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Development of a water filtration system using design thinking for Social Innovation in San Cristobal, Galapagos-Ecuador

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RESUMEN

Las innovación social propone nuevas prácticas e instrumentos con el fin de satisfacer necesidades sociales y de generar el bienestar de las personas. La falta de proyectos de innovación social en Latinoamérica constituye una limitación para el desarrollo social en la región, motivo por el cual se necesita más investigación sobre este tema.
La problemática del agua es algo que se encuentra latente a nivel mundial. Las islas Galápagos han tenido dificultades históricamente con el acceso y la confianza en el agua potable y la comunidad de El Progreso en San Cristóbal se ve afectada también por esto. Previos estudios han demostrado que la calidad de agua en Galápagos ha disminuido a la par del crecimiento poblacional e incremento del turismo. Análisis previos tanto de las fuentes de agua como del agua potable en San Cristóbal muestran que las medidas de los parámetros físico-químicos cumplen con la legislación ecuatoriana y con las guías de la OMS para agua potable, mientras que los parámetros microbiológicos no cumplen con la legislación ecuatoriana ni con las guías de la OMS en los dos casos.
Para trabajar esta problemática se toma una metodología de innovación social que nos permita dar una mejor solución a un problema también técnico, utilizando design thinking. El pensamiento de diseño o design thinking es una metodología centrada en el usuario que se enfoca en la resolución de problemas sociales a través de diferentes etapas. En este estudio, la metodología del pensamiento de diseño es empleada con el fin de dar solución a problemas relacionados con el acceso y la confianza en el agua potable en una comunidad rural. Este artículo discute la aplicación de la metodología de design thinking y sus fases: inspiración, ideación e implementación en el desarrollo de un sistema de filtración de agua potable en la comunidad de El Progreso en San Cristóbal, Galápagos. El sistema de filtración fue diseñado para cumplir con las características físico-químicas y microbiológicas dictadas por la normativa ecuatoriana INEN y las Guías de la OMS para agua potable, además de ser de fácil instalación y réplica para la comunidad, razón por la cual, la tecnología desarrollada por la compañía NanoCeram fue adoptada a través de la instalación de sus filtros como parte del sistema. En este reporte se muestran los resultados del análisis del agua en la comunidad realizados antes y después de la instalación del filtro. El problema más importante encontrado en el agua de El Progreso fue la presencia de coliformes totales, los cuales fueron removidos del agua con un porcentaje del 67 al 100% gracias a los filtros instalados. Finalmente se presenta la satisfacción de la comunidad con esta solución en base a la metodología de design thinking empleada.

Palabras clave: Innovación social, pensamiento de diseño, desarrollo rural, diseño centrado en el usuario, acceso a agua potable, filtros de agua.

ABSTRACT

Social innovation proposes new practices and instruments that aim to meet social needs and generate people's well-being. The lack of social innovations projects in Latin America consists in a limitation for social development in the region; so further investigation on social innovation is needed. The water problems are something that is latent worldwide. The Galapagos Islands have historically struggled with access and confidence in drinking water and this also affects the community of El Progreso in San Cristobal. Previous studies have shown that water quality in Galapagos has declined along with population growth and tourism growth. Preliminary analyzes of both water sources and drinking water in San Cristobal, shows that physical-chemical parameters measurements comply with Ecuadorian legislation and with OMS guidelines for drinking water, while microbiological parameters do not comply with Ecuadorian legislation nor with the OMS guidelines in both cases.

To work on this problem, a methodology of social innovation is applied to allow us give a better solution to a technical problem, using design thinking. Design thinking is a human-centered methodology focused on solving social problems through different stages. In this study, the design thinking methodology is employed to solve problems related to potable water access and trust in a rural community. This article discusses the design thinking methodology and its phases: inspiration, ideation, and implementation, through the development of a water filtration system in the community of El Progreso in San Cristobal, Galapagos. The filtration system was designed with the physical-chemical and microbiological characteristics dictated by the Ecuadorian legislation INEN and the WHO guidelines for drinking water. It also had to be of simple installation and replication for the community. For this reason, the Technology developed by the company NanoCeram was adopted through the installation of its filters as part of the system. This report shows the results of the water analysis of the community before and after filter installation. The most important problem found in El Progreso's water was the presence of total coliforms, which were removed from the water with a percentage removal range from 67 to 100% due to the filters installed. Finally the community satisfaction with the solution on the based on the design thinking methodology used is presented.

Key words: Social innovation, design thinking, rural development, human-centered design, potable water access, water filters.

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1. Introduction

The term ¨Social Innovation¨ (SI) has been gaining popularity worldwide in the last years; however, sometimes it is used inaccurately as a buzzword (Neumeier, 2012). There are different concepts defining social innovation, for example, the Centre de Recherche sur les Innovations Sociales (2004) has established that SI consists of a new way of doing things involving new social practices, mechanisms, approaches and concepts that produce specific achievements and improvements (CRISES, 2004). Along with the CRISES concept, Goldenberg (2004) defines SI as a process of development and application of enhanced activities, initiatives, processes, services or products designed to solve social and economic difficulties experienced by communities and individuals (Goldenberg, 2004). Likewise, several studies also refer to SI as a process of development of new ideas, concepts and strategies in order to meet social needs and to achieve social well-being creating changes on the social systems (Cahill 2010; Dawson and Daniel, 2010; Hubert, 2010; Taylor, 1970).

According to Neumeier (2012), numerous authors suggest that SI could be an important factor on the development of rural areas, (Häußermann and Siebel 1993, p. 223) so he presents an actor-oriented network approach as a possible methodological way to advance in rural development research (Neumeier, 2012). He also states that the Organization for Economic Co-operation and Development (OECD) remarks that there is limited information available from innovation surveys and that methods for measuring the role of human capital in innovation remain underdeveloped (OECD 2005, p. 43). In agreement to the OECD, Cajaiba-Santana (2014) stated that the idea of social innovation has been indeed underdeveloped and based on anecdotal evidence and case studies (Cajaiba-Santana, 2014). Edwards-Schachter and co-workers (2012) have suggested that collective action has a transformational potential that support "scaffolding" endeavors to accomplish social innovation (Edwards-Schachter, Matti, & Alcántara, 2012). "Scaffolding," described by Volckmann (2010) is a method that associates people in out of reach activities by promoting collaboration and exchanges throughout organizational or community boundaries (Volckmann, 2010). Therefore, rural development projects could be accomplished by using social innovations as novel social practices generated by collective, intended and goal-oriented activities that encourage social change from a different way of accomplish social goals (Cajaiba-Santana, 2014).

Even though the innovation environment is leading in developed countries, developing countries are also promoting innovation in their agendas. As stated by Hubert (2010), in both, developed and developing countries, the most important factor on their aid programs is social innovation because social organization is been threatened by new risks and inequalities (Hubert, 2010). Developing countries are the best location for human-centered social innovation projects as there are a lot of communities willing to solve their necessities and Latin America is no an exception. In the document ¨La Innovacion social en America Latina¨ (Social Innovation in Latin America), Buckland and Murillo (2014) present a wide picture of social innovation in Latin America including a vision of experts in SI in the region and a directory of platforms, investment funds, academic networks and publications from Latin America that promote the different initiatives of Social Innovation in this region (Buckland & Murillo, 2014). However, in this directory, there is no evidence of agencies or people working on SI in Ecuador, even less in the Galapagos Islands. Nevertheless, there is one published case of a social innovation project developed in Ecuador ¨El caso del Proyecto de Fe y Alegría para la educación inclusiva de niños con discapacidades en Ecuador¨ (Project for the inclusive education of children with disabilities in Ecuador) presented by the foundation Fe y Alegría in which they prompted an improvement in the educational performance of more than 230 children with disabilities in one of the poorest neighborhoods in one of Ecuador's most troubled cities, Santo Domingo, located at the province of Santo Domingo de los Tsachilas (Guaipatin & Humphreys, 2014).

