, also providing help with difficulties related to the use of technical language. The main stakeholders in these processes are the communities and the teams of engineers. Workshops are conducted through which both parties present the way in which they see the problem and how they would tackle it. As a result of these discussions a portfolio of technological solutions is prepared which is evaluated at the laboratories of the universities. These technologies are implemented and improved upon thanks to the feedback obtained from the results and the community's experience.

The Role of Engineers Without Borders

The implementation of these projects is carried out by the communities and groups of engineering professors and engineering students. These alliances or teams of engineers are often called Engineers Without Borders or similar non-profit organizations which work toward the improvement of the quality of life of disadvantaged communities through education and implementation of sustainable engineering projects (EWB-International 2009).

Particularly, the mission of EWB Milano and Colombia is focused on two main fields: Education & Formation and Technology Migration. In this framework, both groups have established the following aims: (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 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, and (6) develop knowledge through the interaction and feedback between the community and the engineers.

The synergy between worlds (technical and community), the constant feedback and the search for the emergence of solutions as a result of an integration process make the methodology of EWB Colombia and Italy systemic.

The Role of the Community

One of the main stakeholders is those directly benefited by the results of the design and implementation of engineering: the communities.

The role of the community in this process is very important. From their relationships with students, emerging properties can be observed such as the generation of trust, application of knowledge and knowledge synergies. Regarding the trust built, the necessity to share between students and teachers is observed in order to achieve success in the engineering process. Regarding knowledge, integration between the community's local knowledge and the university's technical knowledge is observed.

The communities directly identify their needs and during the different stages of the process they are contributing to the accomplishment of the desired results. As such, it is

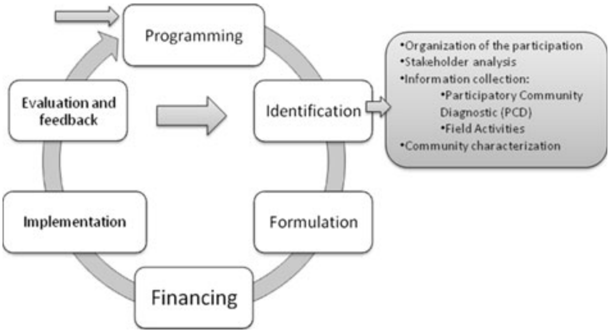

Fig. 1 Integration of participation in the project cycle

necessary to identify those that will be direct beneficiaries of the technology, the different community leaders and the relationships between them and the local entities.

How the Community and the Engineers Got to Work Together: Our Proposed Methodology

As in any engineering process, a project that offers a real and lasting solution to a specific problem requires careful planning, in accordance to what is called the "project cycle". As a result, it might be useful to elaborate a brief guideline for the integration of participation (Fig. 1) within the deadlines established for each stage of the project cycle (programming, identification, formulation, financing, implementation, evaluation). Each case-study is described according to this methodology. As the detailed review of the project cycle is beyond the scope of this paper, we present a brief of the stages so the reader can fully understand the case-studies presented in the following section and the proposed methodology. There is plenty of information available for literature review if the reader should have any questions.

The community's participation is implicit throughout the entire process. The constant dialogue with the local population allows information and knowledge to flow in directions, allowing for a better description and understanding of the problematic situation and the emergence of more appropriate solutions thanks to the feedback between technical and empirical knowledge. The diagram shown below explicitly shows the involvement of the population in every stage of the participative process, which helps design solutions that are better adjusted to the needs and characteristics of the community (Fig. 2).

Case-Studies: Main Results in Congo and Colombia

In this section, two case-studies of Engineers without borders in Europe and South America are presented, where the proposed methodology is applied to water management.

Italy—Africa

In the Congo, the project started in 2005 with a request for cooperation made by Father Silvano Ruaro, an Italian missionary who has worked in the town of Mambasa (in the

