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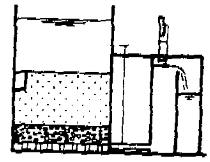
S.S.F. Research and Demonstration Project on Slow Sand Filtration



FINAL REPORT PHASE II

THAILAND

PROJECT UNDERTAKEN BY:

RURAL WATER SUPPLY DIVISION
DEPARTMENT OF HEALTH
(PRESENTLY, PROVINCIAL WATER WORKS AUTHORITY)
BANGKOK, THAILAND

IN COLLABORATION WITH:

INTERNATIONAL REFERENCE CENTRE
FOR COMMUNITY WATER SUPPLY AND SANITATION
THE HAGUE, THE NETHERLANDS

OCTOBER 1982

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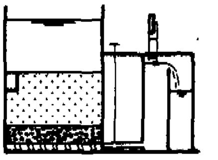
Research and Demonstration Project on Slow Sand Filtration



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THE HAGUE, THE NETHERLANDS

LIBRARY, INTERNATIONAL REFERENCE
CENTRE FOR COMMUNITY WATER SUPPLY
AND SANITATION (IRC)
P.O. Box 93190, 2509 AD The Hague
Tel. (070) 814911 ext. 141/142
RN: ~~4026~~ 3108
LO: 255.1 82FI

OCTOBER 1982

International Reference Centre
for Community Water Supply
and Sanitation
WHO Collaborating Centre

P.O. Box 5500, 2280 HM Rijswijk
The Netherlands.
Offices: J. C. van Markenlaan 5,
Rijswijk (The Hague)
Telex 33296 IRC NL, Phone (070) 94 93 22

ACKNOWLEDGEMENTS

The Project Managing Committee (PMC) is indebted to the International Reference Centre for Community Water Supply and Sanitation(IRC), the Netherlands, who initiated, partly auspiced the research projects and patiently waited for the results.

The PMC should like to express his sincere thanks to Dr. Somboon Vacharothai, Director General of the Department of Health, who understood the well-wishes of the IRC and subsequently provided support to the project implementation in all aspects.

The Asian Institute of Technology (AIT) did the horizontal-flow pre-filter pilot test, which was subsequently tried in the demonstration projects in conjunction with the slow sand filter. The AIT also participated in the monitoring programme which was one of the important features of the research projects. The PMC is mostly grateful to the AIT staff especially Dr. N.C. Thanh, chairman of the Environmental Engineering Division, Mrs. Samorn Muttamara and Mr. Sompol Boonthanon for the mentioned task.

The PMC gratefully acknowledges Prof. Sudjai Champa of the Engineering Faculty, Chulalongkorn University, who assigned a graduate student to study the slow sand filter at Kranuan District, Khon Kaen Province; part of the study was beneficial to the projects.

The PMC wishes to thank the staff of Health Education Division (HED) of the Ministry of Public Health, who gave health education and obtained community participation, especially Dr. Prachaub Sompongse, the Director of HED, Mr. Chet Preecharat and Mr. Adisak Sattam.

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Finally, the PMC wishes to acknowledge Miss Sunanta Buaseemuang of the Rural Water Supply Division, Department of Health (presently, Provincial Water Works Authority) for her close following up of the work progress and coordinating the activities of the agencies concerned from the begining of the projects.

PMC Chairman

July, 1982.

LIST OF PROJECT MANAGING COMMITTEE (PMC)

1. Mr. Lert Chainarong .... Project Director/PMC Chairman
   Director of Rural Water Supply Division,
   Department of Health.

2. Dr. Kusag Komolrit .... Deputy Director/PMC Technical Consultant
   Rural Water Supply Division,
   Department of Health.

3. Prof. Sudjai Champa .... PMC member
   Faculty of Engineering,
   Chulalongkorn University.

4. Dr. Nguyen Cong Thanh .... PMC member
   Environmental Engineering Department,
   Asian Institute of Technology.

5. Dr. Prachaub Sompongse, M.D. .... PMC member
   Deputy Director of Health Education Division,
   Office of the Under-Secretary of the State,
   Ministry of Public Health.

6. Mr. Udom Kasetravetin .... PMC member
   Chief of Design Section of Rural Water Supply Division,
   Department of Health.

7. Miss Sunanta Buseemuang .... PMC member
   Chief of Research and Analysis Section,
   Rural Water Supply Division,
   Department of Health.

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APPENDICES

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1. INTRODUCTION

1.1 History

The Royal Thai Government has developed the community potable water supply project since 1966. The Rural Water Supply Division, Department of Health (presently, Provincial Water Works Authority) is responsible for the project, to assist the community size of 500-5,000 people. By last December 1981, 648 systems have been constructed serving about 2.1 million people, representing 5.6 % of the rural population.

The type of treatment employed varies according to the quality of the raw water sources. It is apparent that the main problem of using surface water as sources of water supply depends upon the turbidity of the water; therefore the most common treatment employed has been the conventional rapid sand filtration process in which chemicals are used to coagulate and flocculate the turbidity for further sedimentation and filtration. It is rather a complicated system requiring well-trained operators.

Deep wells are sources of water used. The treatment of deep well water involves simple chlorination to complicated systems of aeration followed by rapid or slow sand filtration process. In all cases, the treated water is subjected to chlorination before it is supplied to consumers by pipes. Though the slow sand filtration system has more advantages in its simplicity of operation and maintenance than rapid sand filtration system, there are still many factors that influence the choice of the slow sand filtration system. For example, the turbidity of the raw water before filtration, conventionally limited to below 30 mg/l, and high construction cost of the slow sand filter. As a result, at present only 5 % of the total number of the existing water supply systems in Thailand employs the slow sand filtration system.

The use of slow sand filter for water treatment in Thailand is limited due to the reasons mentioned above until recently. Since 1978, the International Reference Centre for Community Water Supply and Sanitation, the Netherlands (IRC) has advised and partly auspiced the Rural Water Supply Division, Department of Health to undertake the field study and research programme on the slow sand filter, through which two plants were constructed to serve as demonstration projects. In addition, the Asian Institute of Technology (AIT) has recommended the use of pre-treatment technique, namely the horizontal-flow coarse material prefiltration which has the main advantage of reducing suspended solids prevailing in raw water to a certain extent.

The purpose of the project undertaken by Rural Water Supply Division, Department of Health (presently, Provincial Water Works Authority) was therefore to review and evaluate the design criteria, the performance of the slow sand filtration systems under actual field operation, its maintenace problems, its benefits and drawbacks, the related health impacts and socio-economic problems.

1.2 Selection of the Demonstration Villages

The selection of the project village was based on the following criteria : -

- Availability of a water source near the village.
- The readiness of the villagers to contribute, land money and labour.