One of the strategies used to promote social innovation projects is design thinking. Design thinking is a methodology that focuses on the idea of using human centered design in order to create a product or a service. The difference between design thinking and other design processes is that design thinking is a deeply human process since it involves human intuition, recognition of patterns and construction of ideas with emotional meanings in order to be functional (Brown & Wyatt, 2010). The process consists on a series of overlapping spaces without a necessity to be employed sequentially; therefore, projects may loop back to any of the spaces in order to refine ideas or search for new directions. These spaces are: *inspiration, ideation* and *implementation* (Brown & Wyatt, 2010). Kolodner and Willis (1996) defines Inspiration as the phase that tells designers what is relevant and what to focus on through the evolution of specifications and constraints of the problem, reinterpretation of ideas and reformulation of the problem when need it (Kolodner and Willis, 1996). In addition, they describe Ideation as the process that involves the understanding of the collected data, as well as the solution proposed and the remarks from the design environment, like feedback from tests with prototypes (Kolodner and Willis, 1996). Moreover, they also indicate that in the Implementation, the design team needs to make decisions over the procedure of the design thinking about the priorities, the elaboration or adaptation of ideas, and the solution of different tasks, subproblems and design processes in an adaptable way (Kolodner and Willis, 1996).

The project presented on this paper employed the design thinking methodology to solve water issues in San Cristobal. There are not many studies related to water quality on the Galapagos Islands (Ochoa-Herrera, Eskew, Overbey, Palermo, Peñafiel, & Moreno, 2014). In fact, there is no baseline information on the management and quality of the water from the supply sources, water for human consumption and for recreational use (Nivelo, 2015).

San Cristobal has three water sources: “Cerro Gato”, “El Platano” and “ La Toma”. The water is captured and directed to a water treatment plant for public supply, with flow rates of 10.5 L/s, 3 L/s and 8.5 L/s respectively. The treated water goes to the supply tanks and then to the distribution network according to López and Coworkers (2007). The Ecuadorian Secretaría Nacional de Planificación y Desarrollo (SENPLADES, for its words in Spanish) states that the public water network coverage for San Cristobal Island in the Galapagos is 89,9% (SENPLADES, 2014). The conduction line that leaves from each of the sources towards the treatment plant is made of PVC pipe of 6 inches and has a length of 16 km. In the last 2 km the pipe is 4 inches. Water issues in San Cristobal begin with infrastructure. Parts of the conduction line are exposed, jeopardizing water safety (López, Rueda, & Nagahama, 2007). Likewise, there are water losses in the distribution network due to defective connections, poor quality or deterioration of materials used in the joints, and network breakages because they are on the sidewalks, exposed to the traffic of people and vehicles (López, Rueda, & Nagahama, 2007).

The water quality in San Cristobal is measured with physical-chemical and microbiological parameters. According to Nivelo (2015), the physical-chemical measurements of the water sources from San Cristobal complies with the Ecuadorian legislation as well as with the Water Health Organization (WHO) regulations with the exception of turbidity for Cerro Gato and pH and Dissolved Oxygen (DO) for La Toma (Nivelo, 2015). In the case of microbiological parameters, San Cristobal's water sources show the presence of total coliforms as well as *E.coli* above the established on the Ecuadorian legislation and on the WHO regulations (Nivelo, 2015). Table 1 shows the physical-chemical and microbiological characterization of San Cristobal's water sources found in literature.

On the other hand, San Cristobal's drinking water follow the established physical-chemical parameters within the Ecuadorian and the WHO regulations (Nivelo, 2015); however, the microbiological measurements in drinking water show the presence of microbiological contaminants in some of the samples; despite this, the implementation of drinking water treatment plants resulted in a significant reduction of microbiological contaminants in the water; indicating that during the distribution and storage phase of the process the water quality deteriorates in microbiological aspects and presents a high temporal variation (Nivelo, 2015). Table 2 presents physical-chemical and microbiological analysis data of water samples for human consumption found in literature.

The case study described in this paper was executed in El Progreso, a rural community located in San Cristobal in the Galapagos Islands with a population of 700 people grouped in 200 families that receive water from the public water network. Water distributed by the public water network in El Progreso comes from a potable water treatment plant operating since September 2013 (CGREG, 2013). The treatment consists in sedimentation, coagulation, flocculation, filtration and chlorination. Raw water is taken in Cerro Gato and goes through pipelines to the plant were it enters to the first tank. In the first tank, the pH of the alkaline water is regulated with sodium salts; the turbidity is around 10-11 NTU. Later, aluminum polychloride is added to flocculate and sediment. After that, the water is filtered. The filters take 24 hours to be saturated and a backflushing procedure is performed to clean the filters. After filtration the water is disinfected with 1 mg/L of $Cl_{(gas)}$ and storage. There are two storage tanks, one of 300 m^3 and the other 500 m^3. 14 -20 L/s of water are treated. The plant has a daily control of pH, turbidity, TDS, conductivity and alkalinity. Other physical and chemical parameters are checked every three days, and biological parameters every six months. Internal maintenance (cleaning and painting the tanks) are performed every month and external maintenance every six months (A. Olaya, personal communication, 1 March 2016).

Since water is only distributed for two hours per day, people have the need to storage the water in PVC or concrete tanks, with a typical volume of 2000 L, in order to use it for daily consumption (G.A.D. El Progreso, 2015).

As reported by Guyot-Téphany and collaborators (2011) there are several studies dealing with water management in Galapagos from technical or natural sciences points of view, but there is a lack of a social analysis to understand water problem in its entirety (Guyot-Téphany, Grenier, & Orellana, 2011). According to the Millennium Development Goals Report (2015) there are 663 million people worldwide that still use unimproved sources of drinking water (UN, 2015) therefore the importance of the affordable access to safe and clean water as a human right has been increasingly recognized (Wimalawansa, 2013).

As stated by Wimalawansa (2013), new out-of-the- box methods are necessary because of the inaccuracy of the commonly used water systems (Wimalawansa, 2013). So as to drive the design process, a design challenge was established. The *design challenge* consists of explaining the mission in a sentence and defining a frame to guide the design process as well as going back to it during the reflection. In this case, the design challenge was "Improving the water experience in El Progreso". Therefore, the objective of this document is to present a social innovation case on the development of a water filtration system employing design thinking methodology in order to solve water problems in the community of El Progreso in San Cristobal, Galapagos, Ecuador and the lessons learned in the process.

2. Methodology

2.1 Water samples

2.1.1. Water quality analysis

Water samples were taken at different points from the houses of the community in El Progreso and from the Junta Parroquial using plastic bottles of 100 mL. Figure 2 shows a map of the sample points in the center of El Progreso and the potable water treatment plant. Samples to determine water quality in El Progreso were taken in March of 2016 before the installation of the filtration system, while samples to verify the water filtration system efficiency were taken in April of 2016.

Water quality was analyzed on the Water Quality Laboratory at the Galapagos Science Center (GSC) at Universidad San Francisco de Quito in San Cristobal, Galapagos. These test were made with the purpose to determine the water quality in the community, in order to find possible issues to be solved with the design process, and to also validate the water filtration system after the installation of pilot filter.

pH, temperature, dissolved oxygen (DO) and conductivity were measured in-situ employing a ThermoScientific multiparameter, Turbidity and residual chlorine were analyzed at the Water Quality Laboratory at the GSC according to standard protocols

(WEF and APHA, 2005). Water samples were analyzed before and after the installation of the pilot filter. In the same manner, samples were analyzed before and after the filtration system to determine its efficiency.

