WATER PURIFICATION USING SMALL ARTISAN FILTERS

J. Fernando Mazariegos, Julia Alicia A. de Zeissig
Analysis and Testing Division
Central American Research Institute for Industry
I C A I T I
P.O. Box 1552
GUATEMALA, Guatemala

Guatemala, 1981

BACKGROUND NOTE

The results of the technological research reported in this paper are part of a series of investigations conducted under the Technical Cooperation Agreement signed between the Inter-American Development Bank (IDB) and the Central American Research Institute for Industry (ICAITI). The one given here refers to technological research on "Water Purification for Human Consumption Using Small Filters". The final report was submitted to IDB for evaluation.

The paper presented at the XIII Central American Congress of Sanitary and Environmental Engineering is based on that technological research. The original conception for this project was prepared by present Director of ICAITI, Licenciado Francisco Aguirre B. (at that time Technical Deputy Director) for submittal to IDB. The research work was conducted under the supervision of Licenciado Fernando Mazariegos Anleu, Head of the Analysis and Testing Division, with the close collaboration of Licenciada Julia Alicia Amado de Zeissig, of the same Division, who carried out the field and laboratory experimental work.

Permission to reproduce the technological information contained in the final report was granted for distribution among the participants to the XIII Central American Congress of Sanitary and Environmental Engineering, in virtue of the fact that this work received the Central American AIDIS Prize, on the ground that its results could have economical and social benefits for the rural population by improving their sanitary conditions.

STATEMENT OF THE PROBLEM

The supply of drinking water is a fundamental aspect in the economic and social development of a country. As such it should be approached from all possible angles so as to identify practical solutions which could be adopted and supported by all agencies interested in fostering development with a maximum potential of social benefits. It is deemed a desirable long-term objective that all Central American inhabitants (and the world) be provided with running drinking-water in their homes and working sites.

In each Central American country there are agencies, ministries and secretariats directly engaged in development and the introduction of drinking-water systems in rural communities. There is full confidence that the contemplated goals would eventually be attained. However, the existing programmes have limited human and financial resources.

Consequently, there are still large population segments (especially rural) that, because they are geographically dispersed and require relatively large investments, lack drinking water services.

A rural population without drinking water services was estimated at 8.7 million for all Central America in 1980[1]. Thanks to efforts of agencies engaged in the

---

1 ICAITI, based on statistics of the "Comité Permanente de Saneamiento Ambiental".

introduction of drinking-water services, this population is growing at a lower rate than the population in general. Hence, eventually all the Central American population will be covered[1].

While these objectives are being reached, there are ample possibilities and justification for undertaking complementary efforts for drinking-water supply, especially if these are self-supporting and at the same time fulfill other economic and social development goals.

ICAITI and the developing agencies share the thought that it is preferable in the long run to help those that help themselves. Therefore, the problem of identifying and developing complementary services of drinking-water supply entails the need to solve it without requiring permanent national or international financial support.

A third aspect of the problem is the raising of the living standards in the Central American countries. Undoubtedly the quality of water, especially the microbiological quality, is an element of utmost importance for improving the health conditions of the population and thus raise their quality of life.

Therefore, the potential social benefit arising from any developing effort is larger on the short and medium terms if it is addressed to low-income social groups.

A fourth aspect of the problem which is worthy of mention from a holistic standpoint concerns the present and future underemployment stemming from the disappearance of cottage activities that require a special talent. As the agro-industrial

---

[1] At the present rates this would occur after the year 2020.

economic development advances following mainly western patterns, some typically artisan activities must compete with cheaper and more convenient products. Such is the case of the earthen jars of Guatemala which are being substitued by plastic jars (lighter and more durable).

Evidently these new products offer advantages to the consumer. However, it is an acceptable assumption that such competition has forced potters to seek alternative occupations and in some cases the alternatives represent an under-utilization of the individual talent of the potters and result in some measure of unemployment.

In the present case, the fourth component of the project is to create new opportunities which will allow a revival of the artisan activities in the Central American region.

Briefly, the project attempts to: a) contribute to solve part of the problem of drinking-water supply on the short and medium terms; b) spur productive activities among the low income economic sector; and c) contribute to a revival of artisan activities in the region.

This is the conceptual framework of the project which gooded the present efforts and towards which were oriented the long term objectives of the investigation.

OBJECTIVES

To the conceptual construe of the problem posed in the foregoing pages is added the interest shown by the Inter-American Development Bank (IDB) to obtain a means of drinking water supply by technology tailored to the needs and possibilities of the Area. Within the Appropriate Technology programmes the present project was conceived with the following objectives:

i) To quantify the potential demand of filters for domestic use in Central America.

ii) To examine and evaluate potential alternative models for making domestic filters for water purification, after carrying out a preliminary evaluation.

iii) To investigate and evaluate the technologies, raw materials and materials available for making the filters. This entails an additional refinement of prototypes.

iv) To evaluate the prototypes that offer the best prospects for: a) contributing to solve the drinking-water problem in rural areas; b) being self-supporting; c) fostering economic activity at low income economic levels; and d) vitalizing the artisan activities. This evaluation will be effected from the physical, microbiological and economic standpoint.

v) To select and describe the prototype that best suit the objectives.

vi) To formulate strategies that lead to the general use of the selected filter.

Since it is unlikely that only one type of filter would be the solution to all problems, first rating will be given to the filter that contributes to a larger extent to solve the drinking-water problem and that do not require permanent financial support.

IDENTIFICATION AND EVALUATION OF DESI-
ALTERNATIVES FOR A LOW COST DOMESTIC
FILTER FOR DRINKING WATER

IDENTIFICATION AND EVALUATION OF DESIGN ALTERNATIVES FOR A LOW COST DOMESTIC FILTER FOR DRINKING WATER

The goal of this stage of the investigation was to determine the filter type which could be best adapted to the general objectives of the project, namely: a) produce a domestic filter of suitable capacity; b) in a self-supporting manner; c) whose production would foster the economic activity at low income levels, and d) foster the artisan activity.

With this purpose, and after a general review of the existing literature related to the subject, the following models which are discussed below were identified:

1. Glass filter with filtering layers of sand, gravel and charcoal.
2. Filter made of carved stone.
3. Gypsoum moulded clay filter with filtering layers of impregnated charcoal.
4. Tin plate filter with filtering layers of sand, gravel and charcoal.
5. Lathed clay filter with a filtering candle.
6. Lathed filter with a pumice candle.
7. Lathed clay filter with charcoal.
8. Clay filter with filtering layers of charcoal,sand and gravel in the upper part.
9. Lathed clay filter with feldspar, sawdust and colloidal silver impregnation.

× 10. Lathed clay filter with sand, sawdust and colloidal silver impregnation.

These ten models were evaluated on the basis of the following criteria:

a) Filtration flow

b) Bacteriological efficiency

c) Ease of manufacture

d) Availability of materials

e) Final cost

f) Contribution to artisan activity

d) Ease of distribution

Since the prime objective of the project was to find an effective filter, the bacteriological efficiency was tested first, that is, the efficacy in obtaining drinking-water. The criteria used were the evaluation of the disappearance of the coliform organisms which serve as an indicator of the bacteriological contamination of the water.

The World Health Organization (WHO) establishes standards of bacteriological quality for treated waters by the method of the most probable number of Coliforms (MPN). The number must be below 1.0 microorganisms per 100 ml of sample. No sample should exceed 10 MPN. In order to determine the efficiency the filters were tested during a minimum of 48 hours. If results were satisfactory the sample water having an initial count of 2 400 coliform groups was recontaminated by the method of the most probable number in 100 ml. These analyses were effected by the Standard

Methods for Examination of Water and Waste Water, 14th Edition, 1975. (APHA-AWWA-WPCF).

Results are shown in Table 5.1. On the basis of these results, the filter models 1, 4, 5, 6 and 8 were eliminated, as well as a variation of filter model 2 manufactured in Honduras.

The following step consisted in discarding those filters whose initial filtration flow was less than 2 liters/day. By virtue of this criteria the filter model 7 was discarded,since its filtration rate was only 0.5 liters/day.

After the filter model 3 was also discarded because it is not easy to obtain charcoal in Central America unless the production is centralized. 7 and silver ento

A variety of the filter model 2 manufactured in Guatemala and prototypes 9 and 10 were submitted to further testing.

The guatemalan variety of filter model 2 (of carved stone) was discarded for the following reasons:

i) Low availability of artisans capable of carving stone filters (Criterium C);

ii) Relative scarcity of materials (Criterium D);

iii) High unit cost, $US 20.00, although the durability of the filter is practically unlimited; from the technical viewpoint, high initial investment.

iv) Difficult distribution (Criterium G) because of the limited distribution areas, although the high impact strength eases transportation.

v) pesa mucho

The remaining filters 9 and 10 were subjected to further physical and bacteriological tests. The results are given in the corresponding chapter.

Table 5.2 shows a summary of the evaluation of the filter models carried out at this stage of the investigation. A more detailed description of the models tested is given in Appendix 1.

TABLE 5.1

RESULTS OF THE MICROBIOLOGICAL EVALUATION BY THE MPN METHOD OF COLIFORMS FOR THE FILTER MODELS EXAMINED IN THE PRELIMINARY INVESTIGATION

	Contamination MPN	Test 1 24 hr	Test 2 48 hr	Test 3	Recontamination
1. Glass filter with filtering layers of sand, gravel and charcoal.	> 2 400	2 400	2 400	2 400	2 400
2. 2.1 Filter of carved stone made in Guatemala	> 2 400	0	0	0	0
2.2 Filter of carved stone made in Honduras	> 2 400	0	1 100	1 100	1 100
3. Gypsum moulded clay filter with filtering layers of impregnated charcoal.	> 1 100	0	0	0	0
4. Tin plate filter with filtering layers of sand, gravel and charcoal	> 2 400	2 400	2 400	2 400	2 400
5. Lathed clay filter with filtering candle	> 2 400	2 400	2 400	< 1 100	2 400
6. Lathed clay filter with a pumice candle	> 2 400	2 400	2 400	2 400	2 400
7. Lathed clay filter with charcoal	> 2 400	0	3.6	1 100	> 2 400
8. Clay filter with filtering layers of charcoal, sand and gravel at the upper part	> 2 400	2 400	2 400	0	0

9 and 10. These results are not included in this Table, since filters 9 and 10 were subjected to further evaluation which is described in the corresponding Chapter.