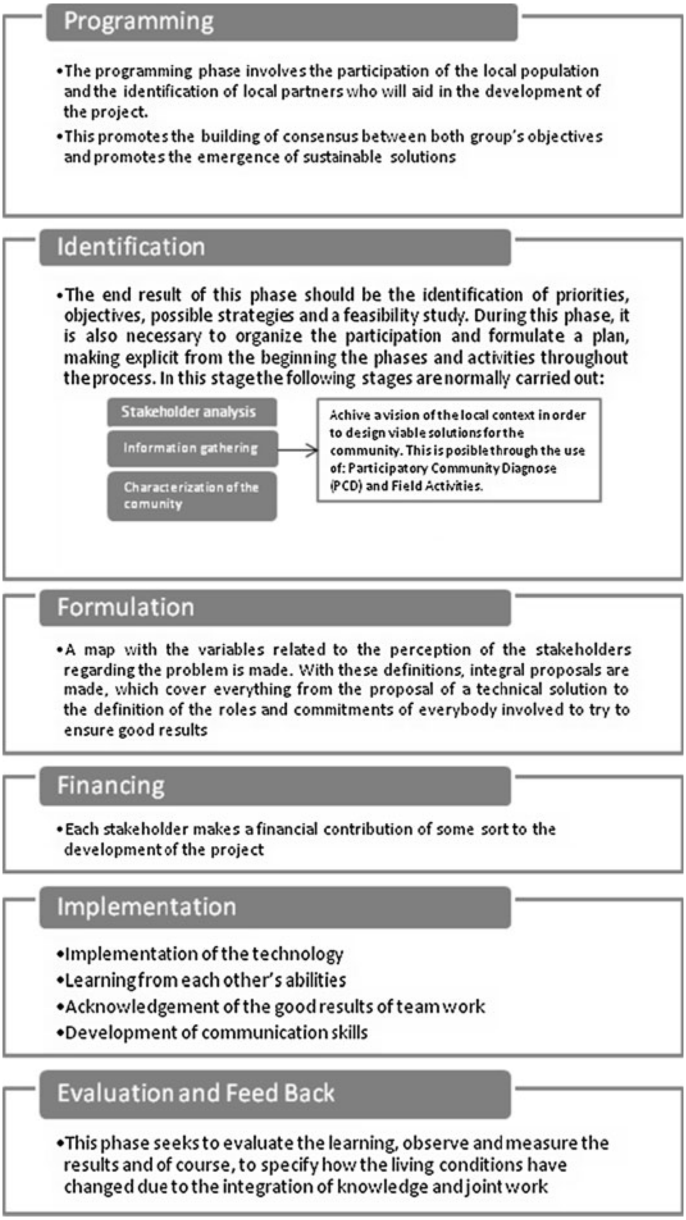

Fig. 2 Phases of the proposed methodology

North East of the Democratic Republic of Congo) for over 40 years, to Engineering Without Borders-Milan (EWB-MI) and Veterinarians Without Borders-Italy (SIVtro-I). So far, SIVtro-I and EWB-MI have completed 4 missions between December 2006 and August 2008. During these missions, the involvement and collaboration among SIVtro-I, EWB-MI and the local population has aimed to understand and define the social, economic and health aspects. The methodologies used were designed to carry out a joint analysis between EWB-MI, SIVtro-I, the local partners, the project beneficiaries and the local institutions, in order to obtain a complete picture of the problems that develop within a complex reality.

Participative Process

The choice of action in the field, as well as the design and conduction of all the activities by EWB-MI, was the result of an actual process of listening and confrontation with the local population and its institutions. The complex process from conception to implementation of the initiative was conducted with the culture and traditions of the local community in mind. To ensure the direct implication of all beneficiaries a strong network with local partners was created, represented by the Club of teachers for the Initiation of Youth Development (C.P.I.J.D[1]) of Mambasa, the hospital and the territorial local institution. Meetings were held with the population during the different stages of the project to obtain feedback from the community and make the necessary adjustments, confronting different points of view in order to try to build a shared vision of the problem, its solution and the way in which it should be implemented. The community facilitators, represented by some members of the club of teachers, helped a great deal in the confrontation process and discussion of the project with the local population.

Programming The Mambasa project plan has set the general objectives of contributing to the sustainable development of the socioeconomic conditions of the community through better management of water resources (specific objective of EWB-MI) and of achieving greater food security (specific objective of SIVtro-I). During the programming phase, at the beginning of the collaboration between the European partners (EWB-MI and SIVtro-I) and locals, information regarding the political situation (1965–2008), population, poverty, water resource management and exploitation of natural resources in the DRC was collected.