Microbiological analysis of water samples was performed with an IDEXX Colilert, chromogenic substrate test for Coliforms and *E.coli* (IDEXX Laboratories, 2011). Based on the Colilert Test Kit Procedure, a Colilert reagent was used for the simultaneous detection of total coliforms and *E.coli* in water. The reagent was opened ensuring that the powder was at the bottom of the pack and then added to a 100 mL water sample in a sterile, non-fluorescent transparent vessel. Then the vessel was aseptically sealed and shaken until dissolved. Subsequently, the sample was poured into the tray avoiding contact with the foil tab and then it was sealed and incubated for 24 hours at 35º °±0.5°C. Finally, the results were analyzed comparing them with the Quanti-Tray Comparator (2011).

2.2. Design thinking

The design thinking process used for this project is shown in Figure 1. Different ethnographic research tools were employed to understand water experience in the community through the Inspiration, Ideation and Implementation phases of the project. All of the tools applied were taken from IDEO's HCD toolkit (IDEO, 2015). This project was executed by members of the Universidad San Francisco de Quito in Ecuador along with members of the Paris-Est d.school in France, under the context of a co-teaching capstone course called Proyecto de Innovación Socioambiental (PISA, for its words in Spanish) at USFQ and Innovacteurs at the Paris-Est d.school.

Inspiration is what encourages the search for solutions, therefore in order to search for people's needs and perceptions about water, as well as, the discovering of useful insights to work with in the design process, tools employed in the inspiration phase included: i) immersion, living with families of El Progreso for a week; ii) shadowing, following a member of the community in their daily use of water; ii) user interviews, asking about the sources, the need of storage, and the use of water by the community; iv) expert interviews, questioning about the problem, the functioning and management of the water system in the community; and v) participatory video making, showing perceptions of the community about the water.

On the other hand, Ideation is the process of generating, developing and testing ideas; therefore, in order to develop or generate a solution that can solve the problems found in the inspiration phase, the ideation phase was carried out in cooperation with community members. The tools applied in this phase included: i) brainstorming session; held with members of the community; ii) heat mapping, a selection model of the most important problem felt by the community; iii) How might we questions (HMW), to determine a specific question that will be answered with a solution; iv) ideation session, used to draw and write solutions to the problem thought by the community itself; and v) a rapid prototyping session, to create "quick and dirty" prototypes of possible solutions. During the ideation phase, a final prototype was created in order to provide a solution to the water problems in El Progreso. This prototype was developed taking into account all the final remarks from the community and the knowledge from the experts as long as all the design work from the design team. This work included: i) consultancy with experts; to solve and assure all the technical part of the solution; ii) creation of a water filtration system; including the installation and the strategies for continuity of the project; and iii) production of a cleaning protocol manual; to make sure the solution remains in time and can be applied by anyone;

Finally, Implementation is the path that conducts the project to a reality in people's lives (Brown & Wyatt, 2010). In order to present and test the results and solutions generated from the ideation phase, where the ideas are turned into a reality through the development of a useful first pilot prototype, the activities carried out in the implementation phase were: i) presentation to the community; to share the results and introduce the solution to the community; ii) installation of the water system, where the solution ideas became a reality for testing; iii) formation of a water league, as part of the solution to assure persistence of the result; iv) development of a business model, creating a microenterprise that sells and installs the water system; and v) final evaluation, to share thoughts and a general opinion of the community about the design process and the solution proposed.

3. Results

3.1. Design Thinking

The tools described in the inspiration phase were used to collect the greater amount of data possible and to get an important takeaway or insight form the community to proceed with the design process. In the first place, the purpose of the immersion activity was to get to know the community and make them feel comfortable with the design team. Since co-designing starts with co-living, the team members lived with some families of El Progreso during their trips to the island. The idea was to understand their way of living in order to improve their life experience. Then, the Shadowing activity helped to understand better the water experience in the community and to assess the difficulties they had because it is used to see every step of the water process. People usually do not pay attention to small things that might be improved in the process of getting and drinking water. The user interviews were applied to know about all the problems regarding potable water in the community including the sources, the need of storage and the use of water. This step was very important because, through user interviews, the design team learned that no one in the community use water from the tanks for drinking purposes. People do not trust the water quality of the water stored in their tanks, so they prefer to buy five gallons “bidons” instead at $2 each. They buy a bidon every 3 days, which represents an expense of approximately $500 USD per year.

On the other hand, the expert interviews helped to get a deep understanding of the problem and the system of the water in the community from different perspectives such as the perception of Fausto Cepeda, mayor of the community working for the central government, he explained that he agreed with the local administration but he purchased water filters at approximately $1500 every six months to get potable water in his home, something that very few members in the community can afford. Fausto also illustrated some flaws on the system by giving examples of situations where the reliability of the system was questionable due to misfortunes or by human action (Fausto Cepeda, 2016). Indeed, he mentioned the case of tens of diesel gallons received by people through the pipes due to diesel poured into the water system. It took a couple of days until water recovery. Likewise, he mentioned the case of the water desalinization station project in Floreana Island (part of San Cristobal jurisdiction) that had a great inversion of the national government along with the Spanish government, but was never finished (Robalino, 2006). Events like these make people distrustful of the water they receive and of the public network managed by the government. Finally, a participatory video was produced with members of the community in order to have different viewpoints about water uses and management. People at El Progreso were aware that San Cristobal is the island with the major quantity of fresh water among the other islands but they believed water was not exploited in a proper way. Using the data collected with the inspiration tools, the principal information was gathered in small groups that explained the main problems felt by the community and this information was turned into insights during a brainstorming session. Different tools were used in the brainstorming session in order to find a solution for the water problem in collaboration with the community. One of the activities performed for the ideation phase was heat mapping. In this activity, people of El Progreso had to select the most important problem felt by the community and the most relevant insight, from the insights previously selected from the clustering, to continue with the common ideation process. The most important insights selected by the community were: "People have potable water coming from the pipes but they buy bottled water", "People want to be self-sustainable but they have no access to proper information", "People are now confronted to the side-effects of the obsoleteness of the system because it has not been cared of", and "People complain about the difficult access to drinking water but a lot of natural and drinking water is wasted". After selecting the main insights, the How Might We questions (HMW) were created. The determination of a specific HMW question is appropriate because it can lead to an answer with a possible solution of the problem. People need to know clearly what they are looking for in order to be creative and to come up with useful ideas of possible solutions to the problems. In this case, the most important HMW question to be answered was "How might we implement something on the tanks to make water trusted?" and with this question a creative ideation session was applied to make people think in probable solutions to their needs.

The tools employed in the project made the community feel involved and participate in the design process because they were able to present their ideas for the solution of the water problems. These ideas were used later for the development of the final solution. The process of co-designing with community members is shown in Figure 3. After the ideation process, the design thinking team held a rapid prototyping session with the ideas proposed by the community where the team developed some "quick and dirty" prototypes. The purpose of the prototypes was to generate a first idea of the solution that can demonstrate the usability of the product and then present it to the community in order to have a feedback and define the parameters for the design of a pilot prototype. The "quick and dirty" prototypes (see Figure 4) created and presented to the community were: i) an indicator to keep track of water quality in the tank through time; ii) a filter system to make water from the tanks drinkable; iii) a protection system to ease cleaning and prevent growth of unexpected microorganisms in the tank; and iv) a double filter system to isolate drinkable water from domestic use water. After the presentation of the prototypes to the community and the reception of the feedbacks, some final design imperatives emerged. The imperatives used to design the final solution for a pilot were: to have a maximum cost of $500/house; to be suitable for large volumes; to be of easy maintenance; to be easy to implement; to use local products; to be adaptable; and to be trustworthy.

