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Articles

Evaluation of isolated sewage treatment systems in Nicaragua

Evaluación de sistemas aislados de tratamiento de aguas residuales en Nicaragua

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Abstract

For some time, interesting projects have been undertaken to treat wastewater in isolated rural areas through low-cost facilities, which allow improved quality access to service for most of the population without economic resources. The present work addresses the problem of access to family sanitation from a low cost technological perspective with the integration of actors: beneficiaries, local operators, National

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Institutions, University, and International Development Cooperation Organizations. This article presents the analysis of the technologies implemented, integrated and socially accepted in Local Projects and International Programs in Nicaragua: The Rural Cup and the Popular Ecological Toilet. After evaluating its operation from an applied approach, proposals for analysis are presented, highlighting recurrent issues in the implementation of low cost technologies such as the need to implement processes of dissemination, technology transfer and knowledge democratization.

Keywords: low cost technology, sanitation, ecological toilet, rural cup.

Resumen

Desde hace ya algún tiempo se están acometiendo proyectos interesantes para el tratamiento de aguas residuales en ámbitos rurales aislados mediante instalaciones de bajo coste, que permiten un acceso mejorado de calidad al servicio para la mayoría de la población sin recursos económicos. El presente trabajo aborda la problemática del acceso a saneamiento familiar desde una perspectiva tecnológica de bajo coste con la integración de actores: beneficiarios, operadores locales, Instituciones Nacionales, Universidad, y los Organismos Internacionales de Cooperación para el Desarrollo. Este artículo presenta el análisis desde las tecnologías implementadas, integradas y socialmente aceptadas tanto en Proyectos Locales como Programas Internacionales en Nicaragua: la Taza Rural y el Inodoro Ecológico Popular. Tras la evaluación de su funcionamiento desde un enfoque aplicado, se plantean propuestas de análisis, visibilizando cuestiones recurrentes en la implementación de las tecnologías de bajo coste como son la necesidad de implementar procesos de divulgación, transferencia tecnológica y democratización de conocimiento.

Palabras clave: tecnología de bajo coste, saneamiento, inodoro ecológico, taza rural.

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Introduction

The transport of wastewater by hydraulic drag is the most widespread way to drive waste from family homes, both in urban and rural areas. These processes can account for between 60 and 80% of family water expenditure (Metcalf & Eddy, 2002). Solid waste is composed almost entirely of organic matter and also contains microorganisms present in our organism such as viruses, helminths, bacteria and parasites. The contact or ingestion of this waste is the cause of 4 billion annual cases of diarrhea in the world, being the second cause of death with 1.8 million deaths per year, 90% of them under the age of five (WHO, 2013; WB, 2001).

Therefore, it is essential to implement sanitation systems, individual or collective, designed for the collection of gray and black water and its subsequent treatment for the elimination of organic load and contaminants. The closure of the treatment cycle is carried out with the purification of the wastewater for the elimination of the contaminating organic load and the solids in suspension, assuring the environmental and sanitary quality both environment where they live and rivers and seas, returning these waters to the riverbed in an "adequate" state (Corcoran *et al*., 2010).

Given the type of waste, the installation is designed for gravity transport, and like any installation, the system must be properly maintained for proper operation. The geographic and demographic reality conditions how to solve the problem generated by wastewater (García, 2007). The geographical characteristics of the rural nuclei, with scattered and remote dwellings, makes the conventional collective systems of collection and transport of wastewater unviable in many populations due to the significant investment in execution as well as in the maintenance they entail (Sato, Qadir &Yamamoto, 2013).

The distancing of these rural nuclei from the decision-making centers and the problems of physical access as well as information makes these areas forgotten, being in them where poverty is mainly concentrated. It is not only a health problem, it is also a question of the dignity of people (UNDP, 2006). The General Comment No. 15 of the Committee on

Economic, Social and Cultural Rights concludes that water and sanitation are indispensable for a dignified life and recognized by the General Assembly of the United Nations in Resolution 64/292 in 2010 as a Human Right.

Specifically, in the Objectives for Sustainable Development, the guarantee for sanitation involves the search for viable solutions to the problems in each area. Appropriate technologies are infrastructures that require less resources in their design and maintenance, being their origin primarily local, which lowers their cost and facilitates their maintenance (Cardoso et al., 2014). In addition, they adapt to the characteristics of each intervention, which gives rise to a rich typology of proposals with a high social impact and a low environmental impact.