Based on the above criteria and for convenience of monitoring, two villages located in central area of Thailand, north of Bangkok, have been selected as demonstration sites. They are :

* Ban Bangloa, Singhburi Province
* Ban Thadindam, Lopburi Province

2. PURPOSES OF THE STUDY

2.1 Technical aspect

The study will aim to

a) determine whether the proposed horizontal flow pre-filter tested at AIT pilot plant is feasible or appropriate for the slow sand filtration treatment under actual field conditions ; this phase of study will be carried out in conjunction with AIT.

b) determine whether the chemical coagulation is needed to enhance prefiltration operation.

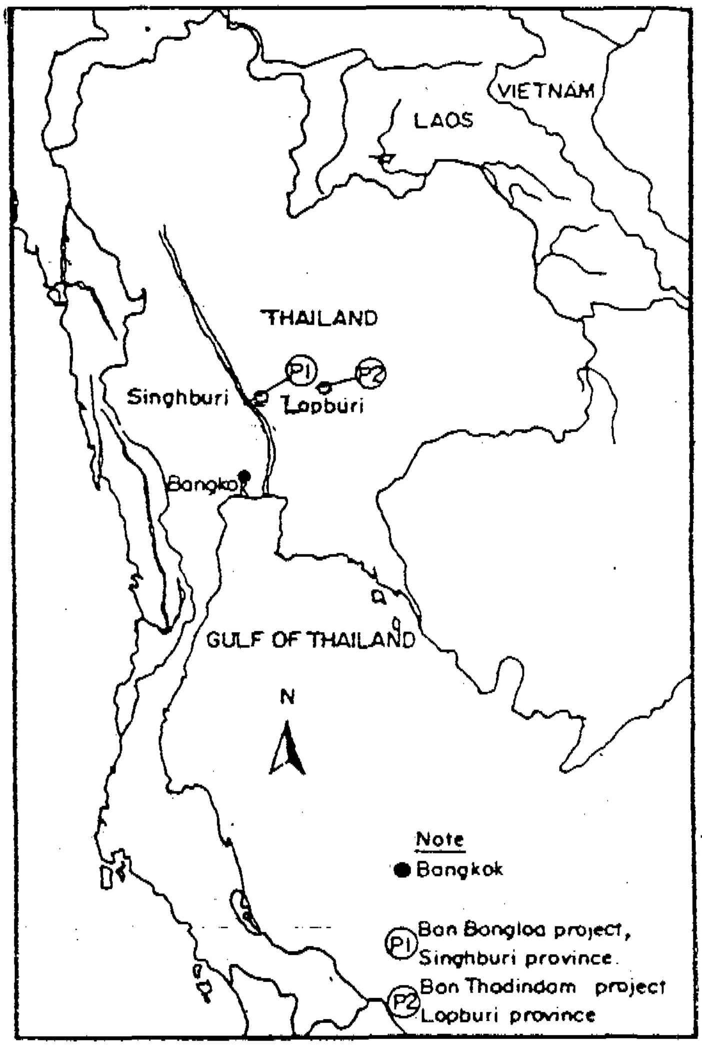

Fig. 1 Map of Thailand showing location of water supply demonstration projects.

c) evaluate the effectiveness of the pre-filter by so-called " roughing filter " and to compare with other pre-treatment process such as holding reservoir which also would be employed in the demonstration systems.

d) determine whether the design of the systems is appropriate, such design including the underdrain system design, the flow rate control design, the flow rate control system, the ease of construction, operation and maintenance.

e) determine whether such systems can be operated and maintained by the village operators recruited by the local communities themselves and trained specially for the purpose.

f) compare the initial construction cost between slow and rapid sand filtration systems, and to compare the operation and maintenance costs of both systems.

g) carry out a long term and follow up each system with regard to their qualities and problems.

2.2 Non-tecnical aspect

The study will aim to

a) determine the degree of community participation and health education required for the success of the projects ; the essential criteria for the successful operation and maintenance are to be analysed.

b) improve public health and socio-economic situation and thus the well-being of the villagers.

c) promote a self-generating autonomous management, leading to self-reliance, by creating capabilities and stimulating the use of local resources in the field of water supply and sanitation.

d) determine the impact of water supply system and its accessibility of operation and maintenance on the self-sustained basis with minimum technical supervision and financial assistance from outside.

3. THE INSTITUTIONS PARTICIPATED IN THE PROJECTS

3.1 Chulalongkorn University, undertaking the evaluation and monitoring of slow sand filter at Kranuan District, Khon Kaen Province.

3.2 Asian Institute of Technology, undertaking the evaluation and monitoring programme of the demonstration projects.

3.3 Health Eucation Division, Ministry of Public Health, undertaking the health education and community participation programme including questionaires preparation and door-to-door interview.

3.4 Provincial Public Health Bureau, especially Singhburi and Lopburi Provinces, undertaking the implementation of the health education programme.

3.5 Rural Water Supply Division, Department of Health (presently, Provincial Water Works Authority), undertaking the design and construction of the demonstration projects, training operators and acting as coordinator among the institutions concerned.

4. DESCRIPTION OF THE VILLAGES SELECTED

4.1 Ban Bangloa, Singhburi Province

4.1.1 Background information

Ban Bangloa is located in Muang District, Singhburi Province, about 120 kms. north of Bangkok. It is situated on the bank of the Chao Phya River (see Fig. 1 Map of Thailand). The village is between the Chao Phya River and an irrigation canal and inhabited by approximately 400 families with an average of about 5 persons. The houses are along the river bank rather than along the canal (Fig. 2 & 3). The river provides a gentle slope along the river bank. And it has been found that the river water floods this area during the monsoon period. During the dry season the land is used for cultivation. Difference of the water level in the river during the two seasons is about 6-7 m. Heavy rain upstream always causes torrents in the river with high turbidity.

4.1.2 Climate

The average temperature throughout the year ranges from 15°C to 38°C. The average annual rainfall is about 1,157 mm.

4.1.3 Occupation and Income

The villagers are mostly farmers, the remainders are labourers, traders and civil servants (see Fig. 4 Masonery-making at Ban Bangloa). The average yearly income per family is ฿ 10,000 - 15,000 (1 US$ = ฿ 23) which is high in comparison with the country's average ฿ 4,000 per year according to the National Statistics Report of 1979.

4.1.4 Education

The village has a primary school of the level up to the compulsory grade (seventh grade). Higher studies are provided in Singhburi Provincial Centre which is only 5 kms. away. At the provincial centre, both secondary school and vocational school are available. More than 60 % of the villagers have already passed the former compulsory level at fourth grade, and most of them are literate.