After the first visit to the community and the ideation phase, the team worked with water experts from the LEESU laboratories, Les Eaux de Paris, Environmental Engineering Laboratory of Universidad Sand Francisco de Quito (LIA-USFQ) and Water Quality Laboratory at the Galapagos Science Center

3.1.1. *Final prototype*

As a result of the design thinking process, and following the requirements and the imperatives of the community, a water filtration system was designed in order to clean the water stored in the tanks and make it drinkable and trustworthy for the community of El Progreso in San Cristobal, Galapagos Islands. The filtration system included a cleaning protocol for the storage tanks which consisted in a series of steps (draining, scrubbing and cleaning) using a dedicated set of tools (gloves, bleach, brush and a sponge). The filtration part of the system consists in a series of supplies connected to each other (see Figure 5). The main materials used are: a pump, a balloon, a grid, a pipe, and the filters. The construction of the water filtration system starts with setting the balloon to a grid located on the pipe in the entry of the pump. The balloon and the grid will allow to capture the water at the right level in order not to get the dirt from the surface of the tank or from its bottom and to filter any rare solid dirt that could have managed to enter the gathered water. Then, the pump, located between the tank and the filters, has the purpose of accelerate the gathering of the water from the tank as well as give enough pressure in the entries of the pre-filter and the filter for better bacteria retention. This pump works with a maximum flow rate of 90 L/min and at a maximum height of 100 m and maximum pressure of six bar (Pedrollo pump specification sheet, n.d.). Subsequently, the pre-filter and the filter cartridges are connected, with their housings, to the system. The pre-filter will retain the larger dirt remaining in the water whereas the second filter will depurate the water from the smallest microorganism that it contains. Finally the water goes out ready to use. Figure 6 shows a flow chart of the water process in El Progreso from the water sources of the Island to the water filtration system.

In the interest of selecting the type of filter used, there was a benchmarking exercise with data obtained from the water quality analysis in which the design team along with the water experts searched for the best solution to the water problems. A lot of filter options came up. Some of the filters considered for the solution are shown in Table 3. Since the major concern of in terms of water quality was the presence of microorganisms a NanoCeram filter and pre-filter were selected for its retention capacity of 0,2 and 5 µm, respectively and for its *E.coli* bacteria retention > 6 LRV. These filters have a Silt Density Index (SDI) minor to 0.5, a turbidity reduction < 0.01 NTU until Terminal ΔP (40psi) and an efficiency of 99.9% reduction of 0.2µ particulate (monodispersed latex spheres) (NanoCeram specification sheet, Argonide Corporation, n. d.). The flow rate of the filters is 4 gpm and works under 4-57 ºC (39 - 135ºF), pH between 5-10 and a maximum pressure of 70 psi (4.83 bar) as operating conditions (NanoCeram specification sheet, Argonide Corporation, n. d.). The NanoCeram filters were Pleated Filter Cartridges that consist in a blend of thermally bonded micro-glass fibers combined with cellulose infused with nanoalumina fibers that creates an electro-positively charged depth filter media. This filter uses NASA-derived technology (NanoCeram specification sheet, Argonide Corporation, n. d.).

The inspiration and ideation phases of the project were developed on a first visit of the design team to the Galapagos in March of 2016. The ideation phase was also completed from Paris, France and Quito, Ecuador, where the design team worked together to design and develop a trustworthy product or process for the community that allows the use of the water from storage tanks for drinkable purposes.

3.1.2. Implementation

A second visit to San Cristobal was conducted in April of 2016 in order to present the solution for the potable water access and water trust problems to the community, create a local organization to introduce the idea into the community in a permanent way, build the water filtration system pilot with the organization, conduct water analysis of the water coming from the pilot filtration system, create a user manual with the steps to build the filtration system and with the cleaning protocol, and to make a final evaluation of the project by the community.

The implementation phase was developed through different stages. The first stage was the presentation of the results of the design process and the solution developed by the design team with the community. In the presentation to the community the stories that led to the construction of the prototypes were explained to the people as well as the results of the water sample analyzes and the technical reasons to choose those filters. The idea with this presentation was to make people have the same conception of the pilot as the team, because the community, as explained above, almost created the characteristics of the pilot prototype itself. The presentation was also centered on explaining the first implementation step of the project: the pilot conception, describing how it was theoretically better than the solution that they had at the moment, in terms of budget and accessibility, and to prove through the certification of the experts that the solution would be effective. The second stage of implementation was the installation of the water system. In this stage members of the community learned how to install the water filtration system by building the pilot prototype located at the Junta Parroquial and to maintain it. The installation process and the maintenance process of the water filtration system were also described in a user manual in order to have the information ready to use for other members of the community in the future. An organization called “Liga Del Agua” (LDA, for its words in Spanish) evolved from the community during the design process in order to assure sustainability of the project in the long term. The objectives of the LDA were to learn how to build and clean the water filtration system for further installation on other houses of the community; to follow-up in water quality analysis in collaboration with the Water Quality Laboratory at the GSC-USFQ; to serve as a reference for the rest of the community to any technical or social questions about the system, and; to be in charge of ordering the filters for future installation. At the beginning, the LDA was formed by four members of the community that offered to be part of it, but later, the LDA was integrated by a group of entrepreneur women due to lack of time and priorities of the first members. The idea of the new LDA was to better establish a microenterprise to comply with the tasks mentioned before as well as the purchase and sale of the filters. As the final idea was to create this microenterprise, the last action of the design team was to create a business model for the LDA. At the end, the purpose of the LDA changed and the Junta Parroquial (community's government) took charge of the project now called "PURA". The project was divided in four stages. In the fist one, the Junta Parroquial will install the water filtration system at four public places in 2017: the school, the park, the health center and the sports center. At the second stage, the Junta Parroquial will install the water filtration system in the vulnerable community, giving priority to elderly and people with disabilities. The third stage consists in the installation of the system in the rest of the community. Here, the Junta Parroquial serves as an intermediary for the community members to purchase their filters. And Finally, the fourth stage will be the development of the "Junta de Agua", a public organism that will be in charge of the installation, control and maintenance of the system.

3.2. Water quality analysis

The physical-chemical results of the water quality test conducted during the inspiration and ideation phases are presented in Table 4. The analyses were conducted before and after the creation and installation of the water filtration system pilot in El Progreso's Junta Parroquial, at the first and second visit respectively. These results show normal and acceptable water conditions for potable water according to Ecuadorian legislation (Texto Unificado de la Legislación Secundaria del Ministerio del Ambiente, TULSMA, 2012, and INEN: Norma Técnica Ecuatoriana, 2011) for temperature, OD, conductivity, pH and turbidity and residual chlorine.

The results of the microbiological analysis for total coliforms and *E.coli* using Colilert IDEXX test are shown in Table 5. The results show the presence of total coliforms in the majority of the samples analyzed before the installation of the filters in houses 1, 2 and 3. In the case of the analysis conducted after the construction of the water filtration system, the results show the presence of total coliforms before filtration and the absence of them after filtration. Either way, the results show that the number of total coliforms found goes within the parameters established in the Ecuadorian legislation for potable water (TULSMA, 2012; and INEN, 2011).

In the case of *E.coli*, the samples of the water taken before the installation of the water filtration system did not show any *E.coli* presence, as well as the samples analyzed after the installation of the filtration system (before and after filtration), which goes along with Ecuadorian legislation (TULSMA, 2012; and INEN, 2011). This is expected given that the water gathered in the tanks comes from a potable drinking water treatment plant. From this we can conclude that that water stored in the tanks has the presence of microbiological organisms.