Identification This stage of the participatory process was structured around some key stakeholders, in order to properly represent the different interests at stake: the Working Group was initially formed by two engineers from EWB-MI, Father Silvano, the hospital physician, teachers of the Club and the Water Committees comprised of user representatives from different water points (which was better formalized during a later stage at the end of the socioeconomic and environmental analysis). The Water Committees are associations of water users already present in the territory, during the project others have been created and they have been the direct beneficiaries of training. Broad participation was also established during all phases of the project through a stakeholder analysis and their involvement. This analysis begins by identifying the problem (Phase 1) where EWB-MI and the community identify the poor management of water. In the second Phase the stakeholders are identified as: the population, farmer's cooperatives, women's cooperatives, the Ministry of Agriculture, the Teachers' Club, the Women's Club, Politecnico di Milano, religious missions (local partners), EWB-MI and SIVtro-I (executors) and the Veneto region (donor). In Phase 3 it is established that stakeholders should be involved through various activities such as participatory rural days, questionnaires, focus groups and at all stages of project implementation and monitoring. Like all other stakeholders, the

[1] Club de Professeurs pour l'Initiation de la Jeunesse au Développement.

Congolese government should be involved in the project's development to improve its chances of success, particularly in an area like the Congo where the government isn't entirely stable. Unfortunately, the Congolese government has not cooperated as the group would like.

A participation strategy was adopted to involve the population in training courses and meetings between the committees and the Working Group. The involvement of stakeholders has allowed the understanding of the interests (Phase 4) of the beneficiaries, who have shown a strong interest in the health and hygiene issues identified by EWB-MI and the issue of food safety underlined by SIVtro-I together with the community, and a constructive willingness to change current management and production practices. The last phase (Phase 5) of the analysis was conducted on the importance and influence of stakeholders, emphasizing the role of local institutions. In developing countries, this can be problematic, because sometimes the institutions may be fragile and do not cooperate fully. The most important stakeholders are, however, direct beneficiaries whose problems, needs and interests coincide with the objective of the project's implementation, which, as was said previously, are representative of the interests and needs of the community. The data collection phase was conducted in the form of Participatory Rural Diagnostic (PRD) and integrated campaigns for data collection, during the three missions that took place during 2006–2007. In Congo, the DRP project was conducted by organizing meetings with the entire population and inhabitants of each district. Tools like "talking maps" provided visual information on the conformation of the territory and the arrangement of items such as neighborhoods, streets, hospitals, farms, and wells. Another important area of focus for the debate was the analysis of the social, economic and health situations, which revealed that problems are perceived differently by different stakeholders (e.g. women of the village and administrative institutions). These were framed in the PRD with field activities to which the public was invited, questionnaires and interviews with executives from the wells. Subsequently, the population participated in organizing field tests to collect data on water quality (measures necessary for the development of the evaluation phase). The field activity was conducted with quantitative and qualitative analysis tools, such as: interviews which focused on local contacts; questionnaires to collect information from each water source; focus groups at the household level, questionnaires to doctors hospital of Mambasa; analysis of water and soil quality and direct observation of water point construction techniques, maintenance practices and wastewater management.

In total, 21 water points in the village participated in interviews and quality analysis. These water points form a circle around the two hills on which the village stands, allowing quick access for women in each district and are located in the lowest depressions, because it is easier to find water there. From our investigations on the population, access and characteristics of the water, we estimated an availability of about 15–30 l/day/person, depending on the season and type of water point. Here are some results of the interviews addressed to the population and the technical analysis (Figs. 3, 4):

After the socioeconomic, environmental and water resource analysis, it was possible to identify representatives from the Water committees who, after being legitimized before the whole town, would be responsible for the tasks recommended by the Working Group. Taking into account the analysis of the social, economic and health context and the data obtained to date, it has been possible to identify weaknesses, strengths, threats and opportunities in the socio-economic development of the village of Mambasa. The SWOT analysis carried out by the Working Group informs the population and prepares them for exchange and discussion. It is not evident that the vision of the context, which arises from an analysis of the information, corresponds to the perception of the individuals involved,