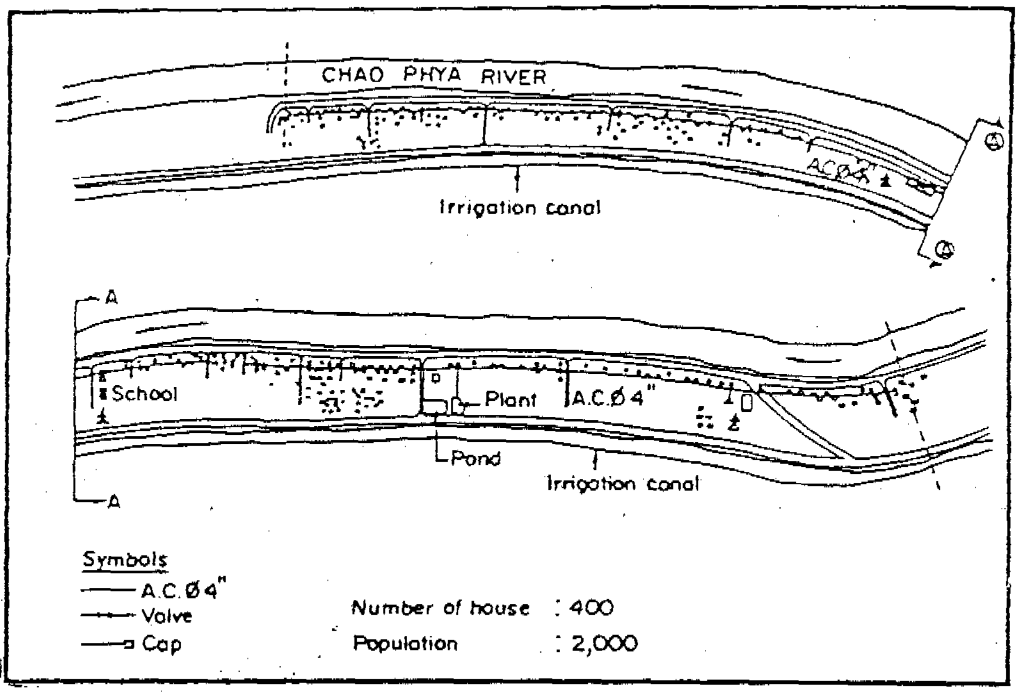

Fig. 2 Showing the characteristic of Ban Bangloa, situated on the eastern bank of the Chao Phya River.

4.1.5 Water and Sanitation

Before the water supply is available the villagers depended on rain water, stored in 100-L earthern jars or water from the Chao Phya River. Those who live along the river dig a shallow well in the sand beach and put the small casing into the opening in order to prevent the well from callapsing. The pipe is then laid to individual houses (Fig. 5); the hand pump or sometimes small diesel engine pump, is installed to facilitate the service for the individual houses (Fig 6).

As the river water is quite turbid during the rainy season, alum is commonly used for coagulation to remove turbidity in the individual house-containers. In some houses they leave the water for self-settling for one or two days and then decant the clear water for use.

Fig. 3 General view of Ban Bangloa, Singhburi Province, seeing the Chao Phya River in dry season.

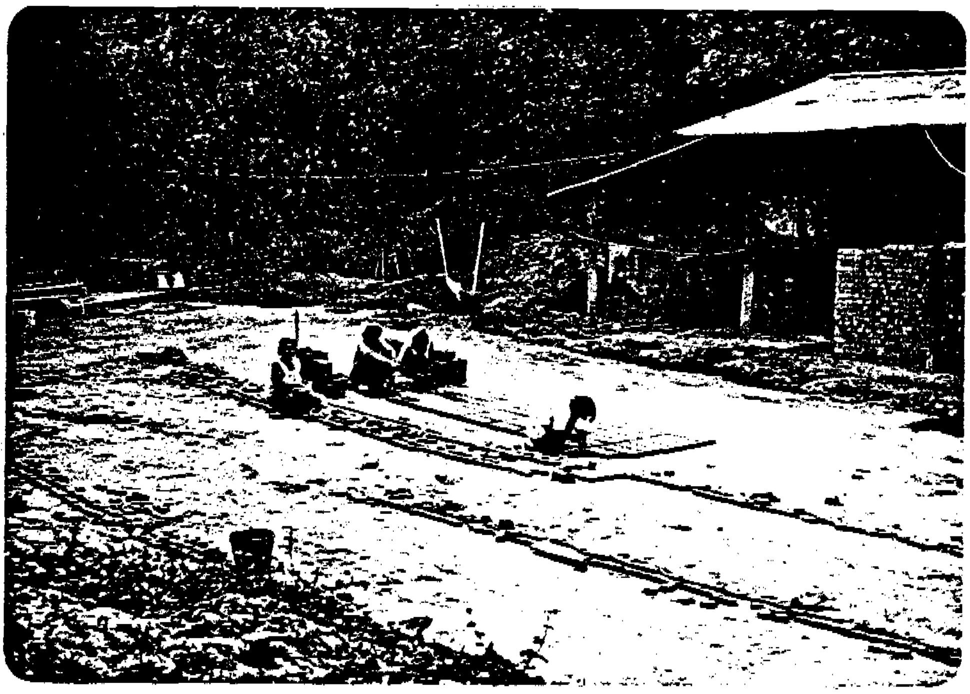

Fig. 4 Masonery-making at Ban Bangloa, Singhburi Province.

The water container is earthern jar of about 100-L which can be seen throughout the country. However, rain water is commonly used for drinking. Boiled water is also used for drinking.

As for sanitation, refuse is collected in an open pit for burning, Live-stock is commonly kept in the house vicinity; small animals such as chickens, ducks, pigs etc. are also raised under the house. The private soak-pit latrine is employed almost universally in the village.