4. Discussion

This document presents a case study to find a solution regarding potable water access and trust problems experienced in the community of El Progreso from a social innovation perspective applying design thinking. Results of the analyses of water quality at the houses of El Progreso show that the physical-chemical parameters analyzed fell within Ecuadorian Legislation for drinking Water presented in INEN's Table 1: physical characteristics, inorganic and radioactive substances and in Table A3.3: Guideline values for chemicals that are of health significance in drinking-water of WHO regulations (INEN, 2011; WHO, 2011) . The temperature values found in the samples range between 24 to 28 ºC as seen in Table 4. Dissolved oxygen (DO) values ranged from 5,8 to 7,1 mg/L. In the case of conductivity, values range from 76,9 to 114,6 µS/cm, but the majority of the samples have conductivity values around 80 µS/cm. In addition, pH values are close to 7 varying from 6,48 to 7,99, which is within the allowable limits established in the WHO regulations (6 to 8,5). Finally, turbidity values vary from 0,10 to 1,77 NTU; this value fell within the Ecuadorian regulation, INEN, and the WHO regulation that states the maximum allowable limit of turbidity is 5 NTU. On the other hand, the microbiological results showed the presence of total coliforms in three of the six samples analyzed, the value of the coliforms vary in each sample from 24,3 to 81,3 MPN/100mL. This may be caused for the difference in water storage from each house because the protection that every family gives to the tank differs one to each other and some of them may be more exposed than others. Considering that there is presence of total coliforms in some samples, the values obtained from the analysis reveal that this samples does not complies with the absence of total coliforms required by the INEN and the WHO regulations (INEN, 2011; WHO, 2011). Finally, results regarding the presence of *E.coli* on the samples show that none of the analyzed samples had the presence of this microorganism, which was expected knowing that the water comes from a potable water treatment plant before it fills the tanks and this complies the Ecuadorian INEN regulation as well as the WHO regulations for drinking water (INEN, 2011; WHO, 2011).

On the contrary, as there was only one water filtration system pilot installed in the community at the Junta Parroquial, the physical-chemical and microbiological analysis of the efficiency of the system was performed with the Junta Parroquial water and, to confirm the results, physical-chemical parameters were analyzed with water from House 2 before and after filtration. Results of the filtered water indicate that the concentration of DO increased in both cases, with the water from the Junta Parroquial and from House 2. Water from the Junta Parroquial had a value of 5 mg/L DO before filtration and 5,6 mg/L DO after filtration which could be explained by a decrease in the temperature. Conductivity increased after filtration of the Junta Parroquial sample from 117,5 to 127,8 μS/cm whereas it decreased after filtration of the house 2 sample from 119,1 to 115,1 μS/cm. Nevertheless, the values stay in the same range.

In the case of pH, it is observed that the values remained relatively constant before and after filtration. In both samples turbidity decreased from 0,17 to 0 NTU in the Junta Parroquial Sample and from 0,53 to 0 NTU in House 2 sample. This decrease in turbidity could be related to the efficiency of the filter. Subsequently, results regarding residual chlorine show a concentration of 0.05 mg/L on all of the samples, before and after filtration

Tests respecting microorganisms after the installation of the water filtration system were done only to the Junta Parroquial water sample. Total coliforms results exhibit the presence of these microorganisms in the water before filtration but the absence of them after filtration. The percentage of removal can range from 66,67 to 100% because the result presented after filtration is <1,0 MPN/100mL but is not an exact value. *E.coli* results show absence on bacteriological microorganisms before and after filtration. From the results obtained it can be concluded that the pilot filters installed at the community complies with the need to improve water quality so that it can be consumed and that it satisfies the INEN drinking water legislation as well as the WHO regulation for drinking water.

Results of the inspiration phase of the project showed that, although the quality of the water distributed by the public network compiles with the parameters for drinking water established by the Texto Unificado de la Legislación Secundaria del Ministerio del Ambiente, TULSMA and the Norma Técnica Ecuatoriana, INEN, people in El Progreso do not use water from the tanks for drinkable purposes; rather, they use it for domestic purposes due to issues associated with the water storage system and the previous low efficiency of the municipal water treatment management. The perception of a bad water quality leads to the need of getting potable water from other sources like the water bidons as described before. According to Guyot-Téphany et al. (2011), people in Galapagos adapt their uses of water under two categories, for consumption and for domestic use; the inhabitants make an effort to pay and / or obtain water considered fit for human consumption, and for the rest of domestic uses they use the water stored in the tanks. This water has little economic value and is perceived as contaminated, reason why it is highly wasted (Guyot-Téphany, Grenier, & Orellana, 2011). The results of the water analysis showed that water stored in the tanks has the presence of microbiological organisms so a mechanism of purification was needed to make water consumption feasible. This result make sense compared with data from the Dirección del Parque Nacional Galapagos (DPNG) that show that the water distributed to the inhabitants of the islands San Cristobal, Santa Cruz e Isabela, contains pathogenic microorganisms and that bad water storage conditions generates an amplification of bacteriological contamination (López et al., 2005, 2007a, 2007b & 2008; Liu, 2011). So, creating a water filtration system corresponded to the problem of the presence of microorganisms in the water as well as with the potable water access and trust problems found. The water filtration system was developed to enable the use of stored water from the public network for human consumption. The system not only included the installation of the NanoCeram pre-filter and filter, but the creation of a cleaning protocol for the maintenance of the water tanks. Cleaning the tanks is an essential part of the solution because it will help keep the water clean and the maintenance and duration of the filters.

The development of this water filtration system was achieved, as a solution for the water problems felt by the community of El Progreso in San Cristobal, as a result of the methodology used in the design process. Johansson-Sköldberg and collaborators (2013) defined the design thinking process as the best way to innovate and to be creative (Johansson-Sköldberg, Woodilla & Çetinkaya, 2013) and this was proved by the design team and the community members that worked together in the search of the solution to the water problems, co-creating a real and useful water filtration system for El Progreso.

In other matters, Neumeier (2012) has established that there is a lack of information about useful methodology to be applied in social innovation projects for rural development (Neumeier, 2012), therefore, this paper wanted to present design thinking as a practical methodology for the development of social innovation projects in rural areas as the community of El Progreso in San Cristobal, Galapagos. People in the community provided positive feedback in terms of the success of the design process using design thinking and in terms of potential improvement of their water experience. For example, Gilmar, one of the firsts members of the LDA said that for him the methodology used was one of the best because it was always experienced on the field by the design team and demonstrated that when one suggests something relevant it bears fruits in the medium term. Also, Paulina Cango, the president of the Junta Parroquial of El Progreso, stated that she liked the way the design team used the working methodologies because it made people participate in the process developing thoughts and ideas to figure out the problems of the community and to find solutions. The reception of the project by the community was productive in terms that they were thinking about replicating and selling the solution in other communities in the same or in other islands of Galapagos, because other islands also experience potable water accessibility problems. This could represent a source of income for the community in the future. The previous information show that the advantage of the design thinking methodology is that it involves users in the process of designing the solution, as a result, the design is human-centered and the solution arise from users ideas, which is also the purpose of social innovation.

The process stages of social innovation described by Edwards-Schachter et al. (2012) goes along with the design thinking process as they starts by defining and identifying the problem to be addressed followed by the identification, definition and selection of possible solution(s) and the implementation of the innovation as well as, the analysis and evaluation of the innovation for adjustment (if needed), and the scaling and diffusion of successful innovations (Edwards-Schachter, Matti, & Alcántara, 2012). According to Dargan and Shucksmith (2008) the role of social innovations in rural development has been underestimated despite of its clear importance in every rural development success efforts (Dargan and Shucksmith, 2008).