The evaluation and analysis of infrastructures is incipient in the field of engineering for development, where the failures of an infrastructure overcome the simple technological choice. The evaluation of a technological proposal, in addition to determining the fulfillment of the objectives of the project, is a tool for knowledge and improvement of both the intervention, as well as future projects, as well as investigating the unforeseen consequences due to the project activities (Lobera, Martínez, López & Narros., 2014).

This article proceeds to the analysis of two particular cases of individual technologies of wide extension: the Popular Ecological Toilet (IEP) and the Rural Cup (TR) in Nicaragua, where 42% of the population lives in rural areas. The interest of the proposals is that they start from the local collaborative work between users, social actors, experts and national institutions such as Centro de Intervención Educativa en Medio Ambiente (CIEMA), Universidad Nacional de Ingeniería (UNI) and consultants such as Ensome-PIENSA. The proposal has been integrating NGOs (ONGAWA), Universidad Politécnica de Madrid (UPM) through Grupo de Cooperación Sistemas de Agua y Saneamiento para el Desarrollo, and the national and international cooperation agencies for development such as World Bank, Swiss Agency for Development and Cooperation (COSUDE) and Spanish Agency for International Cooperation for Development (AECID).

The objective is to evaluate the technological proposal in the fulfillment of its objectives, as well as its risks. Based on fieldwork and user surveys, an integrative analysis, both technical, social and environmental, of the processes that take place in the facility and around it, where the weakest and most problematic points were analyzed, is sought as proposals for improvement for optimal performance.

The interest of this study lies in verifying the suitability of the installation, as well as creating the basis for knowledge and subsequent extrapolation to other experiences and technologies that contribute to the systematization of sanitation evaluations. The purpose is to provide a basis for the establishment of procedures for analyzing the implementation of technological proposals in the field of sanitation and treatment adapted to the demanding contexts with the objective of minimizing the recurrent problems observed in the choice and implementation of low-cost technologies.

This work aims to disseminate knowledge and the transfer of technology as tools to universalize access as democratize knowledge.

Description of the proposed technologies

The Popular Ecological Toilet (IEP), designed and validated by Centro para la Promoción la Investigación y el Desarrollo Rural y Social (CIPRES) is a system of unitary sanitation (on-site), also known as Horizontal Ecological Latrine, with a flow of horizontal drag from the discharge of 1 to 1.5 liters of water, as can be seen in Figure 1.

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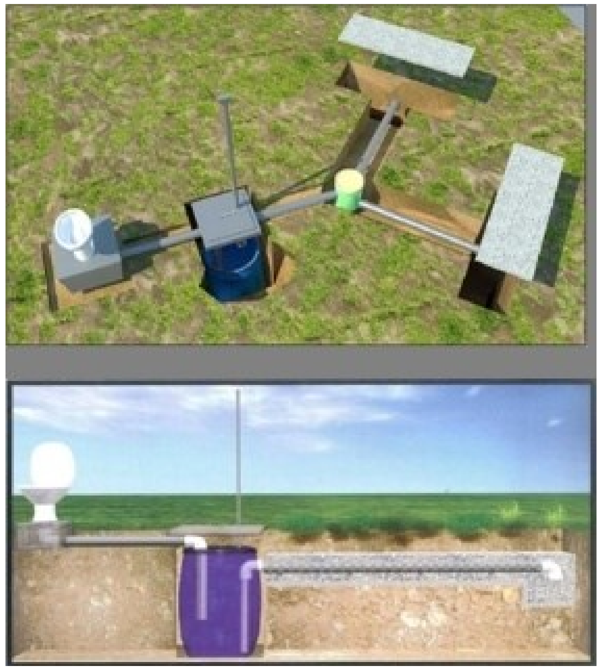

Figure 1. General scheme (plant and profile) of the Popular Ecological Toilet (ENSOME – PIENSA UNI, 2012).

The different parts that make up the installation presented in Figure 1 were designed and sized with the aim of simplifying and ensuring functionality for users (Núñez, 2010), described below:

1. Common toilet to which the siphon has been disabled, so that the material passes directly to the discharge pipe.
2. PVC discharge pipe 75 mm in diameter that transports the material by gravity to the tank.
3. Tank formed by a drum, of at least 200 liters depending on the amplitude of the family unit, where the waste is deposited and stored. The drum must be properly closed for the confinement of the waste and protection of human contact, in addition to facilitating the digestion processes inside. By the characteristics of use of the system, the hydraulic retention time in the interior is very variable depending on the flows used for the drag, being comprised between 2.2 and 32.4 days. In this time, different biochemical processes take place due to chemical and microbial activity, which decomposes matter and metabolizes waste. It is a mainly anaerobic process with little oxygen supply.