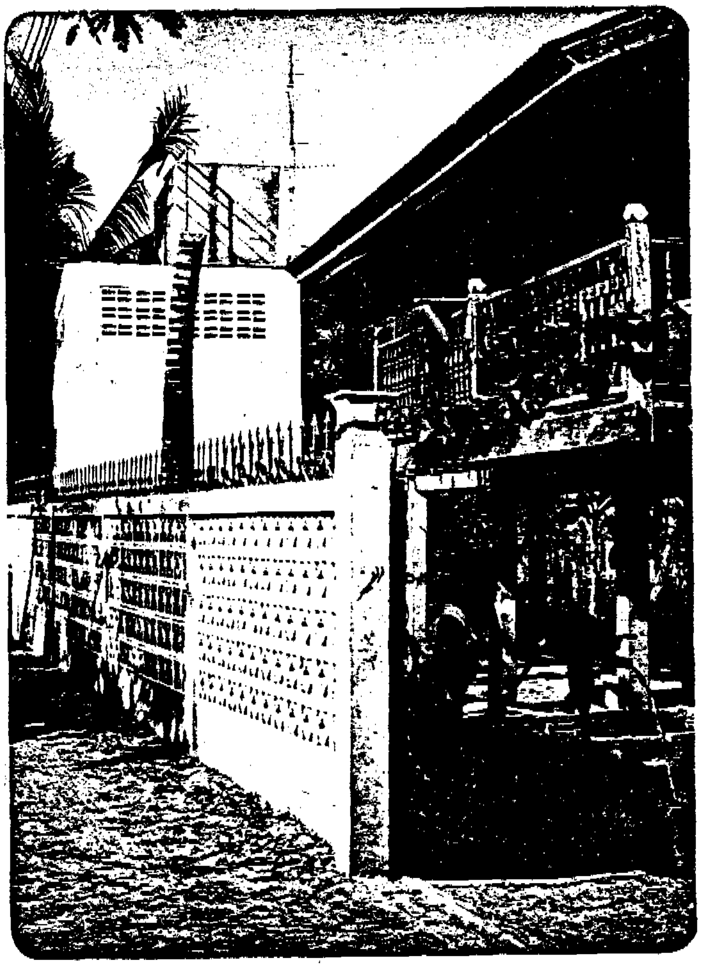

Fig. 5 A hand pump connecting to a dug well being used in a household at Ban Bangloa.

4.2 Ban Thadindam, Lopburi Province.

4.2.1 Background information

Ban Thadindam is located in Chaibadal District, Lopburi Province, about 220 kms. north of Bangkok (see Fig. 1) It is inhabited by 220 families of about 6 persons. It was awarded by the Government

Committee as a demonstration village in the Development Programme in 1978. The village is about 80 kms. from Lopburi Province. The characteristic of the village is shown in Fig. 6.

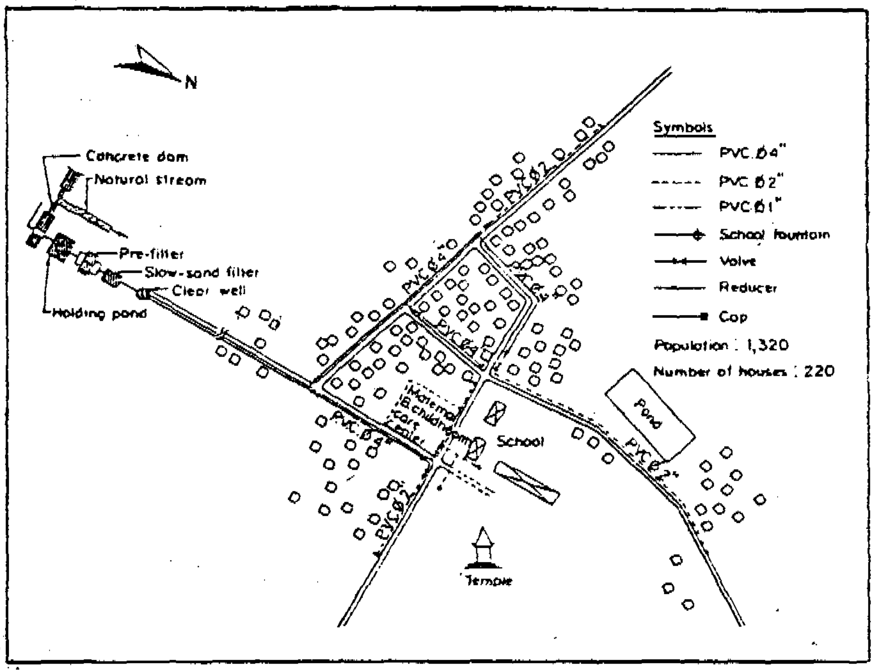

Fig. 6 Characteristic of Ban Thadindam, Lopburi Province.

4.2.2 Climate

Ban Thadindam is also situated in the central part of the country in tropical zone. The average temperature is about the same as Ban Bangloa, 15°C - 38°C. The average annual rain fall is about 1,069 mm., and the average relative humidity is 71.45 %.

4.2.3 Occupation and Income

The land around the village is fertile back soil. Rice-farming is its principal occupation. Other occupants are mat-weaving and stock-raising. The average yearly income per family lies between ฿ 10,000 - 20,000 (1 US$ = ฿ 23).

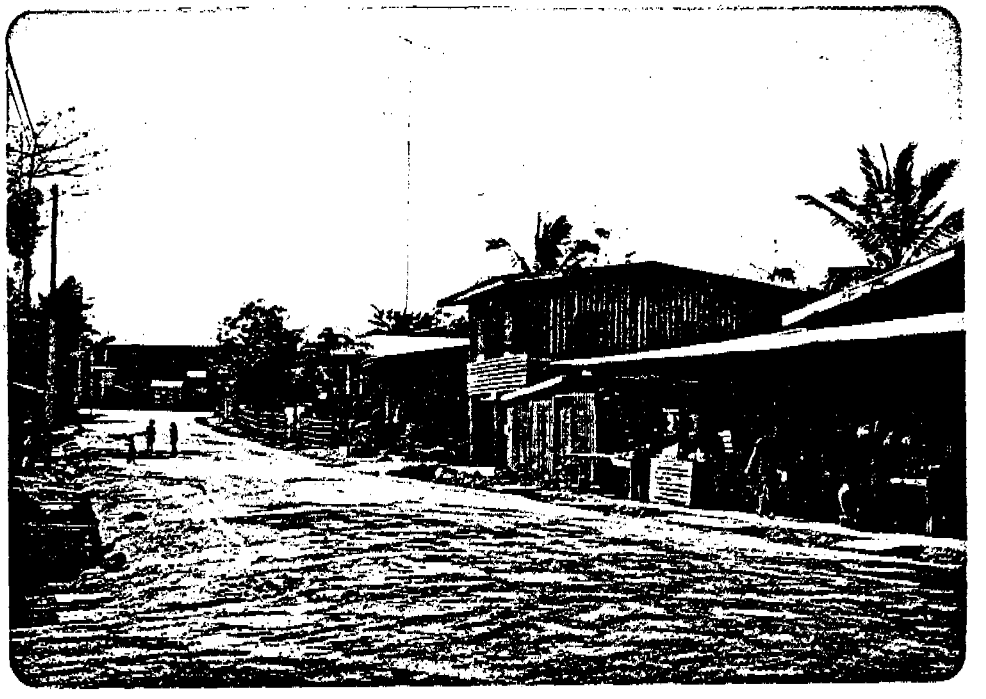

Fig. 7 General view of Ban Thadindam, Lopburi Province.

Fig. 8 Mat-weaving is a typical home industry at Ban Thadindam, Lopburi Province.

4.2.4 Education

A school of the compulsory level is provided within the village . A vocational school and a college of education are available in Lopburi. More than 86 % of the villagers are literate.