TABLE 5.2

SUMMARY OF INITIAL EVALUATION OF THE DOMESTIC FILTER MODELS FOR DRINKING-WATER (1980)

	Filtration flow	Bacteriological efficiency	Ease of manufacture	Availability of materials	Final cost 1/	Contribution to artisan activity	Ease of distribution
1. Glass filter with filtering layers of sand, gravel and charcoal	Good 245 l/day	Bad	Filtering layers must be of suitable size	Yes for filtering materials; no for container	High	None	Difficult
2. Carved stone filter 2.1 Made in Guatemala 2.2 Made in Honduras	Good 8.3 l/day Good 8 l/day	Good	Only few artisans can carve this type of material	Suitable materials are found only in certain areas	High	High	Difficult
3. Gypsum moulded clay filter with filtering layers of impregnated charcoal	Good 700 l/day	Good	Gypsum moulding is not common in all Central American areas.	The coal used must be mineral and it is difficult to obtain as well as the gypsum for moulds	Fair	Low	Fair
4. Tin plate filters with filtering layers of sand, gravel and charcoal	Good 13.9 l/day	Bad	Welding expertise is needed to made the containers	Charcoal and tin plate materials are difficult to obtain	High	Low	Fair
5. Lathed clay filter with filtering candle	Fair 2.8 l/day	Bad	Although it is a pottery process, the manufacture of the candle is difficult	Readily available materials	Low	Large	Fair

TABLE 5.2

CONTINUATION

	Filtration flow	Bacteriological efficiency	Ease of manufacture	Availability of materials	Final cost 1/	Contribution to artisan activity	Ease of distribution
6. Lathed clay filter with pumice candle	Bad 0.6 l/day	Bad	Difficult to make the lathed candle needed	Pumice stone is found only in certain zones	Low	Large	Fair
7. Lathed clay filter with charcoal	Bad 0.5 l/day	Good	Easy to make	Readily obtainable	Low	Large	Easy
8. Clay filter with filtering layers of charcoal, sand and gravel	Good 9.6 l/day	Bad	Like No. 1	Filtering materials, yes ; excepting charcoal	Fair	Low	Fair
9. Lathed clay filter with feldspar, sawdust and impregnation of colloidal silver	Good 10.8 l/day (initial)	Good	Easy to make and incorporate the material	Most materials readily available, except feldspar	Low	Large	Easy
10. Lathed clay filter with sand, sawdust and colloidal silver impregnation	Good 9.3 l/day (initial)	Good	Easy to make and incorporate the materials	All material are readily available	Low	Large	Easy

1/ Low: under US$ 10.00; fair: between US$ 11.00 and 20.00; high: over US$ 20.00

INVESTIGATION OF TECHNOLOGY, COSTS, RAW MATERIALS AND MATERIALS NEEDED FOR THE PROTOTYPE SELECTED

INVESTIGATION OF TECHNOLOGY, COSTS, RAW MATERIALS AND MATERIALS NEEDED FOR THE PROTOTYPE SELECTED

In this Chapter are identified the available technologies for manufacturing filter models Nos. 9 and 10 (Lathed clay filters with sand (or feldspar), sawdust and colloidal silver) and a summary is given of the results of studies related to availability of raw materials (clays) which were conducted as part of this project.

1. Available Technology

Basically two types of technology were identified for making in Central America filter models 9 and 10. These are: i) artisan technology; ii) industrial technology. Although the latter involves less potential for fostering independently the artisan activity (and probably less effect on income distribution), its potential for reducing costs and sales prices could be valuable for extending the scope of the project and for contributing to a larger extent to solve the problem of drinking-water in the region.

In what follows we will give a brief description of these technological levels.

1.1 Artisan level

This is labour intensive (that is, no motive power such as electricity or fuel) and has a relatively small scale of operations (15 filters per day or less). Its organization is typically individual (the owner and his assistants) employing no more

than five persons. Firewood is used as fuel in the kilns and the maximum annual production is about 4 500 filters.

Table 6.1 shows a cost structure for a filter factory at artisan level. This Table includes the necessary investment for installing a filter factory with a production capacity of 4 500 units per year. A unit price of US$8.69/filter was estimated using artisan technology (1980).

Additionally, as part of the investigation, the major part of the pottery zones of Central America were visited with a view towards: a) determining the ability of artisans to make non conventional pottery items; and b) determining the feasibility or tolerance of incorporating new materials to the clay without affecting the manufacturing process.

The investigations showed that there was no difficulty in making clay filters at the Central American artisan level. It was also possible to aggregate 60% of materials associated with clay (sand, sawdust, feldspar, infusorial earth, charcoal dust, pulverized pumice, kaolin, etc.), without modifying the conventional processes of handling, puddling, lathing and baking.

The investigation concluded that it is feasible to make the required designs and incorporate the non conventional materials to the Central American artisan pottery.

Some difficulties were foreseen when the potter did not use a lathe or when he used open kilns with variable temperatures. For this reason a higher technological

level was selected involving the use of lathes and kilns as it is shown in the Annexes to this study.

1.2 Industrial level

In the Central American context the pottery activity is considered at the "industrial level" to be a plant with a production capacity of about 150 filters/day (450 000 filters/year) which uses some mechanical equipment such as milling machines and belt conveyors. Lathes would be manually operated, but the use of some machinery increases the productivity of qualified workers which then engage only in lathing tasks.

Table 6.2 shows costs, profits and possible sale prices for an industrial type operation. The unit price including profits was estimated at US$6.95 (1980), that is, 20% lower than the price of artisan filters by virtue of a larger productivity of the industrial enterprise.

The fixed investments and working capital requirements for both technological levels are given in Table 6.3.

2. Raw materials

An evaluation was made of the availability of raw materials required for manufacturing clay filters in large amounts in Central America. Since the main raw material is clay, an assessment of clay deposits was carried out as regards quantity, approximate size and present use.

This evaluation was conducted by means of direct inspection on site and a study of available bibliography. In addition to geological considerations, economic criteria were also used such as accesibility, land tenure and possible cost of extraction.

The assessment covers Guatemala, El Salvador, Honduras and Costa Rica. An evaluation in Nicaragua was not possible owing to the conditions prevailing in that country at the time of conducting the field work.

2.1 General

In most parts of Central America are clay deposits. However, not many of these deposits are deemed suitable for pottery. There is a lack of important lake deposits which are economically the best sources for development of the pottery activity, both at the artisan and the industrial levels.

The clays available in Central America usually come from igneous rocks in which feldspars and other minerals have been converted to clayey minerals by the action of rain and other environmental agents. These alterations in the components of volcanic rocks are usually sources of montmorillonite. In pottery this is preferred to kaolinite.

Since Pre-Columbian times an artisan pottery has been developed in the area from raw material deposits which, although scant, they comply with requirements for this type of production. The Central American clays do not entail an obstacle for manufacturing drinking water filters of an artisan level.

2.2 Costa Rica

Costa Rica is the Central American country that has the least important pottery industry. Its topography is characterized by a central structure of high mountains compounded by a sequence of volcanoes (some times active, like Poas, Irazú and Arenal) which slop steeply towards the sea coast and make difficult the formation of clayey deposits. The well defined river network, owing to the high moisture of the zone, cannot find closed depressions where to deposit residual clayey materials. Because of the petrographycal and climatological conditions, the clays formed in significant quantities run directly to the sea or are mixed with coarse alluvial material (sand, gravel) on the river beds of the coastal plains.

Costa Rica has three relatively important pottery production centres, namely: Guaitil, Santa Ana and Cartago. There are other significant deposits which are not developed as pottery production centres. Among these we can mention Agua Caliente, Desamparados, Alajuelita, Esazú and Cariz (with common clays) and El Arenal, Desamparados and surroundings, Espanta, Juan Viñas and surroundings, Tierra Blanca Cartago, Potrero Cerrado and Volcan Poas and surroundings (with kaolin).

A summary of the characteristics of the main clay deposits in Costa Rica are shown in Table 6.4.

2.3 El Salvador

What follows is a summary of a report prepared by the "Centro de Investigaciones Geotécnicas (Geotechnical Research Center)[1], at the request of the Insti-

[1] Geologist Mauricio Retana, 1961

tuto Salvadoreño de Fomento Industrial (Salvadorean Institute for Industrial Development - INSAFI), which comprissed 64 field visits, sampling and several chemical and physical tests.

Among the main deposits indentified are: Hacienda San Francisco, Puerto de Acajutla and Depósito Miraflores, and among the least important one may mention Ilobasco, Hacienda San José, Río Grande, El Paisanal, Aguilares, Armenia and La Palma.

Table 6.5 gives a summary of the characteristics of the main deposits.

2.4 Guatemala

This is the Central American country exhibiting a greater geological diversification. The tapped clay deposits are located in the Central and Southern regions which are highly populated.

The volcanic plateau which runs throughout Central America appears only in the Southern and Western part of Guatemala. Since the relief is propounced, the vegetation is poorly distributed and the climate is violent, a strong erosion occurs which drags the soil material including boulders.

This general conditions contribute to the escarcity of large deposits.

The important alluvial deposits consist of coarse conglomerate, sands, gravels and rarely clays, which require still waters without sand.

Suitable deposition conditions are found in small areas.

These deposits are tapped by artisan potters both for commercial and domestic use.

The chief Eastern deposits are Jalapa, San Luis Jilotepeque, Jutiapa and Santa Catarina Mita. The central deposits include Santa Rosa de Lima, Chimaltenango, Chinautla, Rabinal and Purulhá, and the Western deposits are in Totonicapán. There are other deposits in Chinautla, San Pedro Jocopilas and San Miguel Ixtahuacán.

A summary of the characteristics of the main deposits is shown in Table 6.6.

2.5 Honduras

The morphology is favourable and there are deposits in almost the entire land. The mountain ranges with different strikes, the uneven geology, and the complex topography with intricate hydrography permit several clay depositions. There exist abundant almost-closed depressions on which a river-lake deposition type occurs. Simultaneously, the Hondurean forest acts like a filter which only allows the passage of fine material and retains the gravel, sand and stones.

Most of the usable clay resources of Central America are located in Honduras. The main deposits are Ojona, Orocuina, La Arada, San Francisco Choluteca, Siguatepeque, Jesús de Otoro-Masaguara, La Campa, Yarumela (La Paz) and the Western part of lake Yojoa; other deposits include Santa Rosa de Copán, Santa Cruz de Yojoa and the Northern part of Tegucigalpa.

Table 6.7 shows the characteristics of the main deposits in Honduras.

The conclusion based on the foregoing facts is that in all the Central American countries studied there are both significant clay deposits and pottery communities.

Pottery tradition is high in Guatemala, followed by Honduras, El Salvador and Costa Rica. The raw material is not a limiting factor for developing the project, but the most appropriate technology and technological level for each case should be defined.

A summary of results of the clay study are shown in Table 6.8.

3. Materials

In the preselected designs the required components in addition to clay are: a) feldspar, sawdust and colloidal silver for filter No. 9; b) sawdust, sand and colloidal silver for filter No. 10.