4. Aeration tube 1.9 cm (3/4 inch) in diameter for the exit of gases produced in the processes of decomposition of the barrel. A mesh is installed at the exit end to prevent the entry of vectors into the barrel.
5. Infiltration pipe, which dislodges the material processed in the drum by difference of height to the ground, distributing the load along it. It is a PVC pipe with different grooves in the middle part of about 0.6 cm wide by 7.5 cm long, and where it ends with the aerobic processing of waste.
6. Infiltration ditch of 3-4 meters long, 40 cm wide and 40 cm deep where the pipe is laid on gravel, which facilitates the entry of processed material into the ground where the decomposition process ends.
7. Area of roots on the surface and on both sides of the infiltration ditch to finish purifying the effluents. Characteristics and dimensions are not defined.

There is a significant modification of the system (Núñez, 2010), with the provision of two infiltration pipes, so that they work alternately increasing the capacity and performance of the system, as well as facilitating its maintenance. This type of installation has not been located in the study area.

The Rural Cup (TR) combines elements of the traditional latrine with vertical drainage flow and elements of the Popular Ecological Toilet, as shown in Figure 2 below (COSUDE, 2011).

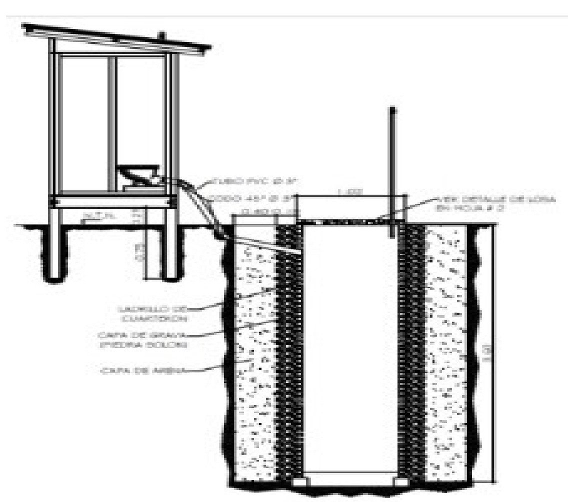

Figure 2. Section of Rural Cup with well (ENSOME – PIENSA UNI, 2012).

The TR is a simpler system with fewer elements:

- The common toilet bowl with hydraulic seal to prevent odors, sometimes a "Turkish bath" type slab is available.
- The discharge pipe to the well by means of a hydraulic drag system.
- Infiltration well, of greater depth, where the material is infiltrated to the ground.

In both facilities (IEP and TR) the land is used as a subsurface scrubber substrate, taking advantage of the natural physical, chemical and biological processes that develop in the soil-water-farming ecosystem, which allow the elimination of most pollutants present in purified effluents (Machado *et al*., 2007). Both proposals presuppose a harmless effluent after passing through the infiltration facility. The IEP proposal, with more superficial infiltration, minimizes the chances of contaminating underground aquifers.

Methodology

With the aim of evaluating both technological proposals, and as a starting point, the state of the art of technologies has been analyzed. The previous collection of information regarding the appropriate technologies in general and the proposals in particular, such as the area where they have been implemented, favored the theoretical analysis. As a complement, interviews were conducted with the different agencies that have implemented or planned the use of this technology in their projects, such as World Bank, COSUDE, FISE, Save the Children, CIPRES, ONGAWA, and CARE.

Additionally, the models for the surveys to be carried out in the field were designed to define the existing relationships between the social, environmental, economic and technical dimension of the project. A total of 300 surveys were conducted in 16 municipalities and 30 communities, in family units where 55% were women. The communities were selected based on geography, representing at least 2 focal groups in the West, 2 in the northern zone and one in the RAAN.

The interviews were complemented with visual inspections of the existing facilities. The representativeness of the sample is 8% of the total units installed in the territories selected to carry out the study, as indicated in Table 1.

As a complement to the interviews, the facilities were inspected as a formula for their evaluation that includes all aspects of the technological proposal.

Table 1. Distribution and representativeness of sample by territory (ENSOME – PIENSA UNI, 2012).

Region	Amount of IEP / TR installed by the executors	Installation time	Houses	Representativeness
Chinandega	1161	4-1 years	115	10%
León	350	3-1 years	13	4%
Estelí	167	5-3 years	32	19%
Jinotega	753	1-1.5 years	52	7%
Matagalpa	1315	1 year	68	5%
RAAN W	244	> 1 year	20	8%
Total	3990		300	8%

Technology evaluation

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The evaluation of the technologies was carried out in the fields in which it directly affects, structuring in the functional evaluation, the hydraulic evaluation, the social evaluation, the structural evaluation and the environmental evaluation.