4.2.5 Water and Sanitation

The village lies at the foot of a hilly area where natural springs can be found flowing through the village and finally into Pasak river. The villagers have depended on this natural stream for their livelihood since the old days. The private shallow wells are also found in this village. The water from the spring is so clear that chemical coagulation is not needed. Rain water is collected in earthern jars for drinking. Each household, in general , has its own latrine which is a good indication of sanitation programme. Refuse is mostly collected in an open pit and burned. Poultry and livestocks are also kept under the house.

5. ENGINEERING DESIGN

5.1 Description of pre-filter

The pre-filter is designed as a rectangular box 6.50 m. x 8.80 m. and 1 m. deep. The box is divided along its length into six sections provided with wire mesh interception (Fig. 9, 10 and 11). Each section is 1 m. wide x 8.80 m. long and packed with crushed stones of various sizes. The pre-filter box is kept for 0.15 m. as free board. In the first section, a concrete trough of 0.40 m. wide x 8.80 m. long and 0.40 m. deep is installed. There are four 4" dia. holes at intervals of 2.20 m.

The raw water is controlled by a gate valve and flows at the rate of 5 m^3/hr. into the trough, passing through the holes into the first chamber. The water flows horizontally beneath the stone top level through the voids among the crushed stones from the first to the last section.

Attached to the last section is a concrete chamber of 0.40 m.wide x 8.80 m. long and 1.0 m. deep. There are 0.10 m. dia. holes at 0.50 m. intervals at the bottom, connected the last section and the chamber.

The water from the last section flows into the chamber via the holes. There is a galvanized steal pipe of 4" dia. installed at the level of 0.15 m. below the top edge for conveying the water from the chamber to the slow sand filter. The effluent is regulated by a gate valve.

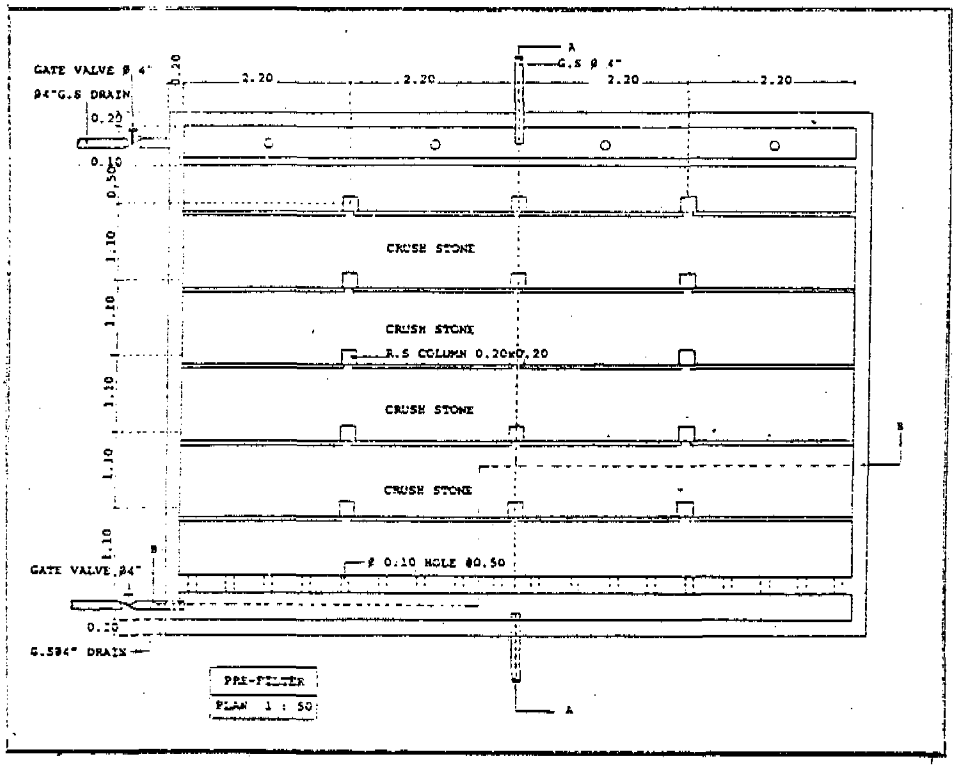

Fig. 9 Pre-filter (horizontal flow pre-filtration unit).

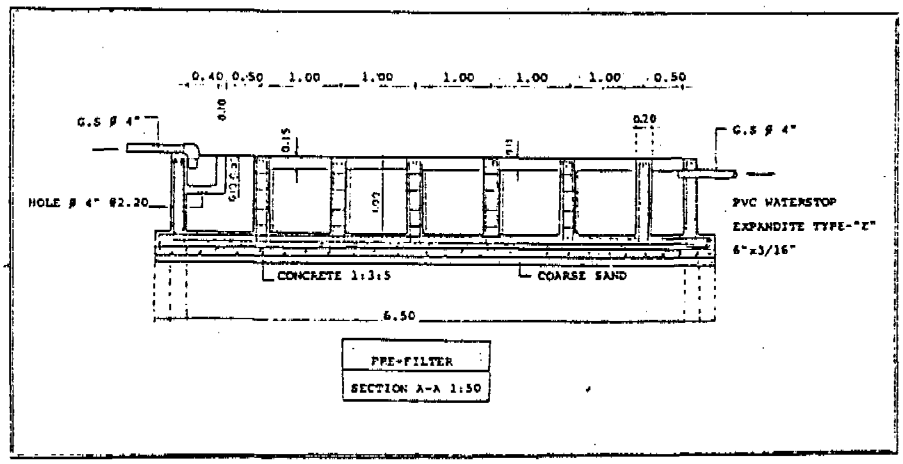

Fig. 10 Pre-filter, section A-A.

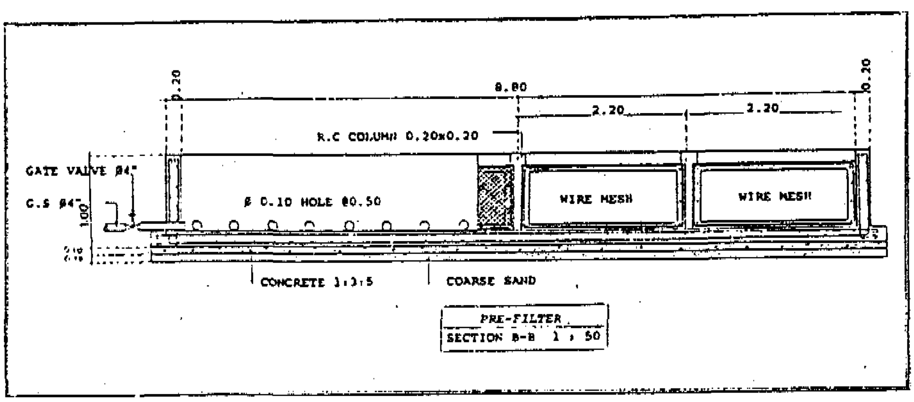

Fig. 11 Pre-filter, section B-B.