Brown showed the importance of using human-centered design in the creation of solutions for communities' problems in his example of a potable water transportation system created in India, where someone designed a five gallons container to transport water when people can not carry more than three gallons on their hips or heads (Brown & Wyatt, 2010). So the project described in this paper clearly showed that the use of the design thinking methodology was useful in order to generate a real human-centered solution for a community based problem. The process developed in this case can be compared with the one described by IDEO developed in cooperation with Water and Sanitation for the Urban Poor (WSUP), Unilever, Global Alliance for Improve Nutrition (GAIN), and Aqua for All, where they created a social enterprise to allow access to clean water, personal care products and health education to the inhabitants of Nairobi, Kenya using the design thinking methodology (www.designkit.org). In both cases, the design teams generated an answer to the communities' requirements through a social innovation process. In the case of IDEO's process, they launched SmartLife, a scalable retail business and brand that offer clean water and health and hygiene products whereas the Galapagos team produced the water filtration system to give access to potable water to the people in El Progreso. Finally, the project described in this paper leads to the understanding of the applicability and value of social innovations for the accomplishment of rural developments. It also gives a profound description of the design thinking process used to achieve these developments.

5. Conclusions

To conclude, this paper established the design thinking process, as a useful methodology for the development of social innovations and the search of solutions for social-based problems. It also described the phases of the design thinking methodology: inspiration, ideation and implementation in the creation of a water filtration system to solve potable water access and trust problems in the community of

El Progreso in San Cristobal, Galapagos. Water quality analysis showed that the physical-chemical parameters of the water in the community complies both with the Ecuadorian legislation as well as with the WHO regulations for drinking water, while microbiological results presented the absence of *E.coli* in all samples but the presence of total coliforms in the majority of the samples analyzed. The efficiency of the filter was probed because water after filtration complied with the physical-chemical and microbiological parameters within the INEN legislation and the WHO regulations. The main problem found in water quality was the presence of total coliforms and the percentage of total coliforms removal range from 67 to 100% with the filter.

This project represents a successful case study of the application of social innovation in Ecuador. And finally, it illustrates the importance of social innovations in rural developments.

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Table 1. Physical-chemical and microbiological characterization of San Cristobal's water sources from literature

	Site	
Parameter	**Cerro Gato**	**La Toma**
Chloride [CL^-] (mgL^{-1})	6,15 ± 0,11	4,97 ± 0,07
COD (mgL^{-1})	<50	<50
Conductivity (µS cm^{-1})	99,21 ± 2,20	26,51 ± 3,11
DO (mgL^{-1})	8,04	2,64
Fluoride (mgL^{-1})	0,031 ± 0,00	0,026 ± 0,00
Nitrate [NO_3^-] (mgL^{-1})	1,04 ± 0,04	0,57 ± 0,04
pH	8,17 ± 0,20	5,98 ± 0,82
Residual Chlorine (mgL^{-1})	----	----
Sulfate (mgL^{-1})	62,54 ± 4,76	64,44 ± 5,54
T (K)	21,6	20,5
Total Solids (mgL^{-1})	91,54 ± 5	52,94 ± 5
Turbidity (NTU)	10,31	2,05
Total Coliforms (NMP/100mL)	1101 (1295-1740)	1206 (1289-1719)
E.coli(NMP/100mL)	120 (84-168)	159 (111-222)

NOTE: The 95% confidence intervals are in parentheses.
Data taken from tables 7 and 8 *Monitoreo de la calidad del agua en San Cristóbal, Galápagos* (Nivelo, 2015).

Table 2. Physical-chemical and microbiological analysis data of water samples for human consumption reported in literature

Parameter	Site								
	El Progreso afluente	El Progreso afluente	GSC	TB	MS	CW	TW	PB	AEP
Chloride [CL^-] (mgL^{-1})	5,47 ± 0,11	15,64 ± 0,23	16,88 ± 0,21	16,86 ± 0,52	17,33 ± 1,07	17,05 ± 0,17	19,87 ± 0,23	15,47 ± 0,19	14,90 ± 0,27
COD (mgL^{-1})	---	---	---	---	---	---	---	---	---
Conductivity ($\mu S\ cm^{-1}$)	27,72 ± 5,16	96,95 ± 19,7	116,07±16,06	119,25 ± 32,87	113,05 ± 20,27	118,64±18,81	124,46±21,67	89,50±10,76	84,69±13,66
DO (mgL^{-1})	5,71	6,28	5,66	6,01	6,76	6,94	6,34	6,61	7,08
Fluoride (mgL^{-1})	0,02 ± 0,003	0,02 ± 0,003	0,03 ± 0,00	0,03 ± 0,003	0,03 ± 0,003	0,03 ± 0,004	0,03 ± 0,002	0,02 ± 0,002	0,02 ± 0,003
Nitrate [NO_3^-] (mgL^{-1})	0,77 ± 0,04	1,03 ± 0,05	1,19 ± 0,06	1,12 ± 0,02	1,09 ± 0,03	1,15 ± 0,03	1,73 ± 0,04	1,04 ± 0,03	0,9 ± 0,03
pH	6,13 ± 0,29	7,32 ± 0,44	7,83 ± 0,28	7,98 ± 0,46	8,3 ± 0,46	7,82 ± 0,14	7,89 ± 0,16	7,99 ± 0,19	7,85 ± 0,71
Residual Chlorine (mgL^{-1})	<0,05	0,41	0,11	0,17	0,32	0,49	0,77	0,13	0,17
Sulfate (mgL^{-1})	65,15 ± 5,54	69,13 ± 7,66	62,31 ± 5,54	66,93 ± 4,03	67,59 ± 2,38	64,09 ± 2,01	64,80 ± 8,06	70,04 ± 6,11	63,35 ± 2,85
T (K)	20,9	21,1	24,4	25,2	25,2	24,2	24,6	21,7	21

Total Solids (mgL-1)	27 ± 5	39 ± 8	91 ± 19	69 ± 10	62 ± 8	84 ± 8	79 ± 10	59 ± 9	44 ± 12
Turbidity (NTU)	1,84	0,58	1,1	1,21	0,8	0,8	0,99	1,57	0,74
Total Coliforms (NMP/100mL)	779,1 (610,4-1144,2)	6,5 (0,8-5,9)	2,6 (0,1-89,8)	179,5 (39,0-74,3)	10,9 (2,8-10,4)	1,0 (0,0-3,8)	247,4 (33,2-74,7)	142,4 (31,5-71,1)	195,3 (148,0-133,5)
E.coli(NMP/100 mL)	55,5 (36,5-81,4)	1,0 (0,0-3,8)	<1,0 (0,0-3,7)	338,1 (37,1-70,0)	8,5 (0,2-4,3)	<1,0 (0,0-3,7)	579,4 (19,0-45,9)	<1,0 (0,0-3,7)	1,0 (0,0-3,8)

NOTE: The 95% confidence intervals are in parentheses.
Data taken from tables 10 and 11 in *Monitoreo de la calidad del agua en San Cristóbal, Galápagos* (Nivelo, 2015).

