DISINFECTION SYSTEMS OF APPROPRIATE TECHNOLOGY IN COCHABAMBA – BOLIVIA

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Bolivia is a country located in the heart of South America, its economical conditions does not allow it to supply good quality water for consumption to the most of the population, which live in the country field, far from the main cities or in the peripheries of them. The main problem of these group of people is that most of the water available is bacteriologically contaminated, coming from rivers, channels, irrigation systems or wells which are prone to be in contact with animals or residuals coming from other organisms.

No more than 40 percent of the population is supplied with treated water, while more than 50 percent have access to water of not controlled quality.

According to a study on mortality made in 1981, 34% of mortality is related to intestinal or parasitic diseases, which are commonly caused by consumption of bad quality water.

Since most of the affected people have low income, as well as low educational level in water related health matters; the systems which intend to benefit them should be effective, versatile, requiring of low maintenance and operational skills.

Aiming to deal with situations like the above mentioned, the university of Cochabamba (UMSS) by means of Programa de Aguas, has been working in the improving of the quality of the water by means of appropriated technology techniques. Some of these techniques are a hydraulic chloride dosing system (already presented in the previous simposium), and the use of slow sand filtration as disinfection methods.

Programa de Aguas, in collaboration with EAWAG – SANDEC, also tested and verified, in laboratory and in field, the disinfection by solar radiation.

Summaries of the mentioned technologies are presented in the following paragraphs.

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SOLAR WATER DISINFECTION FOR HUMAN CONSUMPTION [1]

Antecedent

Water disinfection for human consumption is a requirement in regions where the water is considered as not safe, since contamination affects to most of surface sources. This situation is worst in arid and semiarid regions where due to the short rainy seasons, people is obligated to drink water that has been stored for long periods, or which is also used by animals.
The sustainability of a method is important, since even though a method is effective, its sustainability depends on the operation and maintenance of the users.
In the rural area, a sustainable disinfection method must be available for a common family, which means that it must be easy to understand, to operate and with a minimum cost.
Temperature is one of the forms of eliminate or reducing the quantity of microorganisms in the water. EAWAG – SANDEC studied the sinergic effect of the pathogen microorganisms inactivation by means of the solar radiation and heating, proposing SODIS as an alternative of water disinfection for low income and dispersed populations.
Programa de Aguas performed a field survey to verify the acceptability of the people to the proposed system.

Zone of the project

It was located approximately to 90 km to the south of Cochabamba city, in a region called Sacabamba.

Technical aspects

From experiences in many countries it has been showed that with two effects of the solar energy: the radiation and the heating, it is possible the disinfection of water for human consumption.
The process consists on filling transparent containers with water and exposes them to the solar light for some hours. Solar radiation inactivates and destroys pathogen organisms present in water, without changing the taste and odor.
The solar disinfection occurs even with solar radiation intensities of a partially cloudy day (350 to 400 W/m^2 in Cochabamba). Lower intensities may require a longer exposition time.

Materials

The tested containers were the available in the region, plastic and glass bottles of carbonated beverages. Among the plastic bottles, two types were tested: the non-returnable and the returnable ones. Also especial plastic bags provided by EAWAG-SANDEC were tested.
Materials used as support of the bottles were also tested: concrete, wood, and metal plates (used for covering the roofs).

Laboratory tests

For different exposition periods, water, air temperatures, as well as radiation were recorded; also water samples were taken to analyze the existence of fecal and total coliforms.
It was also determined that the best supports for the bottles were the metallic ones.
From a comparison between containers: non returnable plastic bottle, returnable plastic bottle, glass bottles, and SODIS bags, the ones which higher temperature reached were the SODIS bags, followed by returnable plastic bags.(see fig. 1 and 2)
The fecal coliform remotion was higher in the plastic bottles than in the glass bottles.