5.2 Description of slow sand filter

The slow sand filter is designed as a rectangular box of 5 m.x 6 m. x 3.10 m. deep. The box contains a supernatant raw water layer, a bed of filter medium, a system of underdrains and a set of filter regulation and control devices (Fig 12, 13 and 14).

The effluent from the pre-filter passes through a galvanized steel pipe of 4" dia. into a semi-circular chamber of 0.70 m. radius. The galvanized steel pipe is installed at the level of 0.90 m. above the filter bottom and is covered with soil 60 m. thick.

The chamber is filled with water up to the level of 1.70 m. above the filter bottom. A 6" dia. hole in the filter wall, 1.70 m. above the filter bottom, conveys water from the chamber into the filter box. The water from the chamber passing through the hole spreads out on a 0.50 m. concrete slab and falls onto the sand bed without disturbing the filtration sand.

The sand bed is filled with graded filter sand 1.25 m. thick. It is underlaid by three layers of gravel of various sizes 1-2 mm. dia., 4-6 mm. dia. and 16-23 dia. respectively.

The underdrain system consists of a 6" dia. galvanized steel pipe. The 6" dia. pipe is 5.5 m. long, connected with lateral perforated PVC pipes of 2" dia.

The water collected in the drainage pipes is regulated by a gate valve before passing through a V-notch weir. The weir is made of a galvanized steel pipe ¼" thick (Fig. 15). It is cut into V-shape with a 60° apex angle.

The water passes into a storage tank ; its flow rate is measured by the weir. Another gate valve is installed at this junction for future enlargement.

Two filter units were originally planned and designed. When the construction cost was estimated and found to be over the allocated budget, only one filter box was installed.

In the filter box, there is a 4" dia. galvanized steel valve at 1.25 m. above the filter bottom. Its purpose is to drain off the water above the sand bed for cleaning the sand.

There is another hole at 1.25 m. above the sand bed. The hole is made of galvanized steel pipe of 4" dia. Its purpose is to keep the water level at a height of 1.25 m. above the sand bed. There is 0.30 m. free board above the water level.

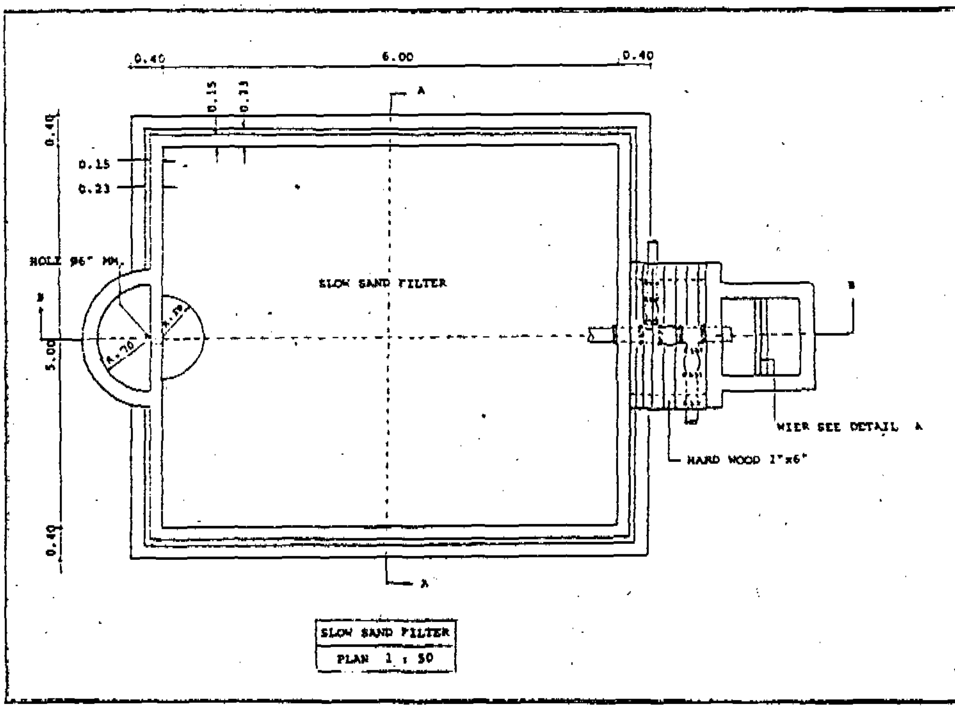

Fig. 12 Slow sand Filter.

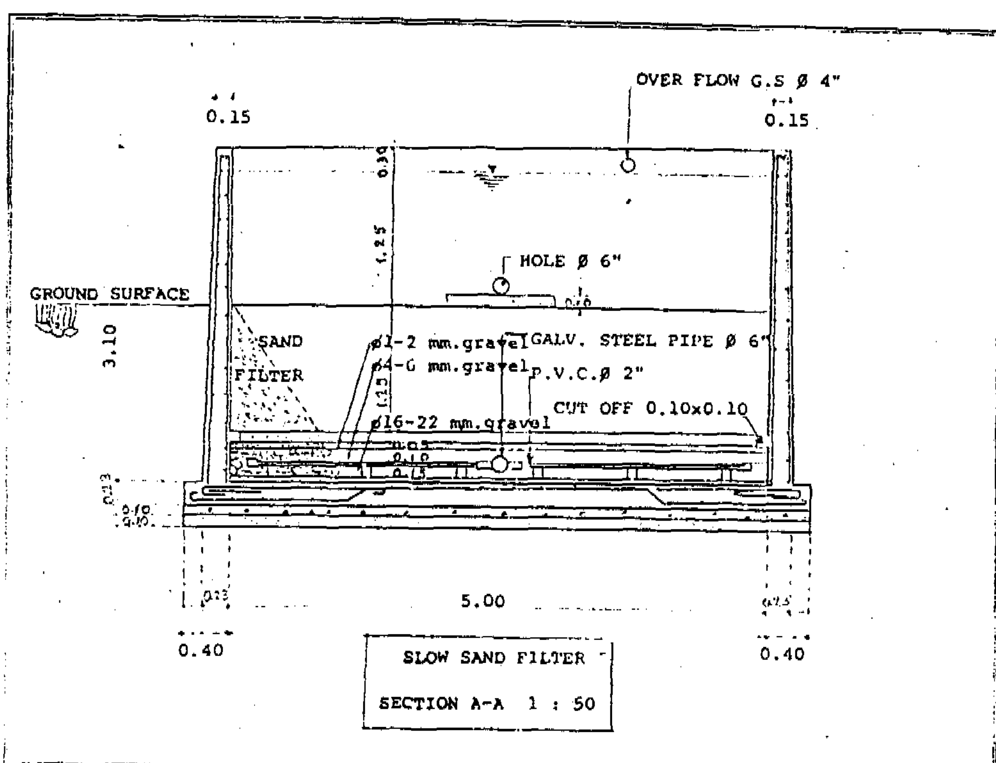

Fig. 13 Slow sand filter, section A-A.