Fig. 3 Water points surveyed in Mambasa

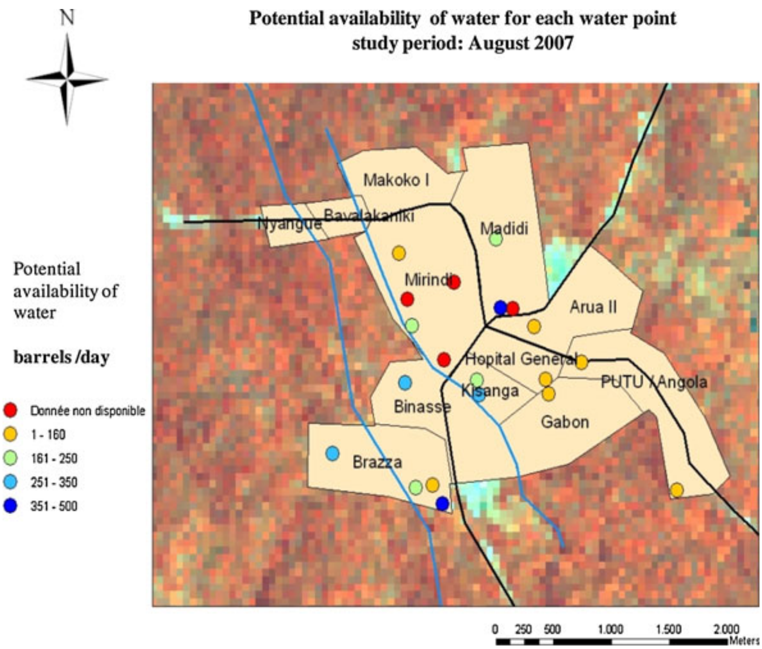

Fig. 4 Potential availability of water for each water point, calculated as barrel/day based on interviews with population

even though it is primarily based on information obtained from the population itself. In the case of Mambasa, the SWOT analysis has helped to identify weaknesses according to three macro themes: health problems, social problems and economic problems. It also revealed a difference in situations perceived by village women, the Community and the hospital in connection with the theme "health problems".

A survey carried out with the doctors of the small local hospital has highlighted the many diseases from which people suffer, most of which are caused by the lack of microbiologically-safe water and spread by the lack of hygiene. In a 3 month period, 1.694 people were attended in the hospital: 173 suffered of diarrhea or other water-related illness, 26% (with the exclusion of malaria-related illness), that is 29% if only children under 5 years are considered, though much more people in Mambasa could suffer of water-related illness (Table 1).

The SWOT analysis has helped build a problem tree with cause and effect relationships that relate to all major macro themes. However, the problem tree does not explicitly indicate the relationship between poverty and low agricultural production; low profitability of agriculture and trade, and, indeed, these factors could be linked to form the so-called vicious circle of poverty (poverty → low savings and low efficiency of investments → low rates of productivity and growth → poverty). The analysis has highlighted the need to improve the management of water resources (lack of access to water and poor water quality) and the low profitability of agriculture: the solution of these problems, which coincides with the specific objectives of EWB-MI and SIVtro-I, could help break the cycle of poverty and initiate a process of development and growth.

The quantity and quality of water depend strongly on the season and constructive typology. During the dry season all constructive solutions suffer a significant reduction in the amount of extractable water; in some cases the type (d) is completely dry. During the rainy season quality degrades quickly as the water points are not adequately protected from soil contamination and surface runoff. In some cases, the type (d) is practically flooded with contaminated water in the area underlying pipes (Fig. 5).

Formulation Having highlighted in the identification phase, the fact that health problems and water resources are strongly linked to the population's inadequate training (problem tree), two strategies have been identified for the management of water resources in the project; the awareness of health concerns and management of water resources and the technical training of local staff in hand with the parallel creation of new wells with lift pumps. To succeed, it is very important to create an institutional link between government, citizens and hospitals in good water use practices.

A previous feasibility study of technical systems (pumps, latrines and water purification systems) was made with the Club of teachers for the introduction of youth development of Mambasa and Politecnico di Milano, considering factors such as ease of construction, using easily acquirable or locally available materials and ease of management, preferring

Table 1 Incidence levels of diseases linked to water quality (Hospital of Mambasa 2007)

Pathologies linked to poor diet		*Diseases linked to water*		Tropical diseases		Pathologies associated with sexual transmission and poor hygiene		Other diseases	
Malnutrition	+++	*Intestinal diseases*	+++	Malaria	++++	HIV/AIDS	++	Respiratory infections	++++
Anemia	++	*Typhus*	+++	Filiariasis	+	Venereal diseases	++	Hospital infections	+
		Diarrhea and enteritis	+++	Anemia	+++	Infections to urogenital apparatus	++		

Fig. 5 Constructive typologies of water points

technologies that do not require special handling or complex controls for their adequate and continuous operation. The most used drinking water technology in developing countries, because it meets the above requirements, is slow filtration (Antonelli et al. 2008). It was nevertheless decided to proceed in stages, initially offering a limited group of people slow filtration systems appropriate for the size of each group, which can be made by them, with intermittent feeding operation. The experience of this group of people has served to assess the degree of acceptance of the technology, identify management problems and to show real improvement in water quality. The first pilot experiments have been useful in explaining and showing to the population the specific benefits of these treatment systems and have provided invaluable feedback from the population regarding the technologies, methodologies and joint work. The success of this step, supported by the degree of sustainability from different points of view (acceptance, proper and adequate management by user, ease of understanding, use and maintenance), have lead to the construction and delivery of slow filtration systems for coupling to different water supplies.