People's participation

The introduction of the SODIS method was made during the periodic community meetings. The relationship between the water quality and the diseases besides the importance of the disinfection were explained. Most of the explanations were made in the quechua language.
The people who initially worked with the disinfection system were chosen from the results of a survey, according mainly to their interest and education level.
Starting from 5 families using the disinfection system, more families asked for working with the disinfection system.
The main mean of diffusion of the method was the commentaries of the users with the other people of the region. Another form of diffusion was the design and distribution of graphic and easy to understand educational charts, among the interested people.

Asessment of the project

It was mainly done by means of periodic visits that included collection of samples for analysis of pH, conductivity, turbidity, temperature, total and fecal coliform, previously and after the treatment.
Most of the water used by the people had the following characteristics:

Turbidity	:	25 NTU
Conductivity	:	15 – 80 μmhos/cm
Salinity	:	0.01 – 0.03 mg/L $CaCO_3$

Conclusions

- The efficiency of the solar disinfection was proved in the field.
- Total and fecal coliform removal has been proved to be in the order of 90% even in partially clouded days.
- In a partially clouded day the removal from 1910 to 310 colonies forming units/100 ml was achieved with a maximum temperature of 34°C in the glass bottles.
- The parameter considered more important in the tests is the solar radiation for Cochabamba (2600 masl) and Sacabamba (3200 masl).
- The containers used in the field were the returnable plastic bottles, since these are more resistant than the other tested plastic containers and are less fragile than the glass bottles.
- The use of a metallic support under the bottles improves the efficiency of the method since it increases the temperature that the water in the bottle can achieve.

- The best period of time to obtain maximum temperature and solar radiation is between 10 and 15 hours.

Figure1.- Variation of temperature for different types of support for SODIS bags. Variation of solar radiation with time. The measurements started at the same time