Although feldspar is abundantly found in mixtures, it is not readily available isolated or in sound mixtures easily identifiable which permit a systematic and controlled incorporation to the manufacturing process of a filter. Therefore, the feldspar produced by industry would have to be used. At present, a metric ton of granulated feldspar has a factory price of about US$30 000, in the Southern coast of Guatemala. Transportation to a pottery centre in Totonicapán would cost approximately US$15/t. The transportation cost to Jalapa would amount to about US$35.00/t. The feldspar plants are associated or are part of the glass plants operating in the Central American area. However, the price and transportation cost will add about US$0.05 to the final cost of each filter and the situation would be complicated by the need to install warehouses, or to waste resources by having to place frequent small orders which would result in increasing costs.

It was found that the river sand availability was not a limiting factor, for this material abounds in the entire region and it is mostly found near clay deposits.

Likewise, sawdust is not an important limiting factor, although it is necessary that the potters or filter makers assure themselves of an adequate supply by contacting one or several sawmills so as to prevent a shutdown for lack of this input.

As regards colloidal silver, this is imported at present at a price of US$90.00 per litre. ICAITI established that it could be made in Guatemala at the Institute, who would see it to filter manufacturers. This would have the following advantages: a) lower costs to approximately US$60.00/litre; b) keep ICAITI directly and permanently involved in the project; c) yield profits which would allow financing the quality control programme for the filters and indirectly fostering the use of the filters.

TABLE 6.1

COSTS, INVESTMENTS AND POSSIBLE SALE PRICES FOR AN ARTISAN PRODUCTION OF FILTERS FOR DRINKING-WATER (US$)

	US$
1. Possesion Costs	
1.1 Insurance and taxes	1243
1.2 Interest	1600
1.3 Depreciation	2133
	4976
2. Service Costs	
2.1 Water and Electricity	350
2.2 Fuel (firewood)	2660
2.3 Maintenance	350
	3360
3. Operating Costs	
3.1 Management and Supervision	6000
3.2 Qualified Labour	6000
3.3 Non Qualified Labour	3000
3.4 Fringe Benefits	2700
	17700
4. Raw Materials and Auxiliary Materials	
4.1 Mud	700
4.2 Sand	550
4.3 Sawdust	125
4.4 Colloidal Silver	3240
	4615
5. Other Costs	
5.1 Sale Cost	3525
5.2 Incidentals	340
	3865

TABLE 6.1

CONTINUATION

		US$
Total Cost		34516
Unit Cost		US$7.63
6. Profits		
	6.1 Profits of the Artisan-Entrepreneur	4598
		4598
TOTAL COST + PROFITS		39114
UNIT PRICE		US$8.69

TABLE 6.2

COSTS AND POSSIBLE SALE PRICES FOR AN INDUSTRIAL PRODUCTION OF FILTERS FOR DRINKING-WATER (US$)

		US$
1.	**Possesion Costs**	
1.1	Insurance and taxes	9283
1.2	Interest	9080
1.3	Depreciation	11000
		29363
2.	**Service Costs**	
2.1	Water and Electricity	1000
2.2	Fuel (firewood)	26600
2.3	Maintenance	3300
		30900
3.	**Operating Costs**	
3.1	Management and Supervision	22500
3.2	Qualified Labour	45000
3.3	Non Qualified Labour	22500
3.4	Fringe Benefits	20250
		110250
4.	**Raw Materials and Auxiliary Materials**	
4.1	Mud	7000
4.2	Sand	5500
4.3	Sawdust	1250
4.4	Colloidal Silver	32400
		46150

TABLE 6.2

CONTINUATION

5. Other Costs	
5.1 Sale Cost	26206
5.2 Distribution and Packing Costs	18000
5.3 Incidentals	6650
	50856
TOTAL COST	267519
UNIT COST	US$5.94
6. Profits	
6.1 Investor Profits	45400
	45400
TOTAL COST + PROFITS	312919
UNIT PRICE	US$6.95

TABLE 6.3

INVESTMENT REQUIREMENTS FOR DIFFERENT TECHNOLOGICAL LEVELS
- Thousand US$ -

A. Fixed Investments

Item	Investment in thousand US$	
	Artisan 4 500 a/u	Industrial 45 000 a/u
Land	2.0	12.0
Buildings	15.0	90.0
Yards and Civil Works	5.0	20.0
Auxiliary Installations, Water and Electricity	2.0	10.0
Lathes	1.5	5.0
Kilns	1.5	10.0
Miscellaneous	5.0	18.0
SUB-TOTAL	32.0	165.0
B. Working Capital	8.0	62.0
TOTAL	40.0	227.0

[illegible] RICA: CHA[illegible]

	Approximate size of deposit	Access	[illegible] of Extraction	Quality	[illegible]
[illegible] East of San [illegible]	5,000	Good	High	High	
[illegible] East of San José	2,500	Good	High	High	
[illegible], 2 [illegible] South of Cartago	–	Poor	Low	-	

TABLE 6.5

EL SALVADOR: CHARACTERISTICS OF THE MAIN CLAY DEPOSITS

Location	Approximate Size of Deposit	Access	Ease of Extraction	Quality	Pottery Development
1. Hacienda San Francisco, Department of Cabañas, Southeast of Ilobasco	20 000	Good	High		Yes
2. Port of Acajutla, Department of Sonsonate	52 500	Good	High		Yes
3. Miraflores Deposit, Departments of San Miguel and La Unión	1 400 000	Good	High		Yes

TABLE 6.6

GUATEMALA: CHARACTERISTICS OF THE MAIN CLAY DEPOSITS

Location	Approximate Size of Deposit	Access	Ease of Extraction	Quality	Pottery Development
1. Jalapa	300 000	Good	High	Good	Yes
2. San Luis Jilotepeque (30 km East of Jalapa)	2 000	Poor	Low	Low	Yes
3. Jutiapa	2 000 000	Good	High	Good	Yes
4. Santa Catarina Mita	150 000	Good	High	Good	Yes
5. Santa Rosa de Lima		Good	Fair	Poor	No
6. Chimaltenango	1 000 000	Good	Good	Low	No
7. Chinautla		Good	Fair	High	Yes
8. Rabinal	4 000 000	Good	Poor	High	Yes
9. Purulhá	100 000	Good	High	High	No
10. Totonicapán	1 000 000	Good	High	High	Yes

Source: ICAITI

TABLE 6.8

CENTRAL AMERICA: QUALIFICATION OF THE MAIN CLAY DEPOSITS IN EACH COUNTRY

	A	B	C[1]
Costa Rica			
Guaitil	x		
Santa Ana	x		
Cartago			x
El Salvador			
Aguilares		x	
Hacienda San Francisco	x		
Puerto Acajutla		x	
Miraflores-El Carmen		x	
Guatemala			
San Luis Jilotepeque	x		
Jalapa	x		
Jutiapa	x		
Santa Catarina Mita	x		
Rabinal	x		
Purulhá		x	
Totonicapán	x		
Honduras			
Ojojona	x		
Orocuina	x		
La Arada		x	
San Francisco Choluteca			x
Siguatepeque	x		
Jesús de Otoro-Masaguara			x
La Campa	x		
Yarumela		x	

1 A: Excellent
B: Good
C: Acceptable

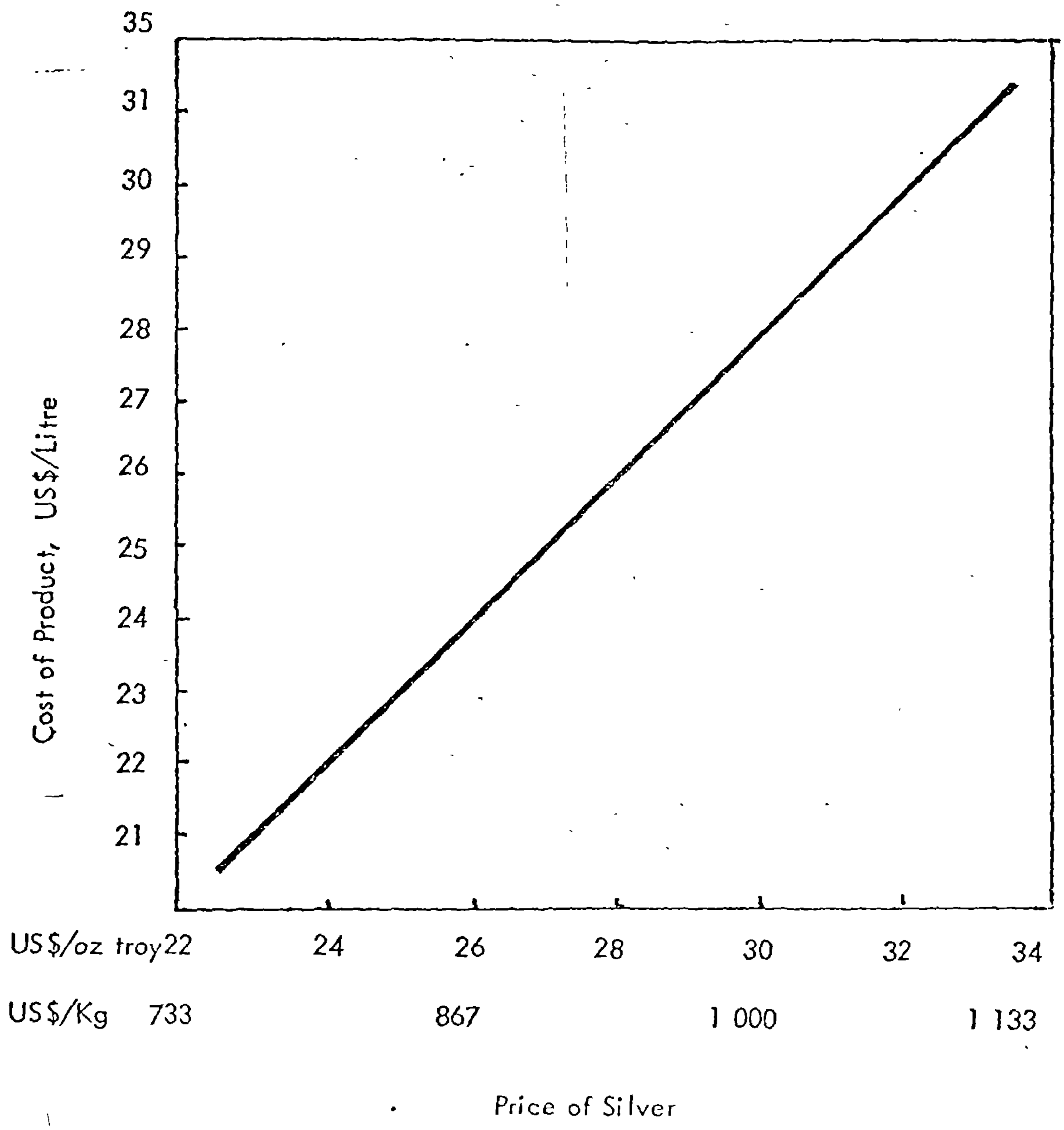
TABLE 6.7

HONDURAS: CHARACTERISTICS OF THE MAIN CLAY DEPOSITS

Location	Approximate Size of Deposit	Access	Ease of Extraction	Quality	Pottery Develop[illegible]
1. Ojona, 30 km South of Tegucigalpa	50 000	Good	High	Good	Yes
2. Orocuina, 30 km Southeast of Choluteca	5 000	Good	Fair	Good	Yes
3. La Arada	2 000	Good	Bad	Good	Yes
4. San Francisco, 35 km Northeast of Choluteca	2 500	Fair	Fair	Fair	No
5. Siguatepeque	1 000	Good	High	Good	Yes
6. Jesús de Otoro Masaguara	-	-	-	-	No
7. La Campa	50 000	Bad	High	High	Yes
8. Yarumela	5 000	Good	High	High	Yes

FIGURE 6.1

VARIATION BETWEEN COST OF PRODUCT AND PRICE OF SILVER



EVALUATION OF PROTOTYPES

On the basis of analysis of the possible filter models and the technology, raw materials and materials available in Central America for their manufacture, a detailed assessment of the models that offered the best possibilities of achieving the goals of the project was made. The selected filters were: the lathed clay filter with feldspar,sand and colloidal silver impregnation (model 9) and the lathed clay filter with sand, sawdust, and colloidal silver impregnation (model 10).