The functional evaluation is focused on the design and operation of the infrastructures. In both (IEP and TR) the siphon has been eliminated, maintaining the slope of the drain pipe to facilitate the hydraulic drag and reduction of the amount of water needed for discharge. Although the odor is not eliminated, it is greatly reduced by being able to place the system very close to the house or even inside it, which facilitates the use and improves safety, mainly for women. Both proposals work with important variations of hydraulic load and contaminant due to the occasional use by the family and the products used that are discharged by the toilet.

The hydraulic evaluation is carried out with the objective of analyzing the operation of the different components of the system through its modeling in the laboratory. The laboratory modeling of the discharge pipe was carried out, similar in both proposals, in which between 1 and 1.5 liters of water were poured, with pipe slopes between 0.5% and 5%, verifying flow velocities around 1 m / s, well above the speeds between 0.3 and 0.5 m / s recommended by different regulations.

The plastic material of the pipe minimizes the erosion caused by over speed, in addition to avoiding the sedimentation in the pipe, improving the hydraulic operation. It was not possible to model in the laboratory the rest of the components of the IEP and TR from the execution of a pilot installation, due to the high number of possible operating conditions in the facility and the difficulty and biological risk associated with the piloting of a decanter-digester for the specificity of facilities and procedures. The design as digester of the barrel of the IEP requires the definition of design parameters such as the retention time of sludge, temperature, pH achieved and reduction of COD and BOD, which exceed the scope of the evaluation.

Complementing the laboratory analysis, we proceeded to the hydraulic evaluation from field studies of selected units, a total of 40 IEP and 15 TR. The selection criteria of these units are summarized in: similarity in the size of the user families and different volumes of water used for cleaning, representation of the different installers, distribution among the different communities, and time of use of at least seven months. It was observed that, of the 40 installations inspected, only 17.5% are in full use in their original configuration, and 25% of the installations are not used regularly by users, which expanded the questions about the system.

The infrastructure is designed for discharge volumes between 1 and 1.5 liters of water, an amount that, besides conditioning the drag, is responsible for the operation of the digester (in the case of the IEP). During the inspection visit it was observed that quantities are used that even triple the amount of recommended water, as shown in Figure 3.

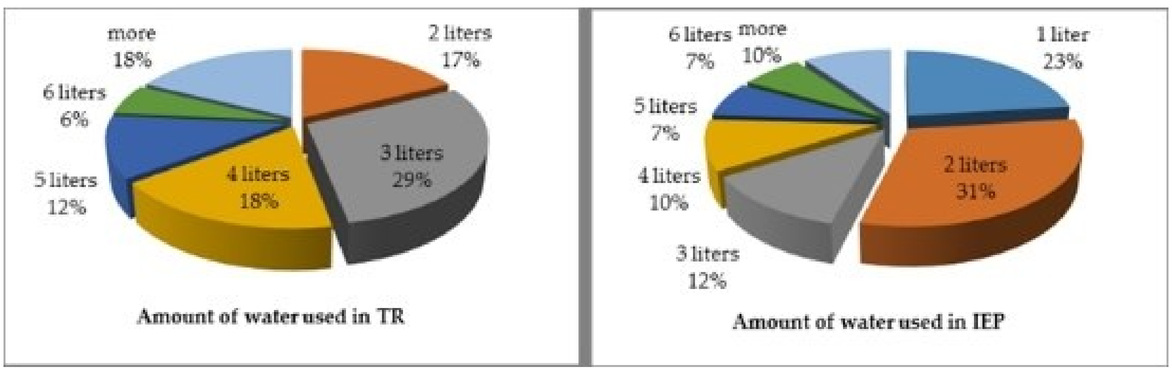

Figure 3. Amount of water used after using the IEP and the TR.

The social evaluation is based on the analysis of social acceptability, operation and maintenance activities, hygiene aspects, aspects of convenience and preference related to the use of the ecological toilet and the Rural Cup. From the sanitary point of view, the ability of the devices to be a barrier to the risk of disease transmission is analyzed, which guarantees the quality of the installation, its use and cleanliness (Mancebo, 2010). In addition to the physical barrier that the installation supposes, the users presented as main advantage the disposition of the cup: comfortable, hygienic and easy to clean, besides safe to minimize the dangers in the deposition especially for minors.