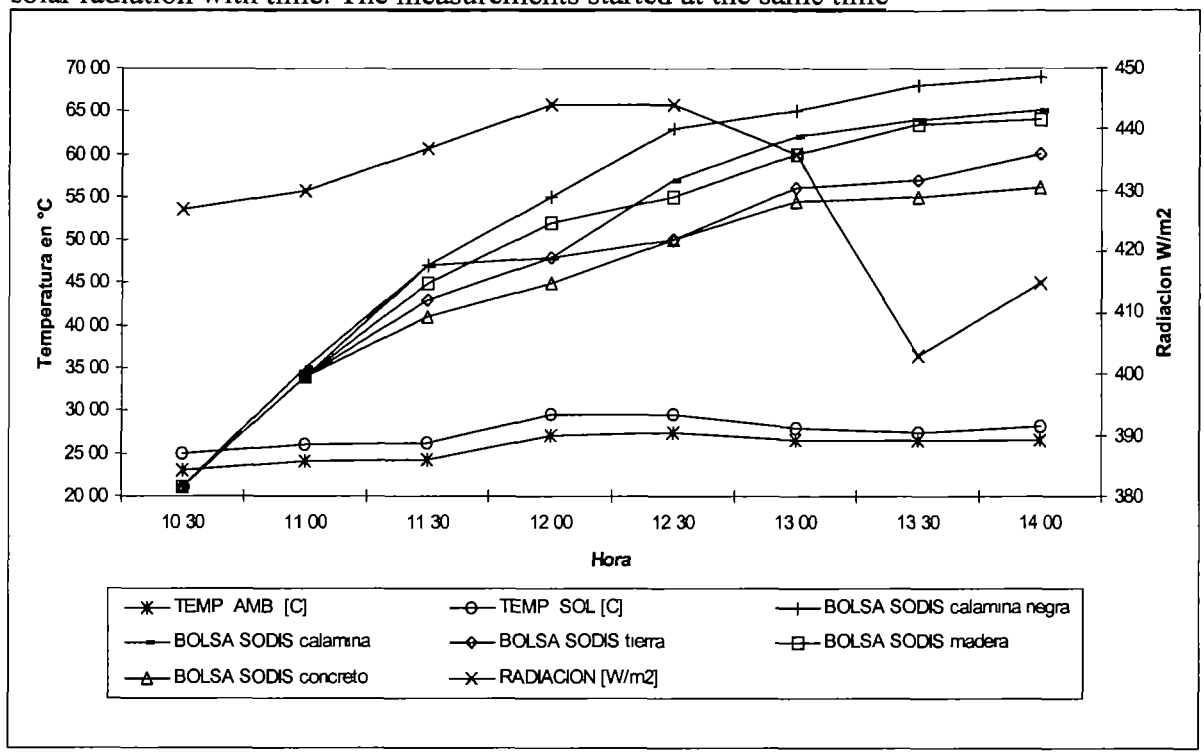
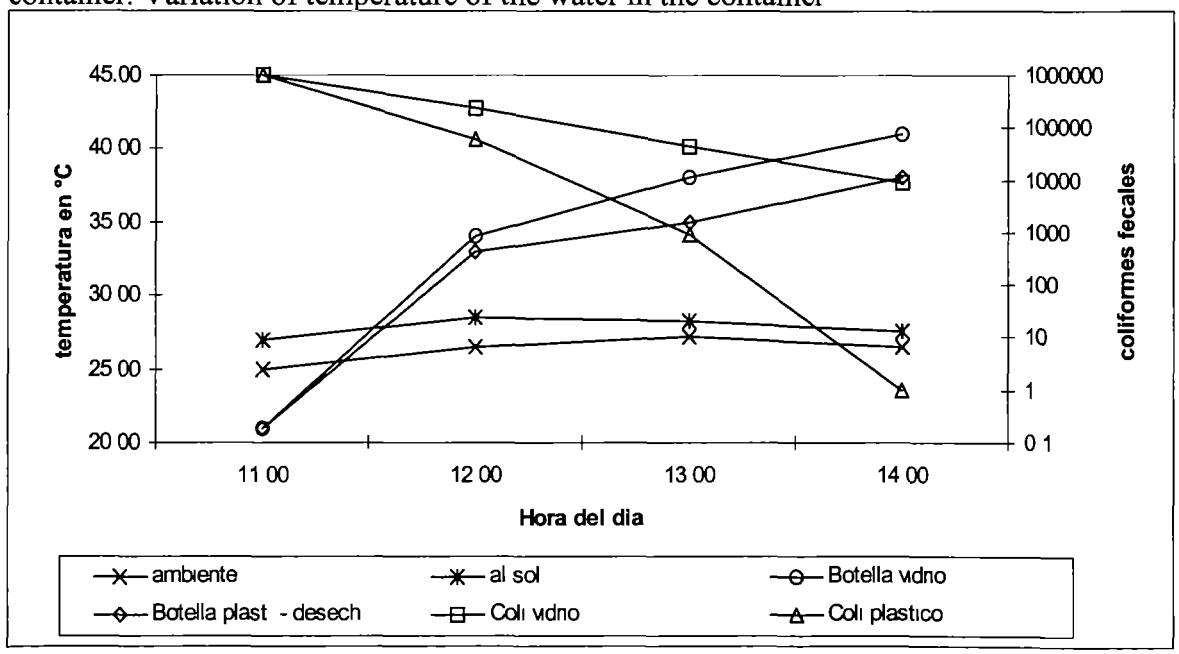


Figure 2.- Variation of removal of coliform, with the exposition time and the type of container. Variation of temperature of the water in the container



EVALUATION OF THE CHARACTERISTICS OF SAND FOR SLOW FILTRATION (2)

Antecedent

The diameters of sand used for slow filtration according to literature go from 0.15 to 0.30 mm, which is usually difficult to fulfill. A slow sand filter to be considered of appropriated technology should use materials available in the area of use.

Objective

The main objective of this work is to determine whether the use of higher sand diameters than the ones suggested by literature, modifies the efficiency of removal of microorganisms present in water.