Regarding the choice of type of construction of new wells, the decision was taken by the population once it was proved that a better water system could be made. EWB-MI promoted the study, conducted by local engineers of teachers' Club, and proposed a fast and cheap drilling method. The conditions of the clay and sandy soil enabled the application of a drilling technique that uses only local materials and labor. It is important to point out that every choice regarding field work has been made with the involvement of the local population.

Financing The financing for the development of the project in the Congo was provided mainly by a private bank and the local administration of the Veneto Region. These two institutions provided approximately 60 k € (30 k € each) in funding and carried out communication activities in Italy. The group of engineers used this money to finance all project related activities and thanks to the amount has been able to implement the project on a considerable scale with a large number of beneficiaries and tangible improvements in the management of water resources through simple technological solutions.

Implementation This phase has provided from April 2008 to August 2009 the following activities:

1. Training
   - Training of 10 local technicians on the construction and maintenance of different types of drinking water points (springs, wells, etc.).
   - Constitution and training of Water Committees to enable the community to technically and economically manage the facilities in their area (training of approximately 50 people during 20 days).
   - Improvement of the awareness of 500 households on the theme of sanitation and personal hygiene at home.
2. Construction/Facilities
   - Construction of 6 wells equipped with hand pumps (1 installed, 5 self installed by local technicians).
   - Redevelopment of the wells of the General Hospital.
   - Installing the software platform for wireless monitoring of cooperatives (production, diseases, health management and economic performance, etc.) and water points (production, quality, economic management, performance, etc.) (Fig. 6).

Evaluation and Feedback The use of Information and Communication Technologies (ICT) in developing countries can facilitate the development process (documents found on the Internet can be a valuable support in medicine, health and technology). This instrument was used in the Congo project for this purpose and to facilitate, among other things, the communication between Mambasa and EWB-MI in Italy and to allow the evaluation and monitoring of the progress of the project. Moreover in February 2010 an assessment mission of the project was carried out. The mission analysis showed that the population manages autonomously new wells, is satisfied with the results of the project and is planning to build more wells.

Main Results The main project results which are focused on the impact of the proposed methodology on the stakeholders involved are:

– 10,000 people (almost 30% of the population of Mambasa) have better access to water (quality and quantity) thanks to six new drilled wells
– 10 local engineers are able to build wells independently.

Fig. 6 Training moments, stages of construction of wells and filters

- 10 Management Committees have a better capacity for mobilization and management of water points, thanks to the training received.
- 5 management committees are achieving total economic sustainability for the maintaining of the wells, with more than 1.000 $ in their cash, earned by selling water at prices accessible to all (10–20 FC per container, depending on quality).
- 500 families live in better hygiene conditions, thanks to the awareness raising campaign conducted.

Table 2 shows the impact of the project on the nine communities. As shown, the number of direct beneficiaries involved/satisfied by the self-installed wells is very high. These results highlight the fundamental role of the methodology applied and its sustainability. Indeed after the first well was installed by the local working group with the collaboration of EWB-MI members, another five wells were built without any external technical support, management or maintenance.

Colombia—Colombia

The Universidad de los Andes and the Corporación Universitaria Minuto de Dios have been leading a community work project in the field of engineering called Community

Table 2 Impact of improved wells in the Mambasa Project

	Installed	Self installed	Total
Wells	1	5	6
Direct Benieficaries satisfied	11%	56%	67%

Innovation Project (CIP). Inspired by the international organization Engineers Without Borders (EWB-ISF), a group of teachers and students of industrial, civil, environmental and chemical engineering have been conceiving, designing and implementing technologies in vulnerable communities in Colombia where water conditions are not the best.

This preliminary design phase of social intervention in engineering has been developed in the Torres district, attached to the municipality of Guayabal de Síquima, 150 km from Bogotá. In this area, the group has been working with the mayor, UMATA, the community and students and teachers from the two engineering schools involved. Through the development of diagnostic, technical tests, joint work with the community and a basic understanding of their needs, the group has designed an appropriate solution supported by an existing technology related to slow sand filters to improve water conditions in the area.

Participative Process

EWB-Col has been worried about the living conditions in many communities around the country due to the poor quality of drinking water. With this in mind, the group began searching for a community which could be a suitable candidate to work with in the improvement of water quality. In the Torres district, a community was identified which expressed its interest in working together with the team of engineers in the joint development of technologies for the improvement of the water conditions, which were tailored to their specific economic and socio-cultural characteristics. During the entire process the community played an active role. In fact, the community's leader, who had been managing and administrating the aqueduct, helped the team to understand the main problems associated to the water resource, and personally introduced the team in each of the homes (Fig. 7).