The acceptance by the population is also related to the imaginary of development, which favors the increase in self-esteem to the population. 88% of families prefer and use the IEP / TR, which indicates a significant level of acceptance of these technologies. The most frequent reasons for preference are hygiene, comfort and safety. Analyzing this variable separately for IEP and TR, the trend is exactly the same. Despite the acceptance of the technology, there are important

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aspects that must be reviewed, such as the education on cleaning materials that are emptied into the bowl and flow to the IEP digester, maintenance of the infiltration trench and method of measuring sludge in the digester; among others. In conclusion, all referred to training and education on the use and maintenance of the system in general.

90% of the users have been trained in hygienic practices and this is reflected in the visual inspection of the facilities, carried out during the hygiene status survey of the IEP and TR cup. In this survey, it was observed that only in 18% of the cases, the cup had a bad smell, in 21% stool remains were found, only in 2% were vectors (cockroaches) and in 4% it was found dirty water accumulated.

Although 100% of the families received training for the maintenance and repair operations of the Popular Ecological Toilet, 80% of families do not know how and when the digester is filled, as well as what to do when the discharge pipe is blocked and infiltration, feeling incapable of acting. In the original design of both facilities, there is no device or accessory that allows the extraction of the sludge from the barrel, nor the emptying. In 91% of the installations maintenance had not been carried out since they were received and only 16% of the users said they had instructions in writing. Table 2 summarizes the situation, with these data confirming the need for a structural study by parts of the IEP infrastructure, which presented more problems than the TR.

In the surveys conducted, as shown in Table 2, the same users are the ones who demand the need for more information and training for repair and maintenance. This being the greatest difficulty found from the social point of view for the successful and sustainable implementation of the facilities.

Table 2. Survey of use and maintenance of IEP and TR facilities (ENSOME – PIENSA UNI, 2012).

	Using IEP/TR	**Maintenance or repairs IEP/TR**			
		Yes		**No**	
Everyday use since installation	299	24	8 %	275	91%
Temporary use	9	4	45%	5	65 %

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Total	308	28	9 %	279	91 %

The structural evaluation is based on the analysis of the physical state in which the facilities are located and their safe use, analyzing first their location in the house and the construction as the structural functioning as a whole, and then proceeding to analyze each of its parts.

Regulations and design guides, supported by organizations such as OPS / CEPIS and COSUDE, recommend the installation of the latrine house with hydraulic drag inside the house, or at a distance of no more than five meters to facilitate comfort of the user, especially of women, given their hygiene needs for menstruation, in addition to minimizing the risk of suffering aggressions. These parameters are met for the IEP, but not for the TR, as presented in Figure 4.

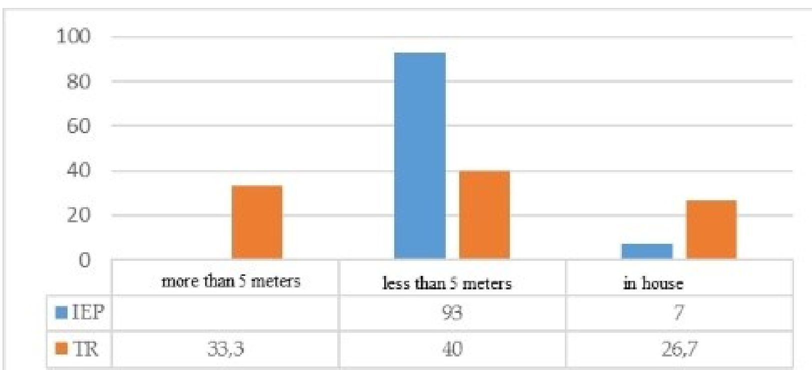

Figure 4. Comparative% of distance from the latrine house to the installation in the house.

During the inspection, in the whole of the installation there are defects in the construction as well as deficiencies in the quality of the materials. Based on the interviews and surveys, it is concluded that there was no systematic follow-up of the execution and completion of the work by non-construction personnel. Some of the deficiencies observed in both the IEP and the TR, are not visible once the units are executed, which facilitates the collection per unit installed to the contractor company. The certification and payment from installed sanitary units promotes the rapidity in the completion of the works instead of the quality. The objective of lower cost, considering that the option is aimed at rural and peri-urban communities with a high level of poverty, should not be contradicted by the adequate quality of the work.