Methodology

1. Evaluation in field of pilot slow sand filter whose sand diameter ranges between 0.15 and 1 mm. This pilot filter receives water from other gravel filters. It is located near Tarata city, approximately to 40 km of Cochabamba city, and to an elevation of 2800 masl.
2. Evaluation in laboratory of two sand filters:
    3. Sand diameters ranging from 0.15 mm to 0.60 mm
    4. Sand diameters ranging from 0.60 mm to 1.0 mm

Experiments

Initially for both the evaluation filters (for the pilot plant and the laboratory filters) the sand was selected and cleaned. The cleaning was performed with chloride solutions, which left the sands disinfected and free of estrange adhered particles.
The pilot sand filter was constructed after 3 gravel filters, it had a internal diameter of 0.80 m and a high of 2 meters, with a filtration thickness of 1 m.(See fig. 1)
Then the two laboratory filters were constructed in 6" pvc pipes. (See fig. 2)

Results

Pilot sand filter (diameter between 0.15 and 1.00 mm)

Date	Turbidity Entrance NTU	Turbidity Outlet NTU	Iron Entrance Mg/L	Iron Outlet mg/L	Fecal C/100ml Entrance	Fecal c/100ml Outlet	Total C/100ml Entrance	Total C/100ml Outlet
28/10/94	2 4	6 9						
29/10/94	2 3	6 6						
30/10/94	6 2	6 9						
31/10/94	1 2	5 7						
01/11/94	3 7	10 8		0 72				
03/11/94	2 7	7 5		0 26				
04/11/94	13 5	10 0	0 20	0 38	28	0	70	0
07/11/94	4 3	8 3	0 15	0 53	6	1	14	1
11/11/94	1 7	4.8	0 07	0 16	4	0	16	2
13/11/94	10 7	6 4						
14/11/94	10 5	7 5						

Laboratory sand filters

Parameter	Raw water	Prefilter	Filter 1	Filter 2
Sand diameter (mm)			0 15 – 0 6	0 6 – 1 0
Sand bed thickness (cm)			84	80
Filter diameters (cm)			15 2	15 2
Infiltration area (cm^2)			176 7	176 7
Flow (L/sec)			0 00070	0 00075
Filtration rate (m^3/m^2 h)			0 143	0 153
Turbidity (NTU)	7 7	4 4	2 1	3 0
Color (APHA)	140	80	40	50
Fecal coliforms (UFC/100 ml)	TNTC	10	0	0

From the last table it is possible to see that 100% of the bacteriological contamination is removed. Also the turbidity and the color are reduced.

Conclusions

- The results show that it is possible to use higher sand diameters than the recommended by literature for slow filtration.
- The efficiency of the filter increases with the percentage of fine particles, but its life also decreases.
- The removal of fecal coliforms is 99.6%. Another important data is that the heterotrophic bacteria are removed in 96%.
- Slow sand filtration is an alternative for water treatment for human consumption, especially in rural areas.