After this first impression of the community's problems, a meeting with its inhabitants was planned in order to identify people interested in working on the design and monitoring of the water improvement systems. From this moment on, groups of engineers and

Fig. 7 Introduction between the community and EWB-Col (students, professors, community)

inhabitants of the community were formed to specify the characteristics of the filters to be implemented. Approximately every 15 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 socialized 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 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.

Aside from working with the community, EWB Colombia also worked together with the mayor and an employee from the UMATA[2] 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 this participatory methodology. 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. Paula González, an industrial engineering student says that, even though it has not been easy to understand each member's participation, her work has been very beneficial as it has developed communication skills, teamwork and integration. For teachers of engineering, it has been a potentializer to design more clearly their engineering courses, particularly those of final semesters.[3]

The selection of the community, technology and design of methodologies were the result of a dialogue with the community and 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.

Programming The main objective of CIP has been to improve the quality of life in vulnerable communities through the improvement of water resources. During the programming of the project, first-hand information about the main characteristics (economic, political, socio-cultural and geographical) of the community was collected, through visits

[2] Unidad Médica de Asistencia Técnica Agropecuaria (Medical Unit of Agricultural Technical Assistance).

[3] To see the info-video enter the following link: http://www.youtube.com/watch?v=_WnLmV5beWY&feature=channel.

and cooperation with an employee of the UMATA. Before this, the group gathered information on the general situation and on Colombia's capacity to manage water resources, its quality and availability, with emphasis on rural communities. This information was used to develop a comprehensive picture of the situation in the country and the problems related to the quality and availability of water specifically in rural areas. With this information, and its discussion and validation with the members of the community the team of engineers was able to begin designing sustainable solutions based on the population's needs, characteristics and input…. For example, 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.

Identification During the identification phase, 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 to group to adjust the initial proposal based on the community's feedback, resulting in a more appropriate and productive solution (Fig. 8).

The analysis begins with the identification of the problem (Phase 1). EWB-Colombia and the population identified the problem associated with the quality of water used for human consumption. The stakeholders identified in Phase 2 are: the inhabitants of the

Fig. 8 Training workshop held in Torres regarding the maintenance of the filters

community, EWB-Colombia, Universidad de los Andes, Universidad Minuto de Dios, the directors and employees of the district's aqueduct and the mayor of Guayabal de Síquima. Phase 3 of the project consists in the involvement of stakeholders through various activities organized by EWB-Colombia, which include 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. Through the development of the project, the community's participation and cooperation has been achieved as well as a good level of appropriation of the technology and independence in the use of the filter. 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.

The involvement of the stakeholders has enabled the group to understand and identify local interests (Phase 4) such as the interest in the management of water resources proposed by EWB-Colombia. During the last phase (Phase 5) an analysis of the importance and influence of stakeholders on the development of the project was carried out. In particular, it is worth highlighting the interest of some community members in gaining support from EWB-Colombia during talks with politicians and in getting support in the improvement of the aqueduct and water supply in search for longer term solutions. The data collection phase was carried out during visits and interviews with people with previous experience working within the community allowing the group to revise initial suppositions 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 and between it and EWB-Col regarding the scope of the project, its aims and technical details.

Formulation Two strategies have been 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 has 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 and seeking new communities which might suffer from poor water quality and be willing to work together with the group in order to develop joint solutions. The group has 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 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.

In the case of Torres, 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. The group began with a pilot project in which four families cooperated, and later, with 10 additional families after having verified the effectiveness of the filters and their cultural suitability. 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. At present there is a high degree 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. The training workshops have had the desired results as they have led to gradual changes in the community's habits; the filters are being managed by the members of each household with excellent results and minimal need of intervention from the group of engineers. The work with the community and their involvement in the development and implementation processes have helped establish trust and mutually beneficial relationship which opens up future cooperation possibilities.

Financing The financing will vary depending on the community's context and the characteristics of the group of participating engineers but in general terms, in Colombia, 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. Each stakeholder makes 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; the teachers and students make a commitment to invest in research; 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 ownership and empowerment.