1. Evaluation Methodology

Nine different variants of filter model 10 and 2 different variants of model 9 were made with a view towards refining the previous identified prototypes. These variants are summarized in Table 7.1.

The different variants permit the following observations: i) the tolerance of the filters to contain different proportions of clay, sand (or feldspar) and sawdust, taking into account that artisan work with a larger margin of error than industrialists; ii) the tolerance of filters for sawdust of different origin; iii) the advantages or disadvantages of impregnating the filtering elements using a brush instead of simply adding the colloidal silver to the first water filtrate, stir and let impregnation take place; iv) the influence of the colloidal silver concentration on the bacteriostatic efficiency of the filter.

Two basic criteria were taken into account for the evaluation: i) the filter

efficiency to retain microorganisms; ii) the rate of filtration.

This evaluation was conducted firstly on the total of filters subjected to test, then comparatively on model 9 and 10, and finally on each of the variants (combinations) examined.

The standard of comparison for establishing the filters efficiency in microorganisms retention was the "International Standard for Drinking-Water". This Standard specifies that "In 90% of the samples examined throughout any year, coliform bacteria shall not be detected or the MPN index of coliform microorganisms shall be less than 1.0. None of the samples shall have an MPN index of coliform bacteria in excess of 10.

An MPN index of 8-10 should not occur in consecutive samples. With the examination of five 10-ml portions of a sample, this would preclude three of the five 10-ml portion (an MPN index of 9.2) being positive in consecutive samples."

Regarding the rate of filtration, the criteria adopted was to discard those filter variants with an average rate below 2 litres/day or those having in 365 days a rate of filtration lower than two litres/day.

The analysis was conducted as follows:

1. The formula for making each model/filter variant was given to an artisan potter (see Table 7.1).
2. Such model/variant was impregnated with colloidal silver of 3.2% Ag at different concentrations by different methods.

3. A source of water with an average contamination of 390 coliforms was identified and analysed by the MPN method (s = 415).
4. The filters were placed on wooden scafolds which supported them by the upper part and made easier the filling, the measure of the rate of filtration and sample taking for microbiological analysis (Figure 7.1).
5. The filters were filled with contaminated water and samples were taking during 3 to 10 month periods.
6. Samples were analysed by the most probable number of coliforms (MPN) and a record was kept of the total accumulated filtration and the daily rate of filtration.
7. Filling of the filters was continued according to the need.

Upon completion of the first analyses, it was noted that the first 1-2 samples taken from a filter were frequently contaminated. Of the 51 filters on observation, 21 (41%) showed contamination in the first sample, and of the 48 contaminated samples, 29 (60%) occurred in the first sample or in the first and second consecutive samples.

Analysis of the handling and manufacturing process of the filtering element showed that it was contaminated when new and, therefore, it was concluded that: i) it was recommendable that after the baking and cooling the filter element should be placed in a plastic bag which must be sealed by a simple method; ii) as an additional precaution, the handling instructions of the filter should stipulate that the

water should be discarded during the first filtration day so as to eliminate the contamination inherent in the manufacturing and handling of an artisan filter.

For purposes of analyses it was decided to discard the contaminated samples in the first filtrate or in the first and second consecutively. This is deemed reasonable in view of the foregoing considerations.

2. Results of the physical and microbiological evaluation

The general results by filter model and by variant within the same model are given in what follows.

2.1 General results of evaluation

In general, the filters in study (51 in total) showed a satisfactory efficiency with respect to microorganisms retention. Of the 302 samples analysed only 6.3% reached coliform levels over 1 by the MPN method . In eight cases the coliform content exceeded 10, but it was concluded that the contamination stemmed from manual handling of the filtering element during sampling. The taking of samples required a slight tilting of the filter and in some cases the filtering element was accidentally touched (see Figure 7.1). None of the filters whose samples recorded coliform values over 10 showed contamination in subsequent samples or a consistently high contamination in comparison with other filters (variance analyses indicated a low probability (57.7%) that the group averages were different).

Therefore, the conclusion was drawn that contamination over 10 was accidental and caused by the sampling method. This indicates: 1) the need to as-

certain that the user refrains from handling the filtering element during its useful life; 2) the omnipresence of contamination in the environment and the health hazards involved (mainly in the rural area at a low social and economic level) independently of the availability of drinking-water. Usage of the filter must be accompanied by sanitary and hygienic practices in order to maximize the potential benefits to health.

The analyzed filters showd in general an adequate rate of filtration. The daily average filtrate during a total of 7726 days/filter was 2.11 litres/day. On the other hand, the average daily rate of filtration at 72 days of life of the filters was 2.62 litres/day and a projection to 365 days indicates a rate of 2.14 litres/day for the model filters 9, and 1.97 litres/day for the model filters 10.

Since the goal was to produce at least 2 litres per day of drinking-water, the varieties that offer the highest daily rates of filtration must be selected. Likewise, the varieties of filters with the best bacteriological characteristics will be selected.

2.2 Comparative Evaluation of Filter Models 9 and 10

In order to evaluate as a first approximation whether was a significant difference between filter models 9 and 10, a comparison of the microbiological behaviour (coliforms retention) was made, as well as the rate of filtration of two varieties of filter 9 coupled with variants of filter 10, which were the most similar as regards formulation. Numbers 2 and 3 of Figure 7.1 were first compared and then number 1 and 4.

Table 7.2 shows a comparison between the results of the microbiological analyses on filters Nos. 3 (models 9 and 2 (model 10)). Note the sporadic (and some times initial) nature of contaminations. A variance analysis shows no significant difference between the models (F = 1.116 and P (F) = 0.36; a significant effect would obtain if P (F) ≥ 0.95).

When no significant effect was found between models 9 and 10 from the microbiological standpoint, experiments were conducted to establish if a change in the sawdust origin in filters 9 caused some different behaviour or if this change in the mixture did not affect the results. For this purpose filters 9 (No. 4) and filter 10 (No. 2) were compared (variant No. 3 contained conacoste sawdust instead of pine sawdust).

Table 7.3 shows the results of microbiological analyses of filters 9-4 and 10-2. Note the presence of contaminated samples at the start of operating the filters; this suggest discarding the first filtrations and protecting the filtering element. No significant difference were found between the biological behaviour of filters 9 and 10 as the type of sawdust was altered (F = 1.105; P (F) = 0.371).

The second important aspect in filter evaluation was the rate of filtration. In order to determine if there was difference between the models 9 and 10, variant Nos. 3 and 2 were compared again, but this time as a parameter the daily rate of filtration measured in litres/day was taken.

The results of analyses are summarized in Table 7.4. Observe the small decrease of the rates of filtration with time. Variance analyses indicated no sig-

nificant difference between the rates of filtration ($F = 0.551$; $P(F) = 0.77$). However, the coefficient $P(F)$ was close enough to the accepted differential value (0.95) as to warrant a more specific analysis.

At a glance it was noted that model filters 10 dropped to lower filtration levels/day than the model filters 9. In order to control this difference the filtration rates on the last observation day were compared. On the average these were 2.3 litres/day for model 9 and 2.0 litres/day for model 10. Comparison of these averages gave very significant results ($t = 8$, $df = 2$; $\alpha = 0.0076$).

Therefore, it was concluded that the rate of filtration of models 9 decreased at a slower pace and thus the drinking-water yields are higher (0.3 litres/day at 275 days) than those of model filters 10. This difference seemsto be stable during a period between 230 and 275 days of life of the filter (Table 7.4).

In summary, there is no significant difference between the bacteriological efficiency of filters 9 and 10, or between the average rates of total filtration during the first 290 days of life of the filters; however, the rates of filtration of filters 9 decrease at a slower pace, that is, they sustain a higher filtration rate with time (0.3 litres/day over filters 10 at 275 days).

2.3 Evaluation of the Most Favourable Design Alternatives

From the standpoint of project implementation, it is important to ascertain the effect of modifying the basic design of the filters, so as to give a margin of safety to the artisans both in the composition of the filtering element (namely,

proportions of clay, sand and sawdust in models 10, or clay, feldspar and sawdust in model 9) and the origin of materials (sawdust), the manner of application, and the concentration of the colloidal silver solution.

A series of experiments and analyses were carried out for this purpose and the results are given below.

2.3.1 Proportions of the mixture of sand, sawdust and clay

The physical and microbiological tests of model filters 10 were compared with different composition of sand, clay and sawdust. One filter (No. 7) contained 70% clay, 18% sand and 12% sawdust; this could be considered a clayey filter. The other (No. 8) had 55% clay, 40% sand and 5% sawdust; this was a sandy filter.

Results are shown in Table 7.5. No significant difference was detected between the microbiological behaviour of a sandy filter and a clayey filter ($F = 0.57$; $P(F) = 0.78$). An apparent margin of 12% exists in the proportion of clay; 38% in the proportion of sand and 41% in the proportion of sawdust, keeping always in mind the interdependence between the three components.

As regards physical behaviour (Table 7.6), it is also clear that there is no difference both in the total average filtration and the filtration variation with time.

2.3.2 Type of sawdust

In section 2.2 it was indicated that there was no difference between using conacaste sawdust and pine sawdust in manufacturing the filters. That eval-

uation covered only the microbiological aspects. Now the effect of the type of sawdust on the total average rate of filtration and the final rate, that is, the last one observed, will be analysed.