In the analysis by parts, both for the toilet-barrel digester in the IEP and for the infiltration well in the TR, note mainly that the aeration tubes were raised with respect to the initial design, in addition to being fissured. None of the tubes had a mesh or sieve installed to prevent the entry of vectors into the barrel. The slopes of the infiltration ditch-pipe of the IEP vary considerably with respect to the technical recommendations that recommend values of 1.5 per thousand and a maximum of 3 per thousand and never exceeding 4.5 per thousand (OPS / CEPIS, 2003). Figure 5 confirms the difference between the facilities executed with respect to the recommendation, as well as the wide range of inventoried slopes.

The filling material of the trench, in addition to guaranteeing infiltration, must fulfill the support function and stabilize the infiltration pipeline (OPS / CEPIS, 2003). The manual recommends the installation of stone bolon, gravel or pieces of brick cuarterón; nevertheless, in the totality of the ditches the installation of fine gravel mixed with soil, or directly the soil itself is observed. From the surveys it is concluded that infiltration tests were not carried out to confirm the adequacy of the projected installation to the existing soils. The result, as summarized in Figure 5, was that the set of infiltration and ditch pipe does not work properly.

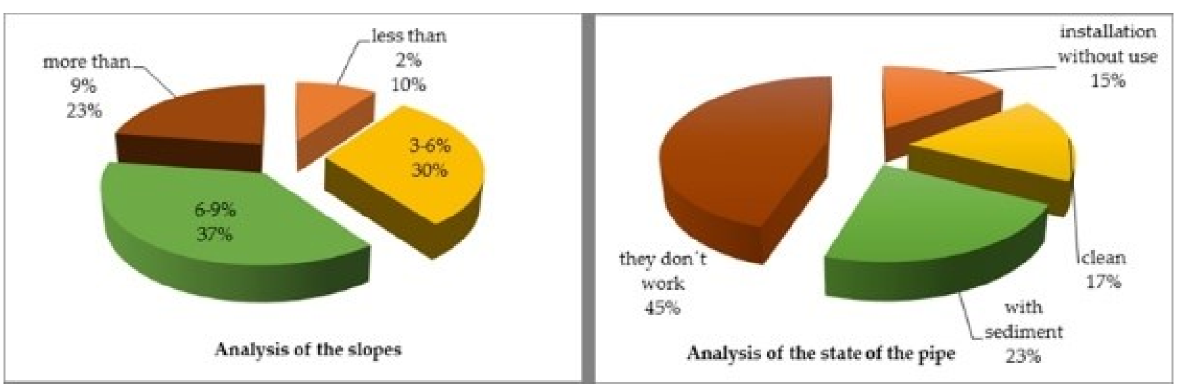

Figure 5. Summary analysis of the slopes and the state of the infiltration pipeline.

The environmental evaluation aims to confirm the adequacy of the installation to the environment and sustainability both in the execution and in its operation. The characteristic of the proposal is the design together with the use of local materials and proximity, facilitating the execution of facilities with a low environmental impact in their execution. The operation has important impacts for the human and natural environment because of the quality of the resulting effluents.

The parameters selected, such as the adequate planning of the sampling, are reflected in the final results, avoiding the transfer of failures in the different stages to errors in the conclusions (CEDEX, 2010). To do this, in the IEP, it was necessary to develop a sampling system for quantitative and qualitative analysis in the digester barrel and in the infiltration pipe so as not to alter the physical-chemical properties as much as possible. Given the characteristics and dimensions of the TR, it was not possible to perform the sampling.

The resulting range of values is broad for all parameters analyzed, the lower values being those corresponding to underutilized installations. The values of total solids (TS) vary between 12 741 mg / l and 63 200 mg / l, similar to the parameters of volatile total solids: 6 871 mg / l and 56 566 mg / l. Parameters such as COD have values between 13 478 mg / l and 75 769 mg / l, while BOD5 varies between 1,300 mg / l and 18,000 mg / l. No significant reductions of these values are observed in the process that allow concluding that aerobic digestion is carried out. As indicative of sludge digestion, the ratio of volatile solids to total solids (VS / TS) can be used, considering that, for digested sludge, values of 0.53 represent a high degree of digestion (Méndez, Gijón, Quintal & Osorio 2007). The values obtained vary between 0.76 and 0.89, and in no sample extracted from the barrels was mineralized sludge found. We proceeded to the emptying and analysis of the sediments in four barrels installed without finding mineralized sludge, characteristic of an anaerobic digester. It can be concluded that this type of digestion is not carried out in said barrel. Where the IEP effluent could be collected, the laboratory reported values, such as MPN / 100 ml, of up to 5.4 x 106 fecal coliforms, very high values to guarantee the conditions suitable for the discharge.