Figure 1.- Scheme of the pilot plant where the slow sand filter was installed

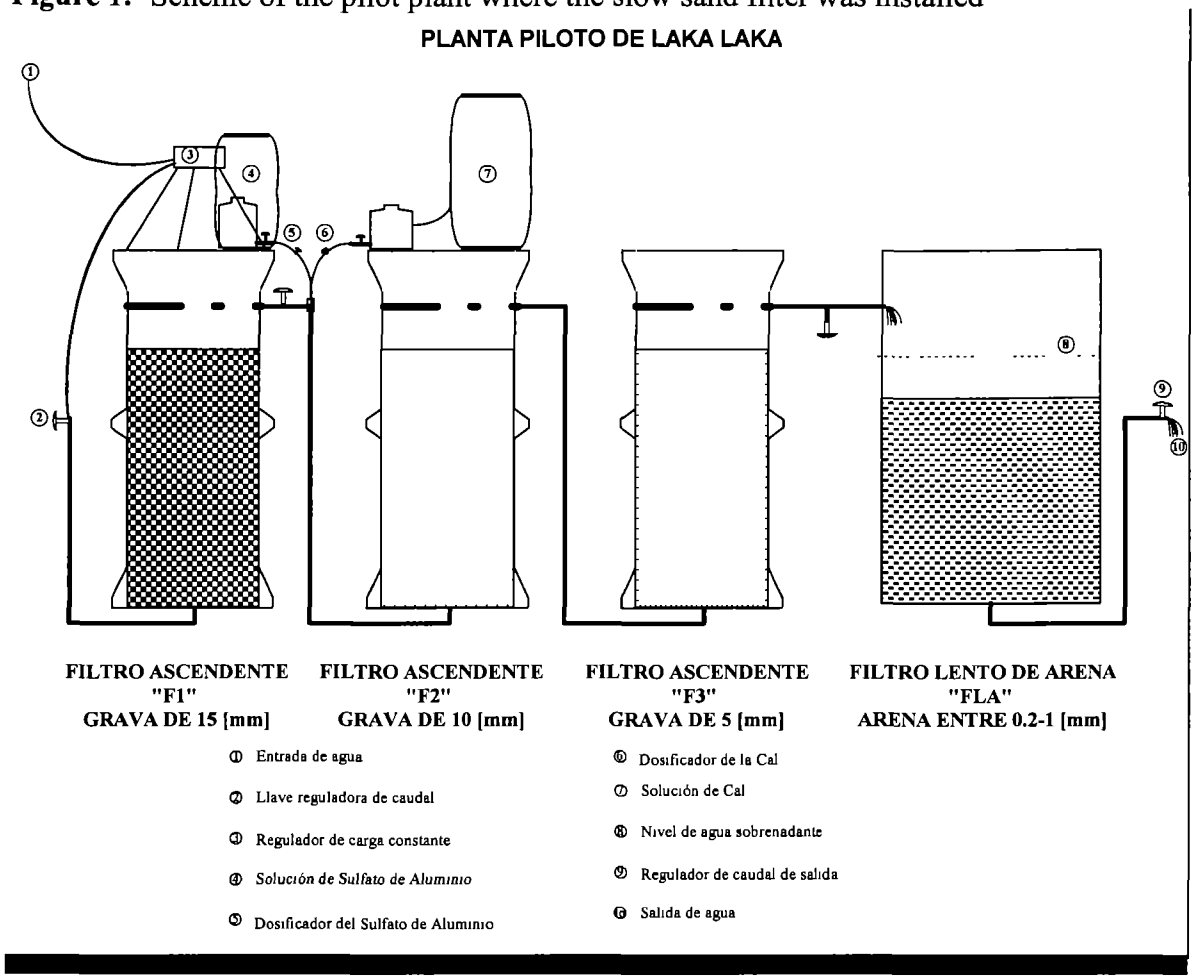
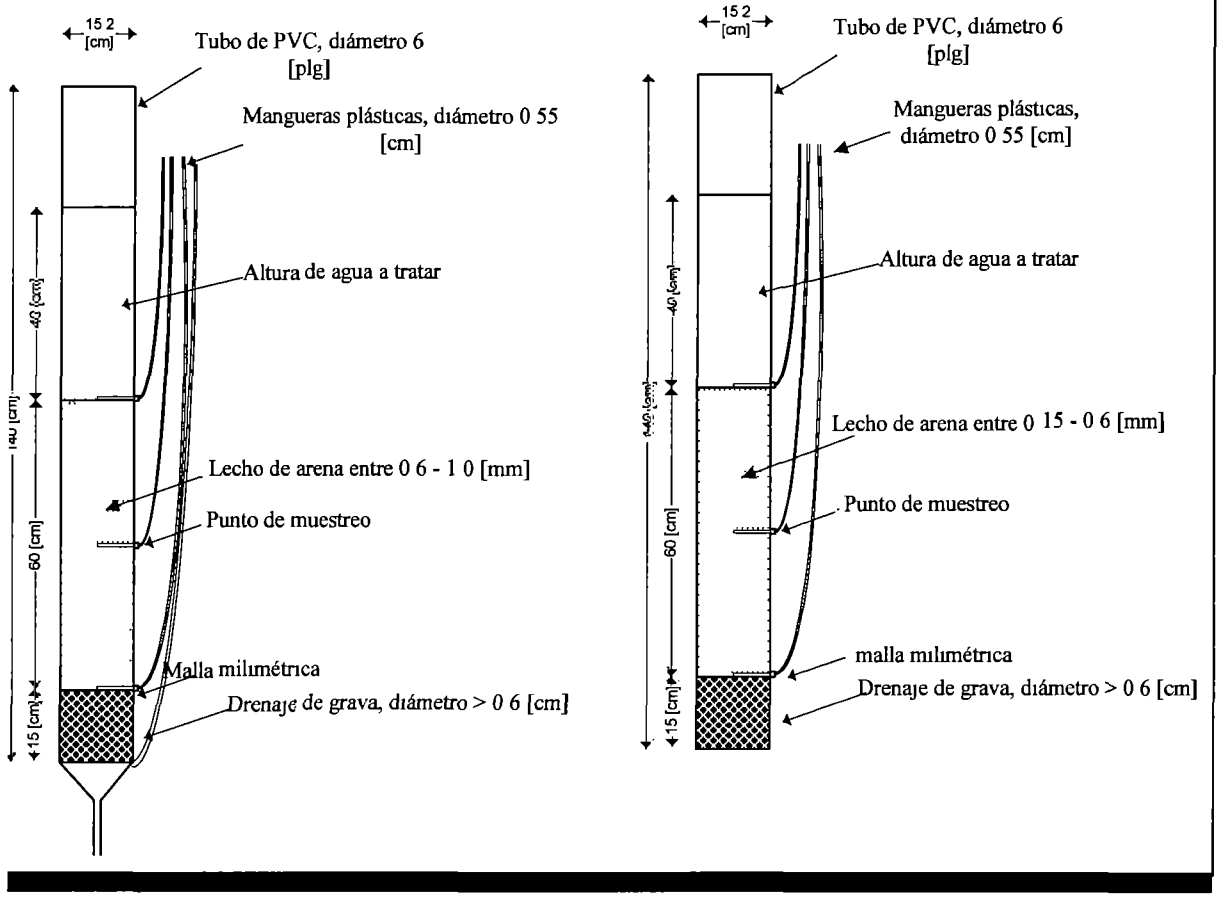