For this purpose filters 9, 3 and 4 will be compared again. Model 9.3 (with pine sawdust) showed a realtively higher average rate of filtration, 2.46 litres/day, compared with 2.39 litres/day for the filter made with conacaste sawdust (model 9.4). However, this difference was not very significant(P (F) = 0.69) (see Table 7.7).

Nevertheless, this slight difference becomes larger if one considers that the conacaste sawdust impart to the water a colour and odour sui generis, especially during the first filtrations. Thus, the use of sawdust from soft woods (pine, cypress) will be recommeded whenever it is possible.

2.3.3 Concentration of the colloidal silver solution

Colloidal silver (at 3.2% Ag) is one of the most expensive inputs in manufacturing the filters. It is also the most important, for without it contamination levels cannot be reduced to the desired levels. Hence, different concentration of colloidal silver in solution were tried so as to optimize utilization.

Maximum levels of 18.3ml of colloidal silver at 3.2% Ag in 200 ml of water and minimum levels of 6.1 ml/200 ml were tried. Results were paradoxical, since the filters with the simple solution proved to be the most effective. This filter showed an average contamination of 2.38 coliforms by the MPN method, whereas those of the filter with triplesolution had 3.42 (difference of 1.04 significative to $\alpha = 0.33$).

However, upon examination of Table 7.8 it was ascertained that such difference was produced by accidental contamination of the filters, hence there was no significant difference between both groups.

2.3.4 Impregnation method

When the use of colloidal silver was decided the first tests were made applying the solution with a sponge or a brush. Afterwards a simpler system was designed, which consisted in dissolving the colloidal silver in the first filtrate batch, that is, simply adding the colloidal solution to the filtering container after the water, then letting the water to be filtered, stirring occasionally with a clean instrument. This first batch was then filtered again.

In order to establish whether this procedure was as effective as the traditional method an experiment was conducted whereby the only variation in the filters was the impregnation method. Two filters of model 10 were made and impregnated by brush (model 10.1) and four filters impregnated by the solution method. Results are summarized in Table 7.9. Clearly, the application method has no significant effects on the bacteriological efficiency of the filters. However, it was noted that the solution method tends to increase the colloidal silver concentration in the lower parts of the filtering element. Consequently, the brush method is recommended because it is more uniform, even though results obtained are equally satisfactory with both methods.

3. Economic Evaluation

In this section models 9 and 10 are compared with respect to their economic efficiency, and the entire programme at national level is evaluated.

3.1 Economic comparison between model filters 9 and 10

According to estimates made in Chapter 2, the cost of model filter 10 was US$7.63/unit, whereas the cost of a filter 9 was calculated to be US$7.70/unit, including the cost and transportation of feldspar to the pottery centres (US$0.07). Figure 7.1 shows the daily rate of filtration for model filters 10, and Figure 7.2 give those of model 9. The equation is: $Y_{10} = 1.78 + \frac{20.23}{X}$; where, Y_{10} = rate of filtration/day of model 10 and X = days, is the relation which best suits the experimental data, and the equation Y_9 is the one that best fits the data for model 9.

The additional benefits of filter 9 (expressed in litres) are given by:

$$\int_0^{365} Y_{10} = 1.78 + \frac{20.23}{X} - \int_0^{365} Y_9 = 4.20\ X^{-0.12}$$

which is equal to: 649.7 - 755.2 = - 105.5 litres in 365 days.

According to calculations, filter No. 9 yields annually 105.5 litres more than filter No.10. Experimentally, this difference was 107.9 litres in 290 days, but the theoretical value is used because it reduces fluctuation effects and sampling errors among the filters.

Assuming that an inhabitant in the Central America rural area is willing to pay US$7.50 for a model filter 10 whose useful life is one year, he is implicitly paying US$0.011544 (US$7.50/649.7) for each litre of filtered water.

Consequently, the 105.5 additional litres produced by model 9 render a net benefit of US$1.22 per filter per year versus and additional investment of only US$0.07. Thus, even though the use of feldspar would double or triple the costs, on the long run the benefits would be greater. If the usage level of the filters stands at 350 000 filters/year, the additional benefit obtained from model 9 amounts to US$426 254/year, in comparison with an additional cost of only US$24 500, that is US$400 000 net, a significant figure.

In economic terms, the use of filter No. 9 is recommended, seeking the ways to solve the problem of obtention and distribution of feldspar.

3.2 National Evaluation

From the economic standpoint, the chief benefits are: 1) fostering the economic activity among the low income segments, and 2) revitalization of the artisan activities.

Only the second item is quantified. For this purpose the difference between salaries paid for qualified labour in pottery (US$250/month) and what a potter would earn in alternative occupations (US$150/month) was calculated. This renders a benefit of US$0.78/filter owing to a better utilization of human resources. To this are added the potter profits over his salary as manager-supervisor of the operations (US$1.02/filter), which gives a total of US$1.80/filter as a net benefit.

These net benefits compared with the project costs are summarized in Table 7.10. Since the project is self-supporting there are no costs, in addition to those of promotion, from 1982. The up-dated value of benefits is US$8.5 million in 20 years, which compares favourably with the up-dated national costs (US$2.152 million and B/C = 3.95) in case (1), and US$3.461 million, B/F = 2.46 in case (2). The cost flow assumes all investment and development expenses including the cooperation of the institutions involved and an initial promotion investment of US$100000/country, which would drop to US$50 000 the second year and to US$25 000 from the third year in case (1), and in case (2) this amount stays at US$50 000. This amount would be invested by the regional goverments in incorporating the filters to their existing programmes of promotion of rural health.

All other benefits resulting from a redistribution of income, health and sanitary conditions, etc., would be additional to those quantified in Table 7.10, and would consolidate the soundness of the project.

TABLE 7.1

VARIANTS OF EVALUATED FILTERS 9 AND 10

No.	Model	Number	%A[1]	%R[2]	%F[3]	%S[4]	TS[5]	TI[6]	Sol[7]
1	10	2	61	35	0	4	P	B	10
2	10	4	61	35	0	4	P	S	10
3	9	3	57	0	32	11	P	S	10
4	9	3	62	0	34	4	CO	S	10
5	10	3	71	19	0	10	CI	S	10
6	10	4	83	0	0	17	P	S	6.1
7	10	5	70	18	0	12	P	S	6.1
8	10	10	55	40	0	5	P	S	6.1
9	10	3	55	40	0	5	P	S	12.2
10	10	2	55	40	0	5	P	S	18.3
11	10	4	55	40	0	5	P	B	12.2

1 Clay % in the composition of the filtering element
2 Sand % in the composition of the filtering element
3 Feldspar % in the composition of the filtering element
4 Sawdust % in the composition of the filtering element

5 Type of sawdust, P = pine; CO = Conacaste; CI = Cypress
6 Type of impregnation, B = brush; S = filtered solution
7 Sol = solution concentration in ml of Ag at 3.2% dissolved in 200-250 ml of water, in the case of impregnation by brush and in entire filtering container in cases of impregnation by filtered solution.

TABLE 7.2

COMPARISON BETWEEN RESULTS OF MICROBIOLOGICAL ANALYSES OF MODEL FILTERS 9 (No. 3) AND 10 (No. 2)

Model 9 (Number 3)			Model 10 (Number 2)			
3.1	3.2	3.3	2.1	2.2	2.3	2.4
0	0	0	2	0	0	0
0	0	0	9.1	3.6	0	9.1
0	0	21	0	0	0	43
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	3.6	0	~~0~~	0	0
0	0	2.73	1/23	.4	0	5.79

Source: ICAITI

TABLE 7.3

COMPARISON BETWEEN MICROBIOLOGICAL ANALYSES OF FILTERS 9 (No. 4: CONACASTE SAWDUST) AND FILTER 10 (No. 2: PINE SAWDUST)

Model 9 (Conacaste No. 4)			Model 10 (Pine No. 2)			
4.1	4.2	4.3	2.1	2.2	2.3	2.4
9.1	9.1	0	2	0	0	0
0	0	0	9.1	3.6	0	9.1
0	0	0	0	0	0	43
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
1.01	1.01	0.00	1.23	0.4	0.00	5.79

F = 1.105; P (F) = 0.371

Source: ICAITI

TABLE 7.4

COMPARISON BETWEEN RATES OF FILTRATION OF FILTERS 9 AND 10 (VARIANTS 3 AND 2)

Age of filters (days)	Rate of filtration, litres per day — Model 9 - 3: 3.1	3.2	3.3	Model 10 - 2: 2.1	2.2	2.3	2.4
15	3.5	3.8	3.5	3.5	5.5	5.5	3.8
38	2.9	2.9	2.8	2.9	4.0	3.7	2.8
95	2.8	2.8	2.7	2.7	3.1	2.8	2.4
140	2.7	2.8	2.7	2.6	2.7	2.6	2.4
187	2.5	2.6	2.5	2.3	2.4	2.3	2.1
229	2.3	2.4	2.3	2.1	2.1	2.1	1.9
241	2.3	2.5	2.3	2.1	2.2	2.0	1.9
261	2.3	2.3	2.3	2.1	2.1	2.0	1.9
275	2.3	2.3	2.3	2.1	2.0	2.0	1.8
365[1]	2.14	2.14	2.14	1.97	1.97	1.97	1.97
$\bar{X}$ =	2.6	2.7	2.6	2.5	2.9	2.8	2.3

F = .551; P (F) = 0.77
t = 4.3657; 5v; .50

[1] Projected by adjusting data of filters 9 and 10 (Figure 7.2 and 7.3).