Implementation The development of this phase is extremely important as it involves the actual implementation of the solutions with the community and provides an excellent opportunity for both parties to learn from actual experience. In the Torres district, EWB-Col worked together with the local population in order to install the filters in each home. Students, teachers and members from each household participated in setting up the pipes, putting together the filter and whenever necessary, building a base to put it on. Last but not least, the team of engineers carried out training sessions to teach the community how to perform routine maintenance on the filters and to improve awareness regarding the importance of basic hygiene practices which should be followed in order to decrease gastrointestinal diseases. Specifically, during this phase the following results were achieved:

- Implementation of the technology.
- Learning from each other's abilities.
- Acknowledgement of the good results of team work.
- Development of communication skills.

Evaluation and Feedback The development of the project must be evaluated continuously and feedback must be shared between all the stakeholders. This phase seeks to evaluate the learning, observe and measure the results and of course, to specify how the

Table 3 Stakeholders involved the Torres District Project

Stakeholders involved		
Institution	Population	EWBColombia
Guayabal de Siquima Mayor UMATA	30 Families	5 teachers 6 sludenls

Table 4 Impact of slow sand filter's installation in the Torres District Project

	Installed	Seif installed	Total
Slow sand filter	4	I0	6
Direct beriefficaries satisfi ed	24%	59%	83%

living conditions have changed due to the integration of knowledge and joint work with the community. This evaluation process will help the team of engineers and the community to identify problems in the implementation of the project and make the necessary adjustments, learn from each other, learn from their mistakes and identify opportunities for both the current and future projects. In Torres, the group of engineers has been monitoring the continuation of the project and has observed that the local population has been able to appropriate the technology and make good use of the filters in an independent and autonomous manner.

Main Results Table 3 presents the project results focused on the impact of the proposed methodology on the stakeholders involved:

In Table 4, the number of direct beneficiaries involved/satisfied by the self-installed filters is very high. These results highlight the fundamental role of the methodology applied and its sustainability. Indeed after installation of the first four filters by the local working group with the collaboration of EWB-Colombia members, a further ten filters were built without any external technical external support, management or maintenance.

Conclusions

We would like to point out that in countries like Colombian and Congo mortality due to poor water conditions reaches very high levels (especially in children). Without doubt, vulnerable populations face many problems regarding their basic necessities, the access to safe drinking water being one of the worst. The intervention of government entities has not been sufficient to address these issues. Our proposal's unique contribution consists of achieving the participation of communities, local entities and universities to propose viable technological solutions that truly improve the living conditions of many. Also, the participation of students and teachers in this type of activities can generate learning which can be replicated. In this way, we are not only generating knowledge but also enabling the formation of future professionals that despite a technical emphasis have a solid formation in global issues which require everybody's active participation.

We are convinced that the systemic proposal which the group of Engineers Without Borders aims to achieve enables the emergence of favorable properties both in the satisfaction of a vulnerable community's basic needs and the formation of communities and students with a level of autonomy which allows them to face difficult problems and propose effective solution alternatives.

Participation and ownership are fundamental to ensuring the relevance, effectiveness and sustainability of this type of projects. The quality of the dialogue with partner countries is a key in establishing effective development cooperation policies and their successful implementation. Partnership and ownership of development processes by the target population, and strengthening of institutional and administrative capacity to effectively manage change, are principles which are now largely shared by all donors.

In participatory projects in vulnerable communities in developing countries, it is essential to involve the community's inhabitants and clearly identify the stakeholders to try to ensure compatibility with the specific characteristics of the problem and the community in an effort to ensure sustainability of the project in the long term. It is also necessary to develop an understanding of the main socioeconomic, cultural, environmental and political characteristics of the region to design solutions and implementation and management plans jointly with the community and actively involve them in the process, taking advantage of their knowledge and experience. The systemic methodology was appropriate in the case-studies because, through the community's and students-professors participation in the activities related to the identification of the problem, definition of the objectives, field research and implementation of technologies, a solution was generated which responded to the area's socio-cultural and economic characteristics, thus promoting sustainability and efficient usage of resources in the future. Besides the generation of knowledge, the methodology of EWB is effective because it takes into account the specific characteristics and needs of the community and translates this into the implementation of more sensible solutions that usually have much better reception and promote empowerment by the target population thanks to their active involvement throughout the entire process.

The use of methodologies that involve the community and the students-professors in the various project planning cycles have better results because they enable the generation of more productive proposals for each community, the identification of real problems regarding water resources, the understanding of the community's perceptions regarding water use; and once a proposal has been made, the community provides the researchers with feedback that will eventually allow necessary modifications to be made in order for the project to respond to their specific requirements and lifestyle. The active involvement of the community promotes a sense of ownership and compromise which improve the chances of the project being sustainable in the long term and its autonomous management by the local population.