Figure 2.- Scheme of the laboratory Sand filters.

UNIDADES EXPERIMENTALES DE FILTRACION



CHLORIDE DOSIFIERS FOR DISINFECTION OF HUMAN CONSUMPTION WATER WITH APPROPRIATED TECHNOLOGY [3]

Antecedent

The disinfection in water supply systems of rural areas is an important requirement and at the same time one of the most difficult to achieve, mainly due to the quality of the constructions of the supply systems and the capacity of the user population to maintain and operate it.
The problem worsens because most of the institutions in charge of the construction of water supply systems provide only water in pipes, but most of the times not disinfected.
There are still some problems with the traditional disinfection systems:

- Dosing proportional to the volume of consumed water.
- Overflow of the storage tanks, loosing in this way the disinfectant solution.
- Permanent technical control of the dosing system.
- High costs of imported disinfection equipment, which in many cases can not be maintained and operated due limitations of the users.

By reasons like the above mentioned, since 1991 the Programa de Aguas de la Universidad Mayor de San Simon, started the study of a clorination with appropriated technology for rural areas, totally hydraulic, and for use in gravity and pumping systems.
This system has been applied to small water supply systems especially in the Chapare Zone, of Cochabamba, but also in other parts of Bolivia.

Technical characteristics

For the chlorine dosing is used a venturi pipe, which is usually used to measure the flow rate in pipes. It is composed by a convergent conic section, a throat, and another divergent conic section, a scheme of the device is showed in the diagram showed in fig.1.
There are two possibilities of application of the venturi pipe:

- Directly applying the venturi pipe in the body of the main pipe. This form is used when the diameter of the pipe is smaller than 2".
- With a "by pass". In this method the venturi is fitted to a pipe which is parallel to the main pipe, but it is connected to it upstream and downstream the venturi, being of smaller diameter. This way of fitting is used when the pipe by which the water flows has a diameter bigger than 2".

Many laboratory tests were made to see the variations of the dosing volume according with the flow in the main pipe and the head of the tank of disinfecting solution.
From laboratory tests, the first systems for real situation in water supply systems were built.
The need of verifying and controlling the concentration of disinfection solution in the nodes of the water supply systems, impulsed to the design and construction of device to know the concentration of chloride based in a colorimetric technique (colorimeter).
A simplified description of the equipment is showed in figure 2.

- Container for the chloride solution.(A)
- ½" valve, used to make the maintenance and recharge of chloride solution (B).
- Small container used to regulate the head of the chloride solution ©.
- Small diameter valve used to regulate the entrance of chloride solution to the main pipe (D)

- Venturi pipe. Used for mixing and regulating the solution that goes in to the main pipe (E).
- Control point, to verify the concentration of chloride in the water (F).
- Small accessories and hoses.

All the materials used in the device can be found in any local market.

Costs

The cost will depend on the flow rate, the diameter of the pipe, the material of the venturi, the quality of the water, etc. An average cost is approximately 300 american dollars for a system of 1.5 l/s and a diameter of 2". Operation and maintenance cost depend on the system characteristics.

Monitoring and continuous assessment

Monitoring and assessment is a necessary activity. A continuous training program for operators and users on the use and maintenance of the system should be carried out.
Asessments to the different systems in which the venturi pipe has been installed, has given as result, standardized characteristics for different diameters, flows and types of systems (pumping and gravity).

Conclusions

Due to the characteristics of the disinfection system, its use is ideal for populations with water supply systems where there is no electricity and technical personal, for pumping as well as for gravity systems.
The use of a venturi pipe enhances the mixing and the process of disinfection.