Table 3. Possible filters to implement as the solution to the water problems in El Progreso

Filter	Chemical constitution	What does it prevent from? What does it eliminate
Ceramic Filter	Fired clay	Microbes
Biosand		Pathogens, Turbidity
UV Filter	No chemicals	Harmful micro-organisms
Nanoceram Filters	None	Chemicals > 0,2 microns
Under The Sink Reverse Osmosis Unit		Dissolved inorganic solids

Table 4. Physical-chemical parameters in El Progreso water measured in the project

Parameter	First Visit[1]						Second Visit[2]				Ecuadorian legislation		WHO[5]
	Junta Parroquial	House 1	House 2	House 3	House 4	House 5	Junta Parroquial		House 2		TULSMA[3]	INEN[4]	
							a	b	a	b			
T (◦C)	25,9	26,4	25,4	24,6	27,5	28,6	-	-	-	-	natural conditions +/- 3º	-	-
OD (mg/L)	7,10	5,80	6,60	7,40	6,10	6,20	5,00	5,60	5,10	5,20	no less than 80% of saturation oxygen and no less than 6mg/l	-	-
Conductivity (µS/cm)	76,9	114,6	87	85,9	84,5	85,4	117,5	127,8	119,1	115,1	-	-	-
pH	7,33	7,53	7,53	7,99	7,12	6,48	7,14	7,1	7,08	7,07	6,0 - 9,0	-	6 – 8,5
Turbidity (NTU)	0,14	0,10	0,23	0,33	1,77	0,28	0,17	0,00	0,53	0,00	100	5	5
Residual Chlorine (mg/L)	-	-	-	-	-	-	0,05	0,05	0,05	0,05	-	0,3 - 1,5	0,3 - 1,5

*All of the samples were taken from different houses of the community; the Junta Parroquial is differentiated from the other samples because there was the installation of the water filtration system pilot after the design process

a Results of the water analysis before the filter

b Results of the water analysis after the filter

[1] Analysis performed at the first visit to the community on March 2016 before the creation of the water filtration system

[2] Analysis performed at the second visit to the community on April 2016 after the creation of the water filtration system

[3] TULSMA: Book VI, Annex 1, Table 1. Maximum permissible limits for human consumption water and domestic use water, which require only conventional treatment

[4] INEN: Ecuadorian Technical Standard: Drinking Water, Table 1: physical characteristics, inorganic and radioactive substances

[5] WHO: Table A3.3 Guideline values for chemicals that are of health significance in drinking water

Table 5. Results of the microbiological analysis for total coliforms an *E.coli* using Colilert IDEXX test for the project

		Yellow			Fluorescent		
	Sample*	**Coliforms (MPN/ 100mL)**	**Coliforms Lower**	**Coliforms upper**	**E.coli (MPN/ 100mL)**	**E.coli lower**	**E.coli upper**
First visit	JP	<1,0	0,00	3,7	<1,0	0,0	3,7
	House1	24,3	15,4	37,1	<1,0	0,0	3,7
	House2	81,3	57,9	111,4	<1,0	0,0	3,7
	House3	36,9	24,9	53,7	<1,0	0,0	3,7
	House4	<1,0	0,00	3,7	<1,0	0,0	3,7
	House5	<1,0	0,00	3,7	<1,0	0,0	3,7
Second Visit	JP[a]	3	0,7	7,4	<1,0	0,0	3,7
	JP[b]	<1,0	0,0	3,7	<1,0	0,0	3,7
Ecuadorian Legislation	TULSMA	3000	-	-	-	-	-
	INEN	-	-	-	<1,1	-	-

*All of the samples were taken from different houses of the community; the Junta Parroquial (JP) is differentiated from the rest of the samples because there was the installation of the water filtration system pilot after the design process

[a] Results of the water analysis at la Junta Parroquial before the filter

[b] Results of the water analysis at la Junta Parroquial before the filter

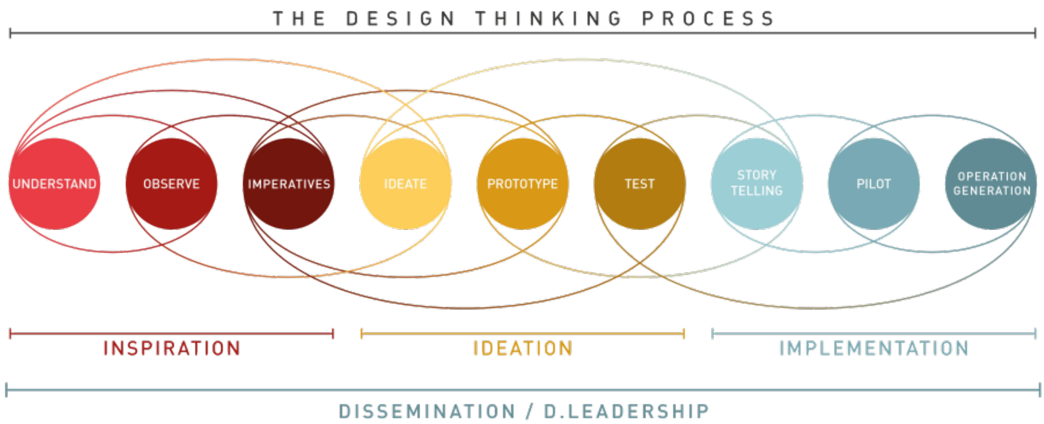

Figure 1. Design thinking process used for the development of solutions in the Galapagos case study. Adapted from d.school Paris design thinking http://www.dschool.fr/en/design-thinking/

Figure 2. Map of the water samples taken in the center of El Progreso community

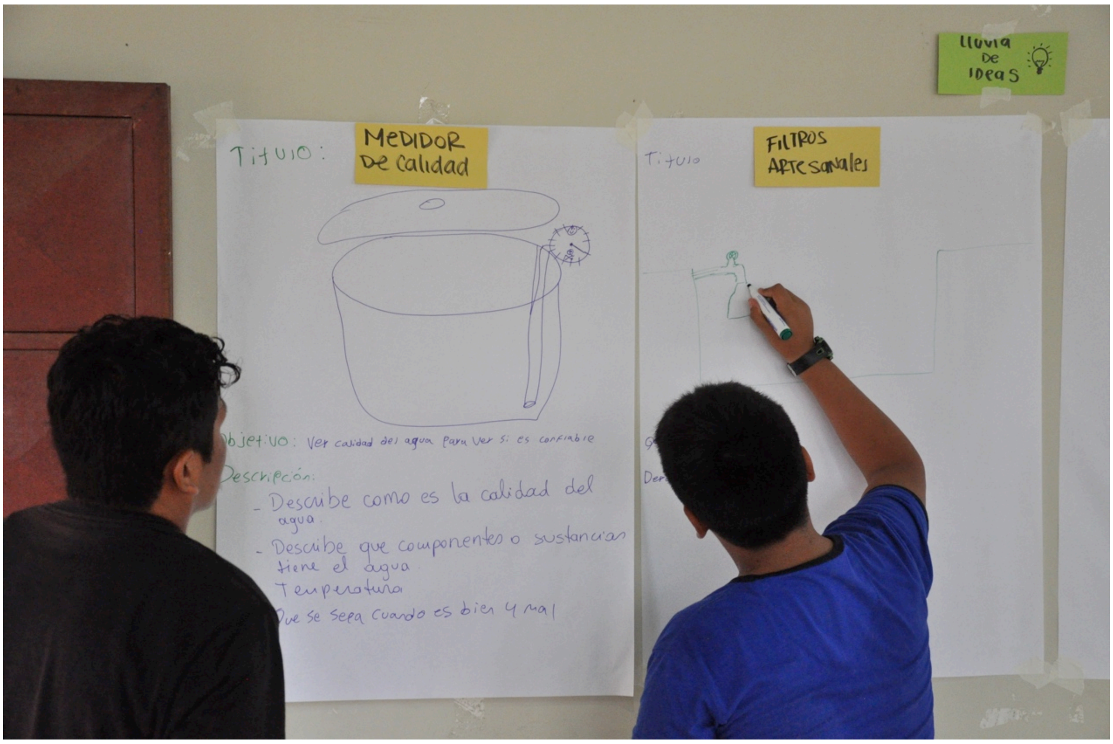

Figure 3. Picture of the community members of El Progreso, San Cristobal, Galapagos proposing solutions for the water problems in El Progreso during the ideation session conducted by the design team throughout the ideation phase of the project.