TABLE 7.5

COMPARISON OF MICROBIOLOGICAL RESULTS BETWEEN MODEL FILTERS 10 WITH DIFFERENT PROPORTIONS OF SAND, CLAY AND SAWDUST IN THEIR COMPOSITION

	Clayey Filters[1]					Sandy Filters[2]		
	7.1	7.2	7.3	7.4	7.5	8.1	8.2	8.3
	3.6	11	0	0	0	11	0	21
	0	0	0	0	0	3.6	7.3	0
	nd[3]	0	0	0	0	0	0	0
	0	0	0	3.6	0	0	0	0
	0	0	0	0	0	0	0	0
	0	0	0	0	0	0	0	0
$\bar{X}$	.72	1.8	0	.6	0	2.43	1.22	3.5

F = 0.567677; P (F) = 0.777

1 Model 10, No. 7

2 Model 10, No. 8

3 This observation was eliminated owing to contamination of sample at moment of taking it.

Source: ICAITI

TABLE 7.6

COMPARISON OF PATES OF FILTRATION BETWEEN MODEL FILTERS 10 WITH DIFFERENT PROPORTIONS OF SAND, CLAY AND SAWDUST IN THEIR COMPOSITION

Clayey Filters					Sandy Filters		
7.1	7.2	7.3	7.4	7.5	8.1	8.2	8.3
2.06	1.94	2.06	1.94	2.17	2.17	2.17	2.26
1.56	1.49	1.56	1.49	1.67	1.61	1.61	1.80
1.45	1.40	1.45	1.40	1.55	1.51	1.55	1.66
1.55	1.51	1.55	1.46	1.62	1.46	1.51	1.51
1.52	1.45	1.49	1.41	1.63	1.45	1.49	1.49

Source: ICAITI, previous Table

TABLE 7.7

COMPARISON BETWEEN RATES OF FILTRATION BETWEEN MODEL FILTERS 9 WITH SAWDUST FROM DIFFERENT ORIGIN (CONACASTE AND PINE)

	Model 9 - 3			Model 9 - 4		
	3.1	3.2	3.3	4.1	4.2	4.3
	2.83	2.83	2.71	2.33	2.37	2.23
	2.47	2.57	2.47	2.52	2.48	2.45
	2.33	2.43	2.33	2.45	2.45	2.43
	2.29	2.45	2.31	2.39	2.39	2.37
	2.29	2.33	2.29	2.34	2.36	2.34
$\bar{X}$	2.44	2.52	2.42	2.41	2.41	2.36

F = .6118; P (F) = 0.69

TABLE 7.8

COMPARISON OF BACTERIOLOGICAL EFFICIENCY BETWEEN FILTERS IMPREGNATED WITH COLLOIDAL SILVER (at 3.2% Ag) AT CONCENTRATIONS OF 6.1 ml/200 ml OF WATER AND 18.3 ml/200 ml OF WATER

	Simple Solution (6.1%)			Triple Solution (18.3%)	
	8.1	8.2	8.3	10.1	10.2
	11	0	21	23	0
	3.6	7.3	0	0	n.d
	0	0	0	0	15
	0	0	0	0	0
	0	0	0	0	0
	0	0	0	0	0
$\bar{X}$	2.43	1.22	3.5	3.83	3.0

F = 0.135; P (F) = 0.967

TABLE 7.9

COMPARISON BETWEEN TWO VARIANTS OF FILTER 10 IMPREGNATED WITH COLLOIDAL SILVER BY TWO DIFFERENT METHODS (BRUSH AND SOLUTION)

	Impregnation by Brush		Impregnation by Solution			
	1.1	1.2	2.1	2.2	2.3	2.4
	0	0	2	0	0	0
	0	n.d	9.1	3.6	0	9.1
	43	0	0	0	0	43
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
	0	0	0	0	0	0
$\bar{X}$	4.78	0	1.23	.4	0	5.79

F = 0.82405; P (F) = 0.538

TABLE 7.10

NATIONAL EVALUATION OF MANUFACTURE OF ARTISAN FILTERS FOR DRINKING-WATER (IN THOUSAND OF US$ IN 1980)

Year	Costs (1)	Costs (2)	Benefits
1980	100	100	-
1981	500	500	-
1982	250	250	659.2
1983	125	250	675.7
1984	125	250	692.6
1985	125	250	709.9
1986	125	250	727.7
1987	125	250	745.9
1988	125	250	764.5
1989	125	250	783.6
1990	125	250	803.2
1991	125	250	823.3
1992	125	250	843.9
1993	125	250	865.0
1994	125	250	886.6
1995	125	250	908.8
1996	125	250	931.5
1997	125	250	954.8
1998	125	250	978.7
1999	125	250	1003.1
2000	125	250	1028.2
	VPN = 2152.0	VPN = 3461.2	VPN = 8530.0

$B/C_1 = 3.95$; $B/C_2 = 2.46$

Source: ICAITI

FIGURE 7.2

RATE OF FILTRATION AS A FUNCTION OF OPERATING TIME

- Model Filters 10 -

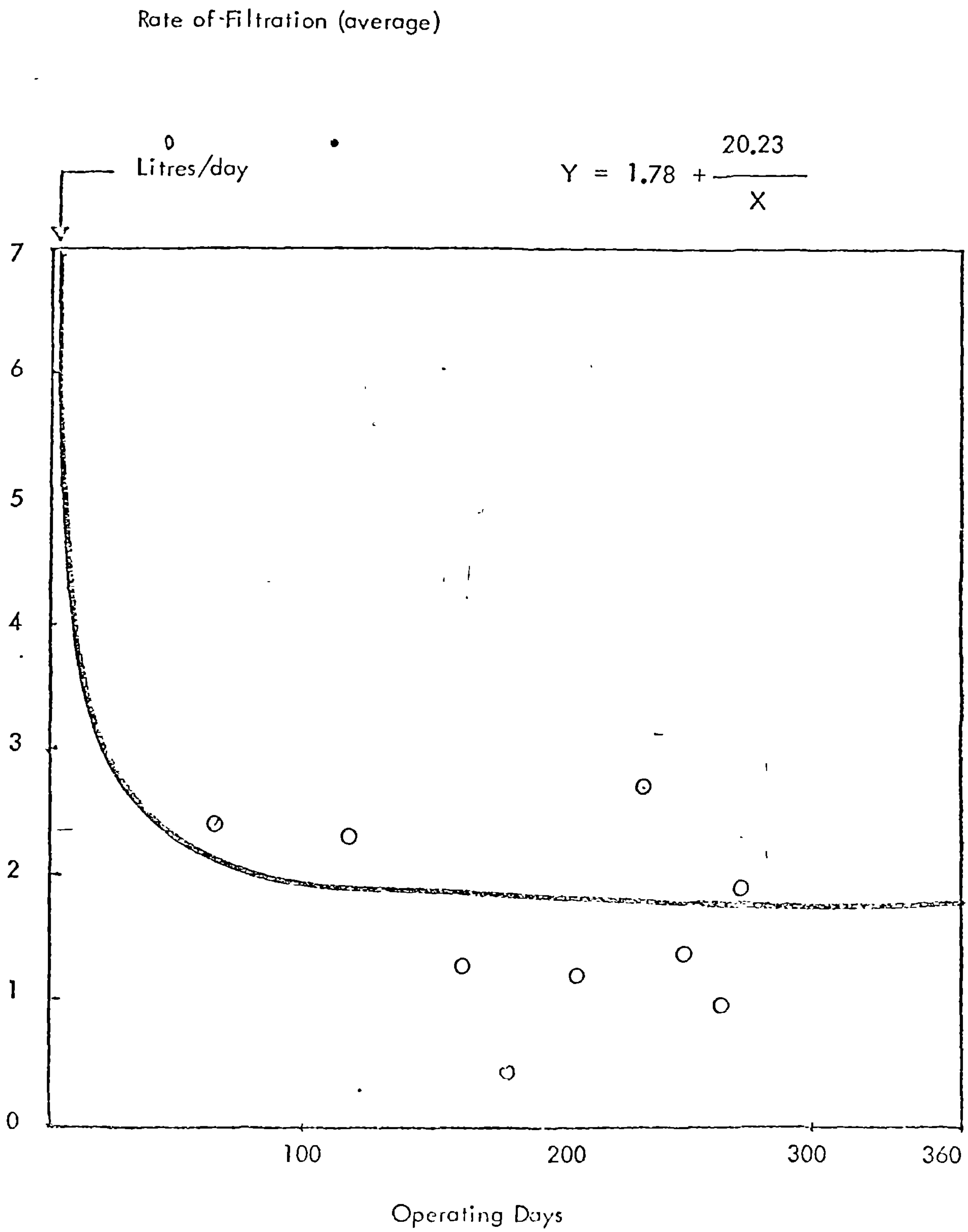
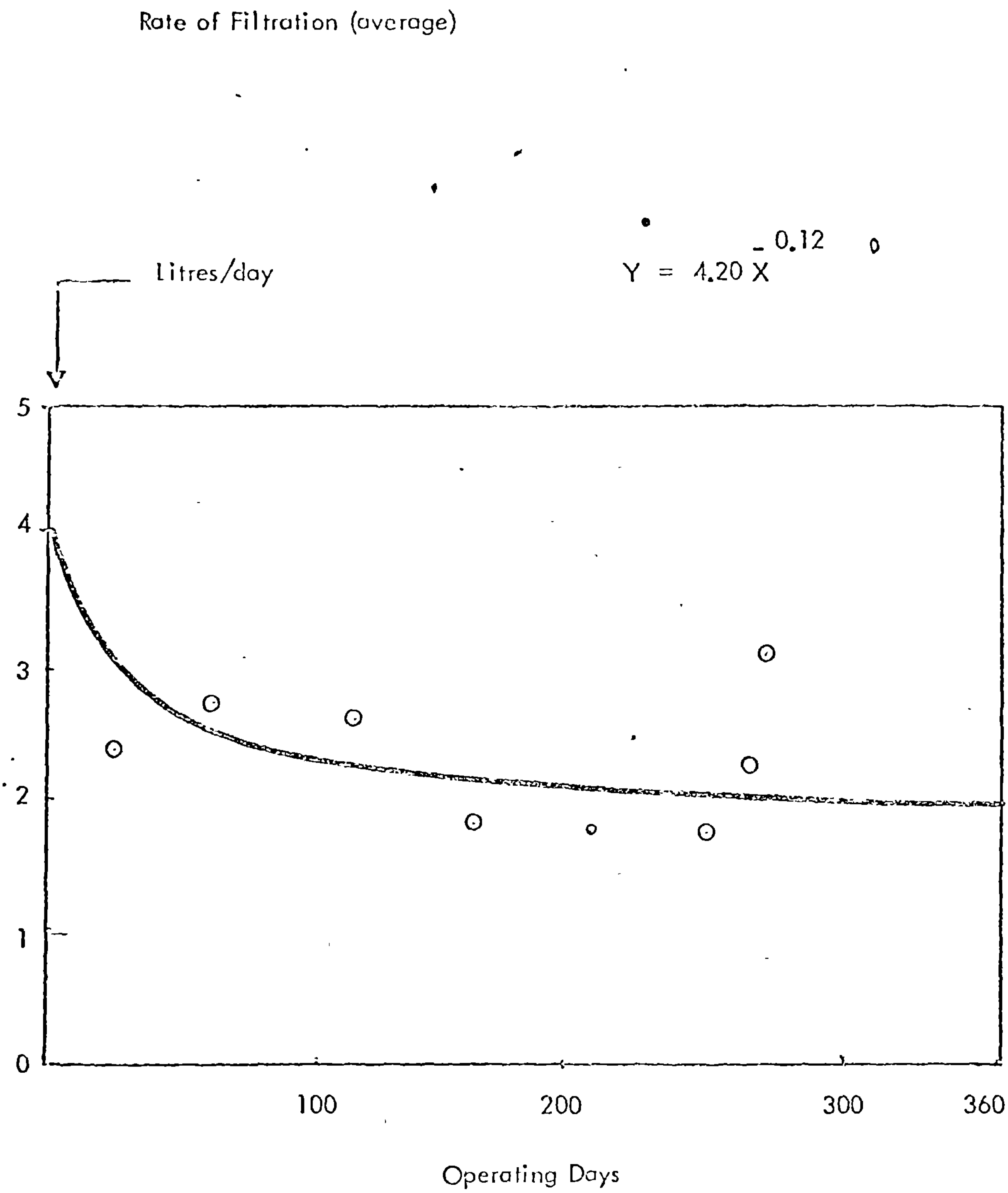


FIGURE 7.3

RATE OF FILTRATION AS A FUNCTION OF OPERATING TIME

- Model Filters 9 -



DESCRIPTION OF THE FILTER MODELS THAT ARE BEST ADAPTED TO CENTRAL AMERICAN NEEDS

DESCRIPTION OF THE FILTER MODELS THAT ARE BEST ADAPTED TO CENTRAL AMERICAN NEEDS

The analyses and evaluation performed indicate that filter model 9 is to be promoted, except in cases in which by reasons of accesibility the feldspar availability is a limiting factor. In such cases the promotion of model 10 is recommended.