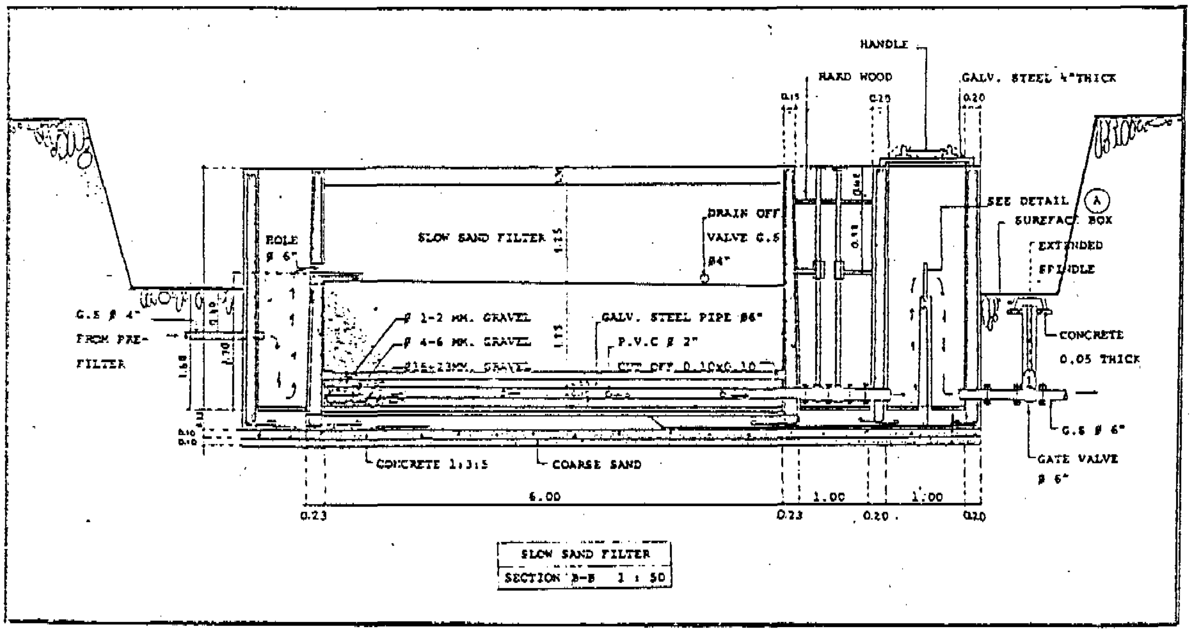

Fig. 14 Slow sand filter, section B-B.

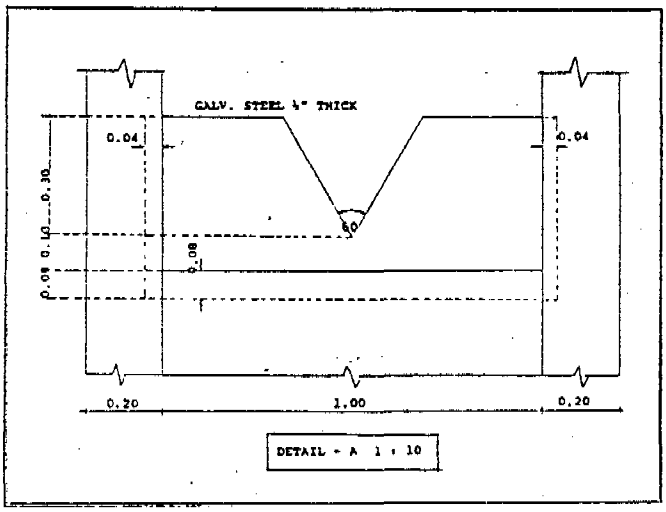

Fig. 15 Wier.

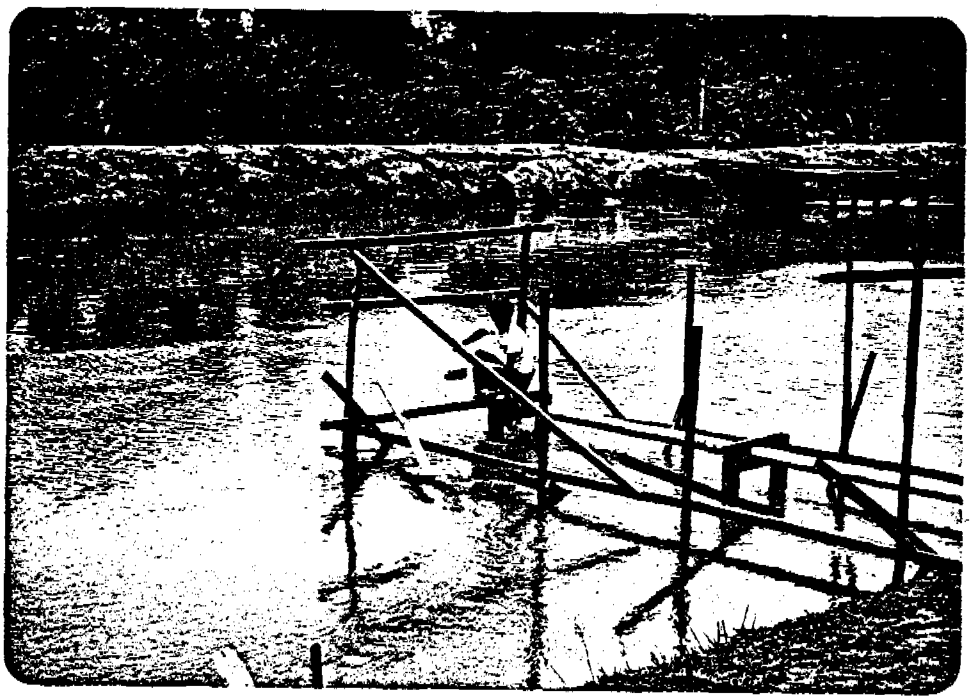

Fig. 16 A water sample being collected from the irrigation canal at Ban Bangloa, Singhburi Province.