The capacity of the soil as a scrubber complement after passing through the infiltration trench is physically related to the filtration capacity of the soil, in particular, the granulometry and texture, while in the chemical actions play a very important role the capacity of ionic change of the soil and its pH, and the conditions of aeration / ponding that affect the oxidation-reduction processes. These processes determine the mobility of contaminants in soil and their availability by plants. The root activity of plants is biologically cleansed, but the main agents are soil microorganisms, which operate both under aerobic conditions (in the upper strata of the ground), and anaerobic (in the deepest strata) (Centa, 2012). The hydrogeology of the land and the pluviometry characterize the phreatic level of the land, having to adapt the design of the infiltration ditch to these characteristics. Given that the analyzed infiltration ditches have not been executed according to standard design conditions, the given sampling process has not been planned.

Results

In this section we will proceed to summarize the conclusive results with respect to both technological proposals. The possibilities of this evaluation have allowed us to take a photograph of the technology, in addition to an approach to other areas related to the technological proposal, such as social and environmental. As a complement, it would have been desirable to carry out continuous monitoring from which a more detailed knowledge of the infrastructure and other aspects related to use and maintenance could be obtained.

This situation presents the following analysis:

For Rural Cups (TR):

- In the TR there were no problems of plugging or sedimentation in the discharge pipe, which indicates that self-cleaning conditions are developed in this pipe.
- No record was found to confirm if the infiltration test, at the sites where it was carried out, influenced the sizing of the sump, although these at the time of the inspections did not present overflow problems.
- The trained technical supervision, including a guide for the design, installation, operation and maintenance, is of utmost importance for the correct installation and proper functioning of the rural cup and its essential components.

For Popular Ecological Toilets (IEP):

- Regarding the tube that communicates the toilet with the barrel of digestion, the recommended water discharge combined with the slope of the tube, is sufficient to cause the dragging of all the fecal material to the barrel. Both the use of insufficient water to wash the cup of the IEP, which causes the slightest drag of sludge to the infiltration tube, and excessive volumes of water, where the sludge is drawn into the infiltration tube without degrading in the barrel, supposes the collapse of the system.
- There is no digestion or complete mineralization of the organic matter that is deposited in the barrel, generating too much biomass to clog the barrel in less than a year, losing its storage capacity.
- Confirmed the operation of the barrel as an accumulator rather than as a digester, it is recommended to extract sludge and floats before 1 year.
- Despite the physical and biological conditions in the barrel, there is no appreciable reduction in total and fecal coliforms.
- System obstructions occur in both the barrel and the infiltration trench.
- Given the resulting low mineralization, the effluent received by the infiltration tube has a high solids content, which hinders its operation. It is not observed that the effluent from the barrel is conducted and distributed uniformly in the filter bed in which a biomass develops, observing a high percentage of obstructions.
- Minor deficiencies are observed in the installation due to the lack of adequate technical supervision and the carrying out of the necessary controls during the execution of the work by responsible personnel who confirm the correct execution of the installation.
- For the correct maintenance of the facilities, it is necessary to adequately train the users to be able to act on the problems that may arise.

The main weakness of the IEP is that it is not planned to extract the sludge that accumulates in the system. As observed in the technical inspection, several design improvement options were identified to perform the extraction and handling of the sludge in the IEP:

- Option 1. Extraction of fluid sludge in the barrel: Confine the sludge in the barrel by placing a device that prevents the passage of solids into the infiltration pipe. The extraction of the fecal sludge, in a fluid state by the water content, would be carried out in the barrel.
- Option 2. Extraction of dry sludge in the infiltration tube: Place two infiltration tubes in place of one and allow the sludge to be dragged from the barrel to these tubes that would receive the sludge alternately.
- Option 3. Change the function of the infiltration pipes to conduction pipes of the effluent of the barrel to be discharged, each in a pit or sink where material would accumulate, and infiltration would take place.
- Option 4. Increase the volume of the barrel. This option would involve extracting fecal sludge in the barrel without preventing solids from also passing into the infiltration tube. It is expected that the number of solids that pass and accumulate in the infiltration tube is much lower.

From a real operation of the installation according to the characteristics of the design and without the interference of the execution, it is essential the analysis of possible problems associated with the implementation that will allow the forecast of solutions that guarantee sustainability and long-term profitability, both the installation and the results of the project in subsequent evaluations. Social analysis is vital in detail about the suitability of the habits with respect to technology, the real needs that this does not cover, etc. and adaptation proposals to meet their demands and ensure full acceptance by users who will also be managers for the forecasting and resolution of problems associated with technology. It is therefore essential that the beneficiaries take ownership of the proposal, know it well and are properly trained for its maintenance.