In each case-study, the identification phase is of vital importance as the information collected, either orally or through different survey means, enables the elaboration of a map to understand the functioning of the community, its social, economic, demographic and cultural characteristics which allows the team to see the different relationships and determine the necessary modifications to the standard participatory methodology. This avoids the implementation of proposals which are incompatible with the community's characteristics.

This interdisciplinary cooperation between universities and local actors seeks to design intervention projects with an organizational structure where the stakeholders have a clearly defined role. Given the nature of projects, the research and experience of communities and universities is fundamental, to adapt appropriate technologies that respond to the real needs of the context.

With regard to the results, it is important to highlight the fact that the communities were involved in such a way that they managed to replicate the technologies brought by the

EWB groups. In the Colombian case, the guidance of the community leader was of great importance, thanks to him the filters are still functioning. In the Mambasa case, the community developed a management system that allows a follow-up from Italy, so the engineers can monitor the progress and condition of the wells. In both cases, the inhabitants were trained in the operation of the technologies. Also, the joint learning processes, between the EWB groups and the communities, have led to the adjustments of the participatory methodologies and allowed the engineering students and teachers to gain knowledge and experience in the development of this type of projects, where the communities are not mere beneficiaries, but also active participants in the decision making process, implementation and management of the solutions.

We hope that the learning of this methodology and the results of EWB in Colombia and Mambasa become a generator of technical and human knowledge which contribute to the solution of the complex problems faced by today's world.

References

Antonelli M, Bengo I, Malpei F, Di Pasquale G, Pileri P (2008) Gestione delle acque nel villaggio di Mambasa (RDC). Politecnico di Milano (DIIAR), Ingegneria Senza Frontiere Milano

Bodorkós B, Pataki G (2009) Linking academic and local knowledge: community-based research and service learning for sustainable rural development in Hungary. J Cleaner Prod 17:1123–1131

Brikké F, Bredero M (2003) Selecting an appropriate technology for water supply projects. Linking technology choice with operation and maintenance in the context of community water supply and sanitation: a reference document for planners and project staff. WHO and IRC, Geneva

EWB-International (2009) About EWBI. Recovered on 2 de April of 2010, from Engineers Without Borders International: http://ewb-international.org/about.htm

Frölich U, Wehrle K, Niederer S (2001) Series of manuals on drinking water supply: management guide, vol 1. SKAT, Suiza

Mambasa Hospital (August 2007) Mambasa Hospital bulletin

Martin A, Sherington J (1996) Participatory research methods-implementation, effectiveness and institutional context. Agric Syst 55(2):195–216

Moser S, Mosler H-J (2008) Differences in influence patterns between groups predicting the adoption of solar disinfection technology for drinking water in Bolivia. Soc Sci Med 67:497–504

Nyong AO, Kanaroglou PS (1999) Domestic water use in rural semiarid Africa: a case study of Katarko village in northeastern Nigeria. Hum Ecol 27(4):537–555

Prokopy LS (2005) The relationship between participation and projects outcomes: evidence from rural water supply projects in India. World Dev 33(11):1801–1819

Roa García CE, Brown S (2009) Assessing water use and quality through youth participatory research in a rural Andean watershed. J Environ Manage 90:3040–3047

Schaap W, Nandi SS (2005) Beyond PRA: experiments in facilitating local action on water management. Dev Pract 15(5):643–654

UNDP (2006) Water rights and wrongs: a young people's summary of the United Nations Development Report 2006 Beyond Scarcity: Power, poverty, and the global water crisis. Recovered on November 8, 2009 from: http://hdr.undp.org/en/media/water_rights_and_wrongs_english.pdf

United Nations (July 2, 2009b) Economic and Social Council: achieving the internationally agreed development goals on water and sanitation. Recovered on July 2010 from: http://www.un.org/en/ecosoc/docs/pdfs/08%20Background%20Note%20Water%20Sanitation%209%20June.pdf

United Nations (March 16, 2009a) The third United Nations world water development report: Water in a changing world. Recovered on September 2009 from: http://www.unesco.org/water/wwap/wwdr/wwdr3/tableofcontents.shtml

UNPFA Colombia. Objetivos de desarrollo del milenio. (s.f). Recovered on September 20 2009 from: http://colombia.unfpa.org/metasdelmilenio.htm

World Bank (2002) Tasa de crecimiento Poblacional. Recovered on January 12 2010 from: http://www.worldbank.org/depweb/spanish/modules/social/pgr/index.html