The model filter 9 is a filter compounded of three parts: 1) a cylindrical clay container of approximately 40 cm height, 28 cm diameter and walls with an average thickness of 1 cm and having a bambu tap near the base for extracting water; 2) a mud cover with a semiespherical handle at the center; 3) an almost semicylindrical filter element with maximum upper diameter of 31 cm and a lower diameter of 24 cm, an external height of 24 cm and 5 cm rim around the entire 31 cm of the upper part. Internal diameter and heigh are 21 cm and 22 cm, respectively. The rim holds the filtering element when it is placed inside the cylindrical container.

When using the filter the cover is lifted and impure water is added to the filtering element (about 7.2 litres capacity), then one waits a few hours until enough filtrate fills the container in the space between the bottom of the filtering element and the base of the container.

Then the stopper is removed and the taps is opened perpendicularly so that the water falls vertical into the glass, bottle or "tecomate" (a container commonly

used by Central American peasants).

The filtering element of model 9 contains about 55 to 65% clay, 30 to 35% granulated feldspar and 5 to 10% pine or cypres sawdust.

The total weight of the filter is about 6.5 Kg of which nearly 55% correspond to the container, 5% to the cover and 30% to the filtering element.

6.1 ml of colloidal plate at 3.2% Ag diluted in 200 ml of pure water (equivalent to one glass) are added to the filtering element with a sponge or brush. After impregnation the filter is allowed to dry for 24 hours and at the beginning it is recommended to discard the first filtrate, for it may be contaminated by handling the filter during its manufacture.

This impregnation has a useful life of one year. Afterwards, the filtering element must be changed.

Reimpregnation of the element is not recommended owing to the drop in filtration rates after a year of use.

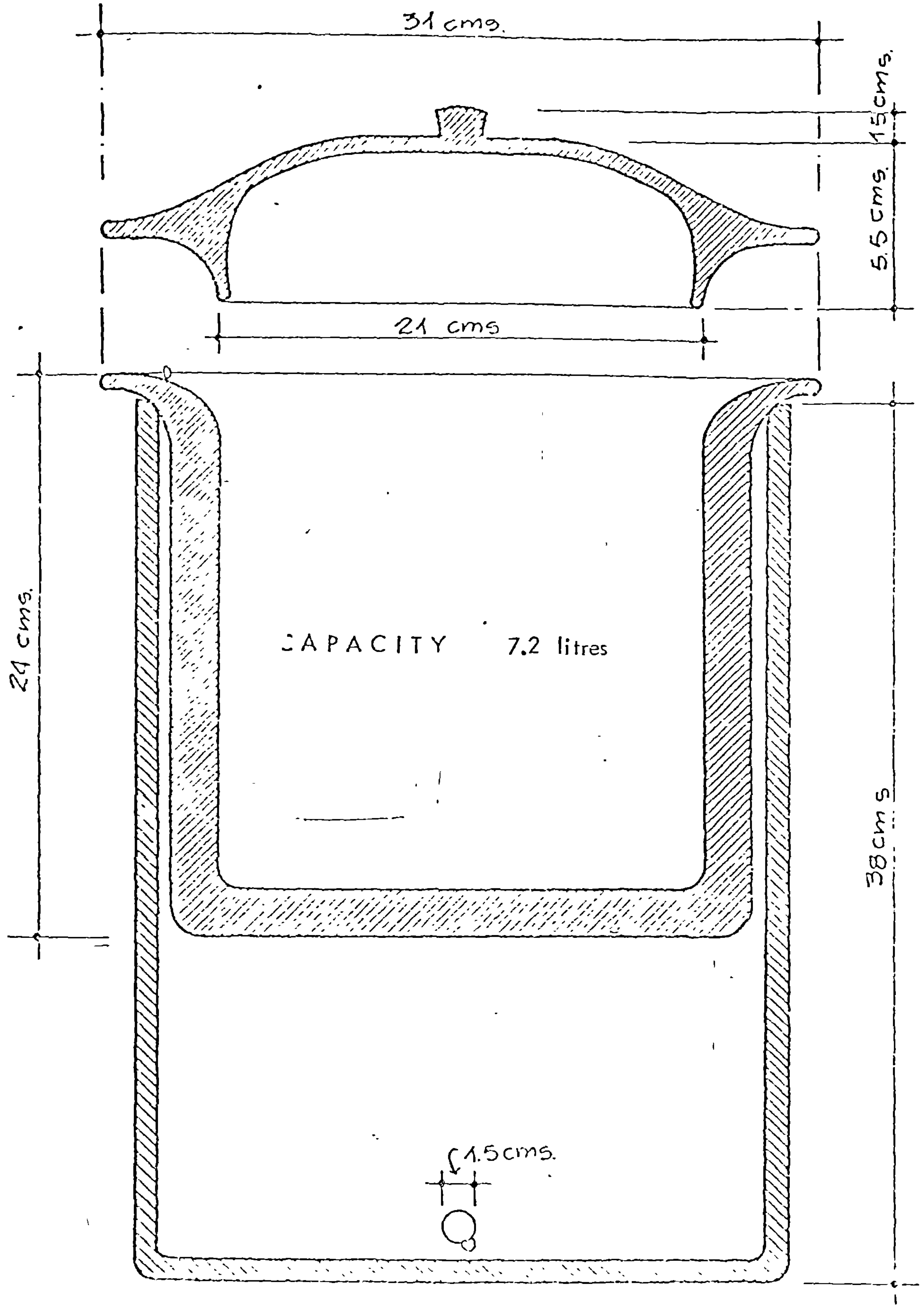
The model filter 10 is identical to model 9, except that the filtering element contains river sand instead of fedlspar. Sand is more readily available than feldspar, but it produces a lower water flow (100 litres less in one year, that is, 15% of the total filtrate of model filters 10). The proportions recommended for the filtering elements of model 10 are 55 to 70% clay, 20 to 40% sand and 5 to 10% sawdust.

The impregnation method is identical for both models.

Figure 8.1 shows a diagram of models 9 and 10 and Figure 8.2 shows a photograph.

The use of feldspar is recommended whenever possible and river sand when feldspar is not obtainable.

Figure 8.1



FILTER, CONTAINER AND COVER

SCALE 1: 2.5

Two Complete Different Prototypes which Consist of Container, Filtering Element, Cover and Tap

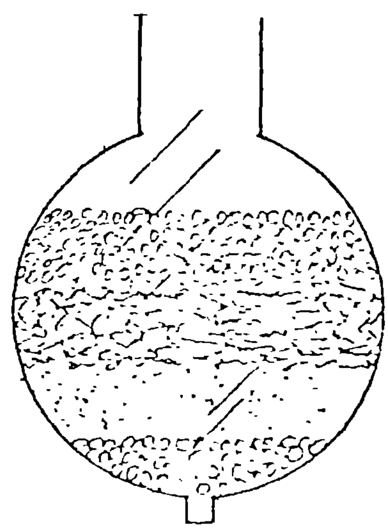
ANNEX I

DESCRIPTION OF THE FILTER MODELS CONSIDERED AS POSSIBLE PROTOTYPES IN THE PROJECT

DESCRIPTION OF THE FILTER MODELS CONSIDERED AS POSSIBLE PROTOTYPES IN THE PROJECT

1. Glass filter with filtering layers of sand, gravel and charcoal.

The filter design was based on experiences in other parts of the world. The container holding the filtering beds is not emphasised. Barrels like those used for gasoline are commonly utilized. In the case of the test conducted at ICAITI, a glass container was selected which fulfilled all requirements, namely: size, wall thickness, shape and a design which readily allowed placing the filtering beds and evacuating the filtrate.



Filter made in Guatemala

a) Excessive weight

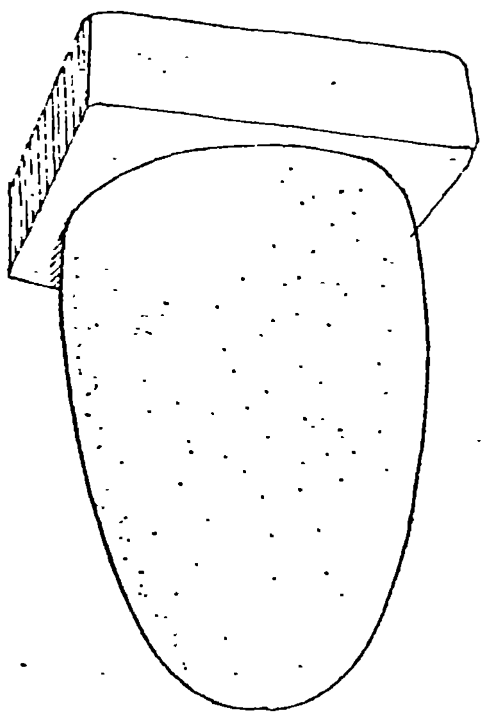
b) Difficult to make and uncommon

c) Transportation and marketing are difficult

d) High cost (approximately US$20.00)

Filter made in Honduras

In addition to the foregoing reasons, microorganisms retention is inadequate.



This prototype was discarded for the following reason:

a) No microorganism retention occurred

b) The preparation of filtering beds required certain technical know-how. It was necessary to ascertain the size of the filtering materials (gravel, charcoal).

c) Transportation and marketing is difficult (it is necessary to make it where it is going to be used).