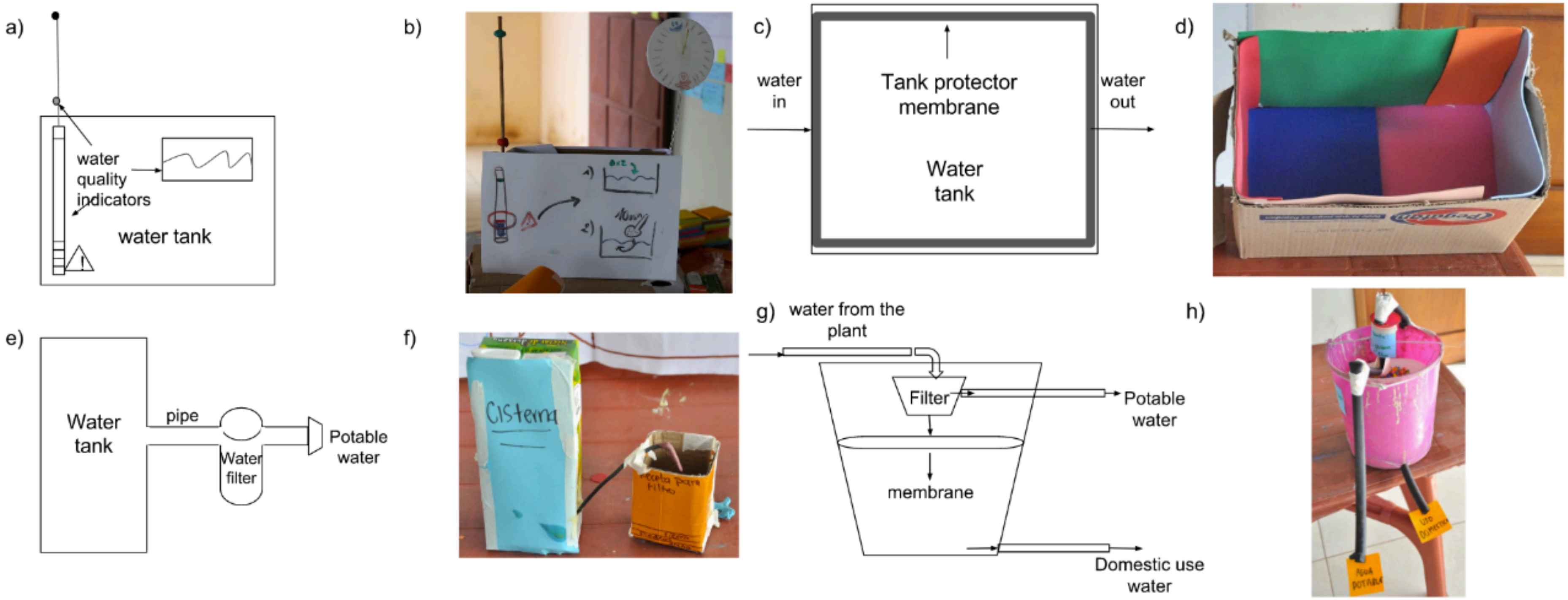

Figure 4. "Quick and dirty" prototypes for the solution of the water problem created for the community a) diagram of the water quality indicator, b) picture of the water quality indicator prototype built; c) diagram of the protection membrane inside the water tank, d) picture of the protection membrane prototype created for the community; e) diagram of the filtration system, from the water tank to the filter and then to the tap, f) picture of the filtration system prototype created by the design team; g) diagram of the double filtration system where the potable water is not mixed with the domestic use water, h) picture of the double filtration system prototype created for the community.

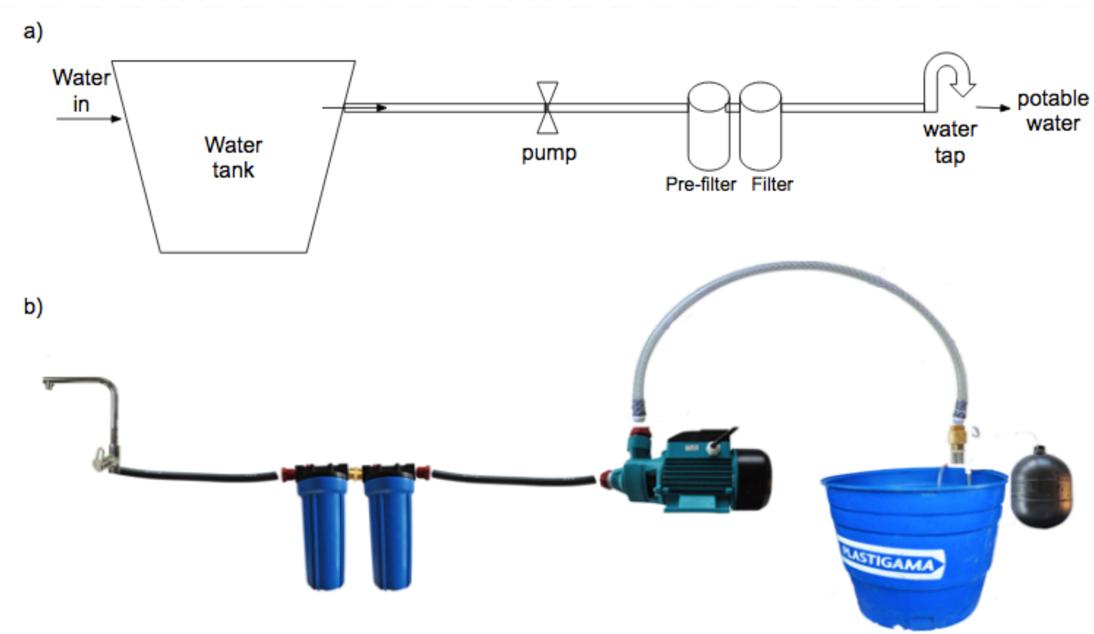

Figure 5. Water filtration system pilot created by the design team after the design thinking process with the community of El Progreso in Galapagos **a)** Diagram of the water filtration system developed to solve people's need of potable water b) Real scheme of the water filtration system pilot developed and installed on the Junta Parroquial of El Progreso.

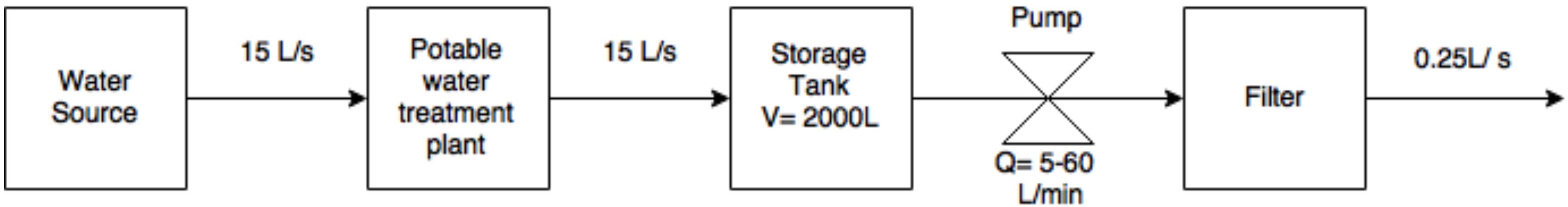

Figure 6. Flow chart of the water process in El Progreso from the water source to the usage of the water after filtration.