The technical problem of the system, its obstruction and loss of functionality in a period of approximately one year is not acceptable for a sanitation system. The ignorance of the operation of the installation, problems in the execution, as well as the lack of prediction of scheduled maintenance has led to failures in the operation of the facilities analyzed.

Regarding the installed units of the IEP, the programmed emptying in the useful life is necessary for what is necessary in its design to have a device or accessory that allows to extract the sludge from the barrel and empty it. An optimal implementation of the technology requires the systematization of the procedures during the life cycle of the project, as well as the implementation of monitoring tools that confirm the adaptation to a reality, a culture and own practices in the community.

The handling of the resulting sludge during emptying is characterized as dangerous, given the organic load and biological contaminants, so this step must be carried out guaranteeing the protection of the person to the exposure of the contamination. But the problem of sludge management has a greater scope and not only concerns the extraction of the system, but the subsequent stabilization of the extracted waste to avoid expanding the problem and pollute the environment and people, so it must be planned properly the management of sludge in an integral way.

However, the analysis of the results presented presents interesting contributions about the importance of sustainability over time of a project based on the joint vision of the problem and the effective involvement of the community and the democratic institutions present in the project zone. This process is vital from the moment of identification to minimize future errors, or even the abandonment of technology.

Areas to be improved have been located throughout the life cycle of the installation, from its planning to its subsequent management. Therefore, it is necessary to invest more efforts from the multiple optics for the implementation of prototype systems with special care in the execution, working according to the real habits of the population and with a continuous monitoring plan in which periodic tests are included that allow the confirmation and clarification of the various hypotheses presented and thus really assess the technology, roles and responsibilities of the institutions and people involved.

In addition to the analysis, proposals were made for the improvement of the IEP facilities that entail the need for a redesign of the system. These designs require a more detailed study, in all the exposed fields, including the most social aspects, given that the beneficiaries will be the users-managers of the technology. These improvements should also be accompanied by pilot facilities that justify the increase in investment with respect to the results.

In the case of the TR, it was not observed so much in its conceptualization as in its components some malfunction when it was correctly installed. Therefore, no design improvements were proposed, but the need for a design and installation guide for this sanitation option was proposed. Because this technology carries a risk of contamination of underground aquifers, the IEP analysis was prioritized.

Conclusions

The IEP as the TR is a technology included in the catalog of sanitation systems of large organizations such as the Pan American Health Organization (PAHO) or COSUDE with a high number of users and a high potential impact. However, a prior evaluation of the technology that confirms the suitability of the technology and its validity as an alternative for future projects has not been carried out.

After the analysis centered on the IEP, due to the technological innovation it implies and the minimization of the probabilities of contaminating underground aquifers, the results of the study show that the proposal has not reached the expected objectives, presenting structural and installation deficiencies and social acceptance associated with its maintenance. The study itself is a good illustration of the problems associated with sanitation by collecting learning.

The formulas can be multiple and varied for the attainment of financing to assume the costs implied by an installation of this type. The economic capacity of families is an important variable that affects both the initial investment and the future of the installation, so the system chosen must ensure its effectiveness at the lowest cost and affordable maintenance.

Therefore, from the technical point of view, the first thing is to make sure that the possible sanitation systems to be implemented are fully functional, including adaptation to local and cultural circumstances, as well as economic and environmental (water table, seasonal flooding, etc.). The life cycle of the operation of an installation exceeds the time of the project, so it requires decision-making processes, supervision, quality controls during execution, maintenance, and permanent revision and correction throughout the life of the installation.

It is vital to ensure the functionality of the technology in the time that users become managers of the installation. Therefore, they must have enough information and training to face the challenges that the maintenance entails, acting with the greatest foresight to the problems to guarantee the continuous operation, ensuring the long-term sustainability and profitability of the infrastructure. This is only possible with the full and effective participation of the communities throughout the life of the project, especially involving them in the initial decision-making process.

The knowledge and integration of the community in the entire scope of the action is confirmed, as well as the acceptance and implication for the achievement of the ultimate goal of the projects, which is the improvement of the living conditions of the population after improving coverage of access to sanitation. For this, among other actions, the proposal must be accompanied by adequate training of users in hygienic-sanitary habits.

This work allows to incorporate the lessons learned to future sanitation projects, as well as to form the bases for the integration of this methodology in systematized processes for the continuous evaluation of interventions in the sanitation field.

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