2. Lathed Stone Filter

Two types of these filters were studied. They were obtained in different zones where they are manufactured. The first was acquired in the Northern zone of Guatemala, and the second in the Northern part of Honduras. This type of filter is made only in certain zones of both countries (it is not known whether they are made in Costa Rica, El Salvador and Nicaragua).

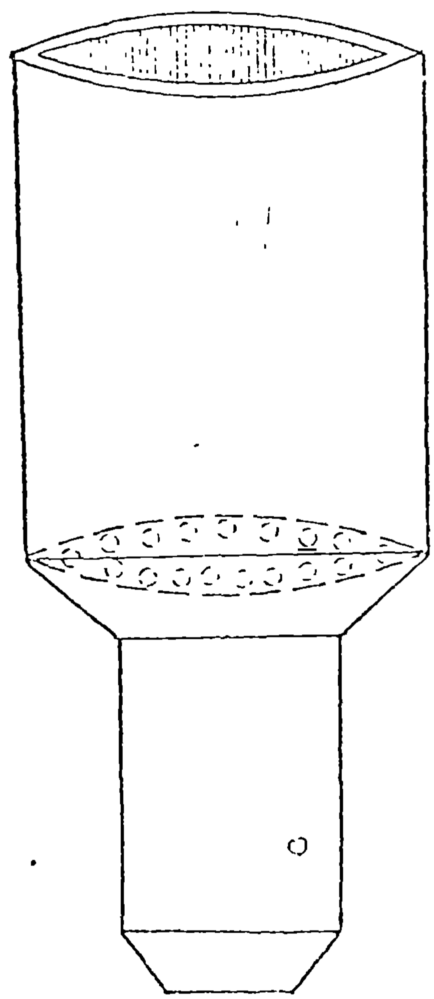
Their manufacture requires much ability, since stone blocks-generally volcanic aggregates - must be lathed to impart them an adequate shape. Very few person engage in this type of work and they do it in zones where the material is available. Its manufacture requires also a sound knowledge of the appropriate type of rock.

In both cases the prototypes were discarded for the following reasons:

3. Gypsum Lathed Clay Filter with Filtering Layer made of Impregnated Charcoal.

The design of this prototype had its roots in the need to investigate the retention capacity of mineral coal impregnated with colloidal silver and to explore the feasibility of making filters by a moulding process using gypsum.

Gypsum moulds were made at the Artisan Centre of Ilobasco, in El Salvador. The filter was made with clay only and without any aggregate. Mineral coal impregnated with colloidal silver was used as filtering material.



This prototype was discarded for the following reasons:

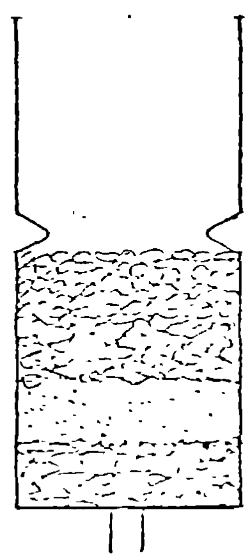
a) The filter manufacture is neither a simple operation nor a common one in the artisan areas.

b) Mineral coal is required which is not readily available in Central America and needs an adequate preparation.

c) Some advanced technology is required for its manufacture.

4. Tin Plate Filter with Filtering Beds of Sand, Gravel and Charcoal

This is a variant of prototype design 1. The difference resides in investigating the feasibility of using tin plate containers made by artisans according to a suitable design.



This prototype was discarded for the reasons given below:

a) The manufacture of tin plate containers involve a more advanced thechnology (welding, tin plate,etc.)

b) The manufacturing process is slow

c) Involves the obtention of material and raw materials that are not readily available.

d) Transportation and marketing are difficult.

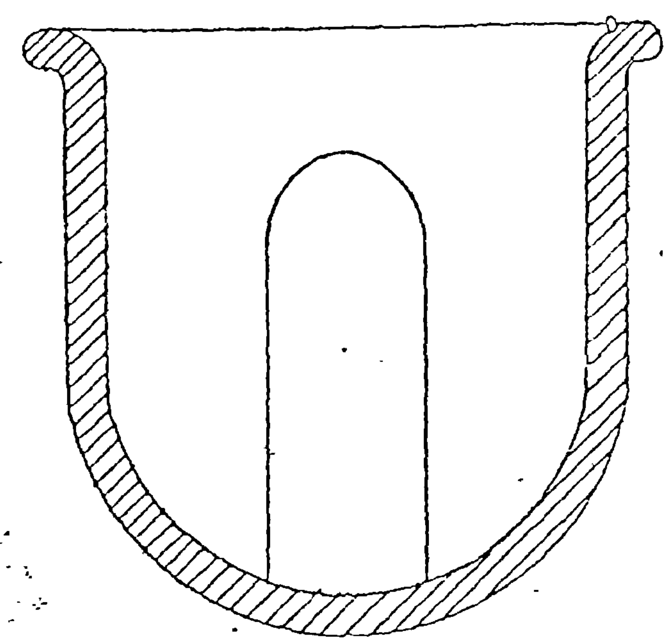
5. Lathed Clay Filter with Incorporation of a Filtering Candle of Same Material

The chief goal of this design was to appreciate firstly the ability of artisans to make, in addition to the filter, a filtering candle like the one manufactured industrially, and also to obtain a larger filtering surface. Both the filter and candle were made with the same materials, and it was possible to ascertain that making two parts with the same material, the filter proper and the candle separately, they could be readily joined together and that the baking process was effective.

Even though manufacture is possible the prototype was discarded for the following reasons:

a) Although the manufacture is feasible, the process is slow and requires much ability to make the candle.

b) Microbial retention is poor owing to the material or the proportion of materials needed to make the candle.



6. Lathed Clay Filter with Incorporation of a Pumice Filtering Candle

The conceptual construe for this prototype was to evaluate the filtering capacity of the pumice stone and the feasibility of making a filtering candle from this material. The investigation was addressed also to ascertain whether the mate-

rial (pumice stone) was readily incorporable in a clay container.

A clay container made in a common manner was used and a hole was provided for incorporating the candle. The candle was made separately from pumice stone. Both parts were then joined using cement.

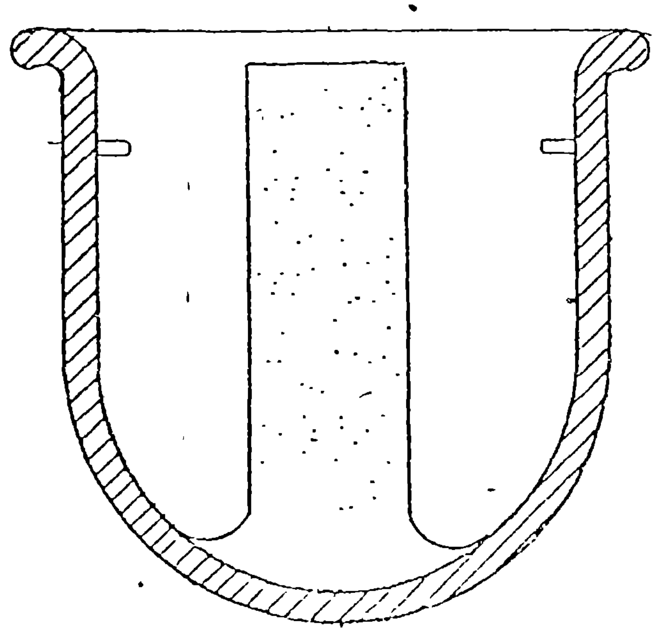
The prototype was discarded because:

a) Filtration is slow

b) The filtering candle manufacture requires special techniques which would make difficult the production in series.

c) Rather large pumice stones are required and this material is not readily available.

d) Microbial retention is poor.



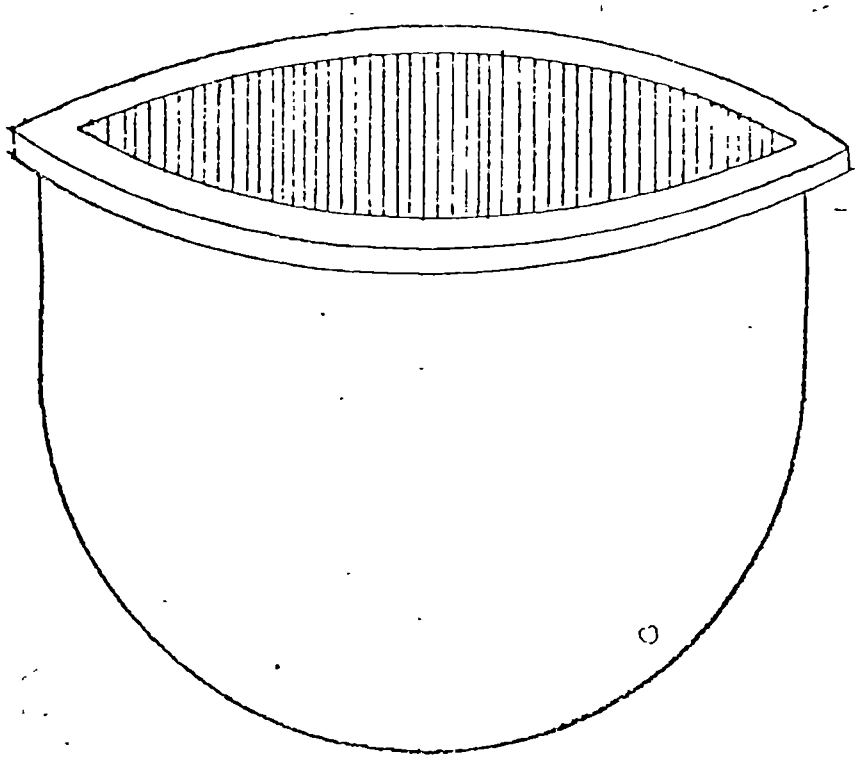
7. Lathed Clay Filter with Charcoal Incorporation

Only a mixture of pulverized charcoal and clay was used for making this prototype. The goal was to evaluate the capacity of charcoal both as regards filtration efficiency and retention of microorganisms, colours and odours.

Eventhough charcoal can be readily incorporated to clay and the manufacturing process is simple, the prototype was discarded because:

a) Filtration flow is too slow

b) Although at the initial stage the microbial retention is considered good, probably due to the porous size, it would be difficult to control this at artisan level.



8. Clay and Charcoal Filter with Filtering Beds of Gravel, Sand and Charcoal in the Upper Part.

This prototype was made to take advantage of two previous experiences. Firstly, the filtration efficiency (to retain suspended particles, bad odours and flavours) in the upper part, and secondly, to utilize the microbial retention assumed in the mixture of clay and charcoal in the lower part, so as to increase the rate of filtration of this filter.

Joining of the two container by means of clay and white cement was achieved. Although the prototype is readily made, it was discarded for failing both the physical and bacteriological tests.