Figure 1.- Diagram of venturi

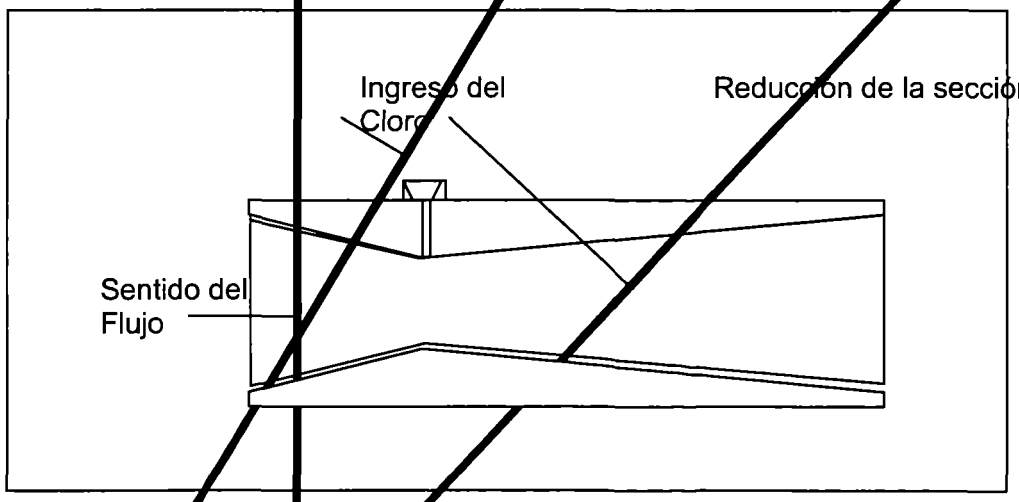
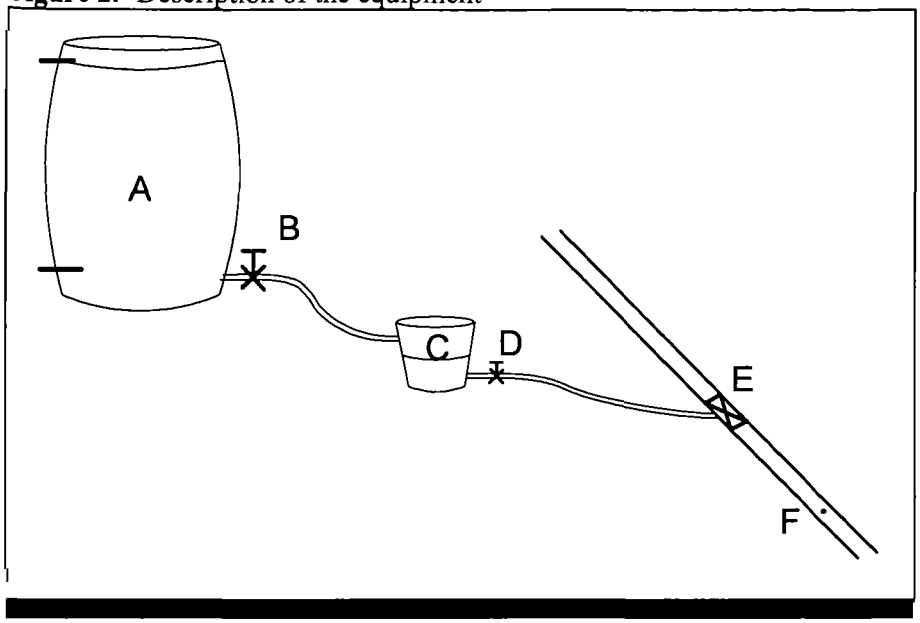


Figure 2.- Description of the equipment



GENERAL CONCLUSIONS

Simple technologies are accepted more easily by people than modern ones, since the simple technology devices and equipments can be repaired or replaced by users, or by personal which can be paid by the users.

The appropriate technologies are an alternative for the developing countries, mainly due the low income of the most of the population. therefore the intended assistance to these countries should be focused in the development of appropriate technologies.

References

(1), (2) and (3) are summaries of presented works in
Taller regional sobre tecnologias adecuadas en saneamiento basico para el ambito rural. Abril de 1998- Lima, Peru. Presented by Olver Coronado

(1) Participants: Olver Coronado, Alvaro Mercado, Ramiro Fuentes G., Sonia Peredo, Rosmery Ayala, Claudia Gonzales, Ernesto Mendoza, Dulio Orellana.
(2) Participants: Olver Coronado, Amadeo Merida, Fernando Zegarra, Jorge Mejia.
(3) Presented work in the I Simposio
Participants: Olver Coronado, Amadeo Merida

Nigel Browne

From: Jan Teun Visscher
Sent: Tuesday, October 27, 1998 9:55 AM
To: Nigel Browne
Subject: FW: For Jan Teun Visscher

Another paper that was prepared for the Barcelona conference containing interesting field data on solar disinfection

Jan Teun
—Original Message—
From: Lia Wahab
Sent: dinsdag, oktober 20, 1998 10 03
To: Jan Teun Visscher
Subject: FW For Jan Teun Visscher

—Original Message—
From: Alvaro Mercado [SMTP Alvaro mercadoguzman@student kuleuven ac be]
Sent: Monday, October 19, 1998 6 21 PM
To: general@irc nl
Subject: For Jan Teun Visscher

Hola Jan Teun, soy Alvaro Mercado Yo me encontraba en el simposio sobre tecnologias adecuadas llevado a cabo en Barcelona Te envio como te comente antes, el articulo que presentamos al simposio
Te lo envio ahora porque me olvide entregartelo y por que no lo publicaron en el CD del simposio, ni en el resumen

Saludos

Alvaro

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