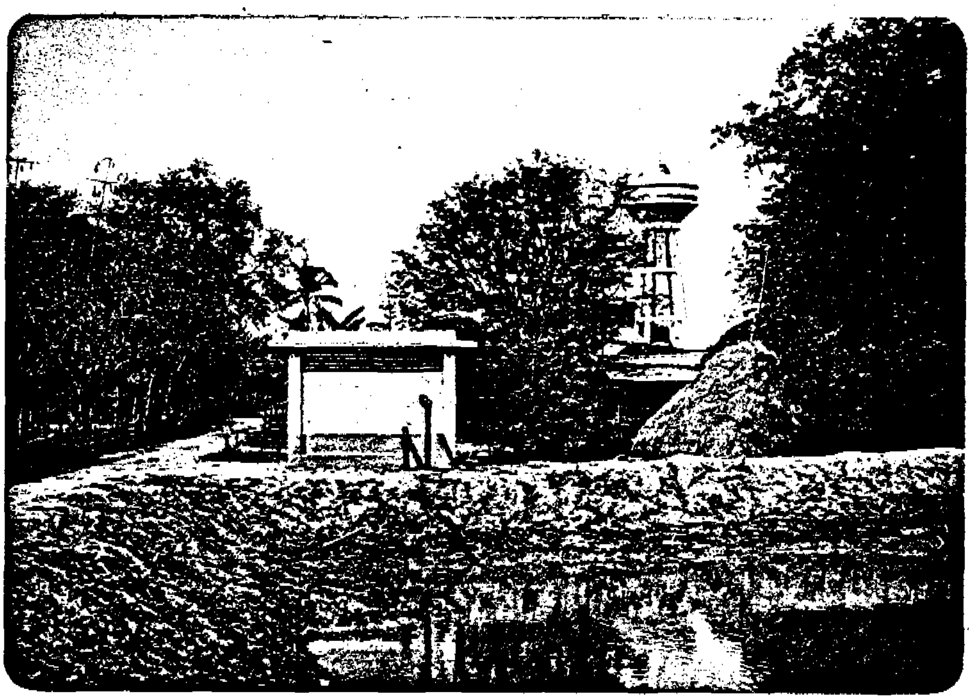

Fig. 17 Showing a holding pond, a pump house and an elevated tank at Ban Bangloa, Singhburi Province.

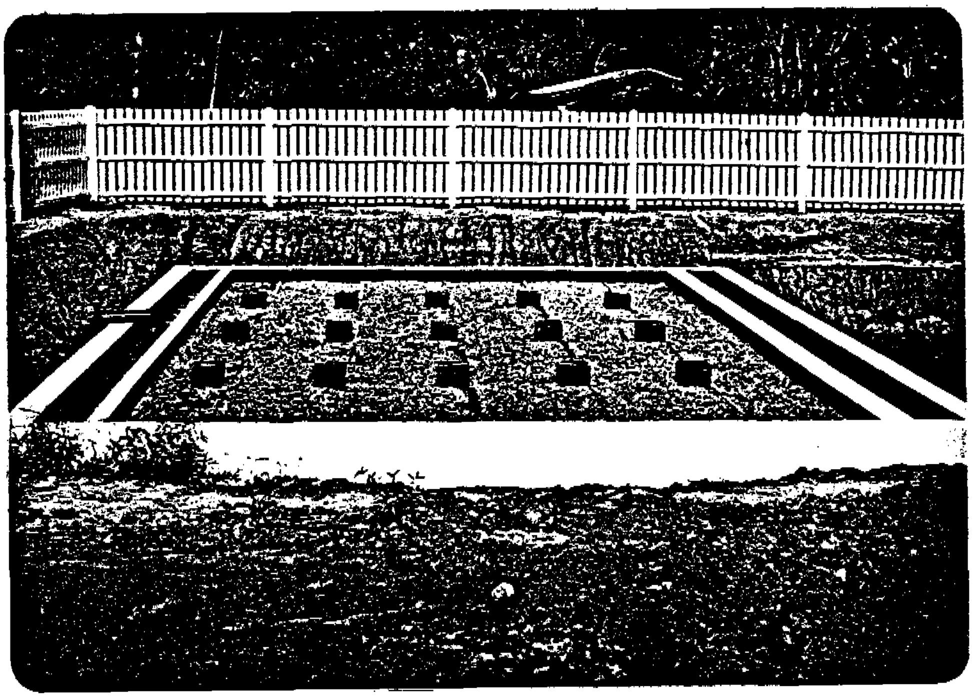

Fig 18 A pre-filter filled with gravel being operated at Ban Bangloa, Singhburi Province.

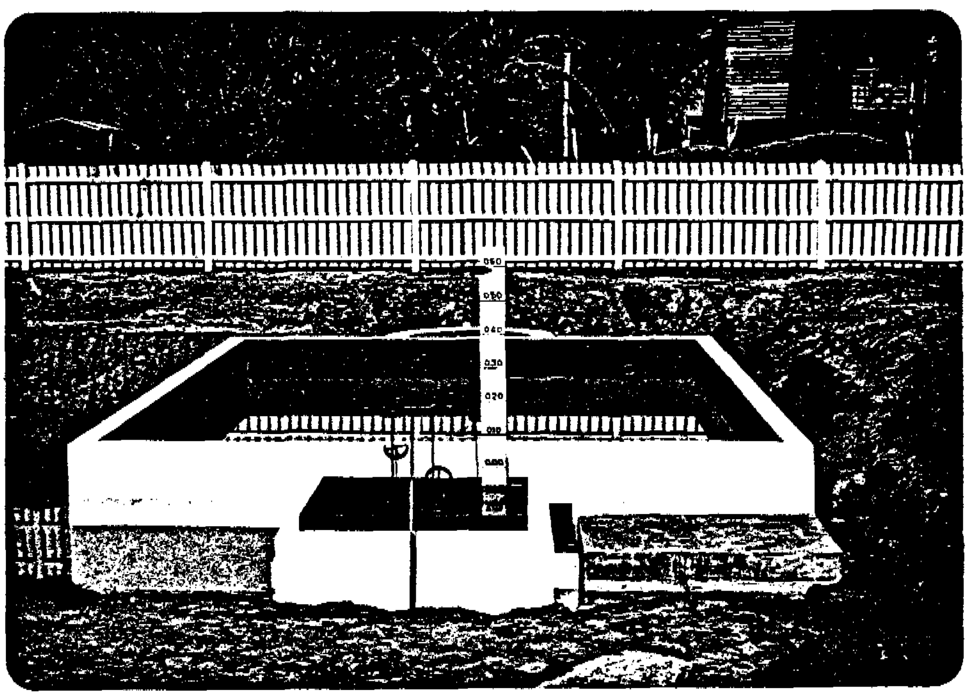

Fig 19 A slow sand filter being operated at Ban Bangloa, Singhburi Province.

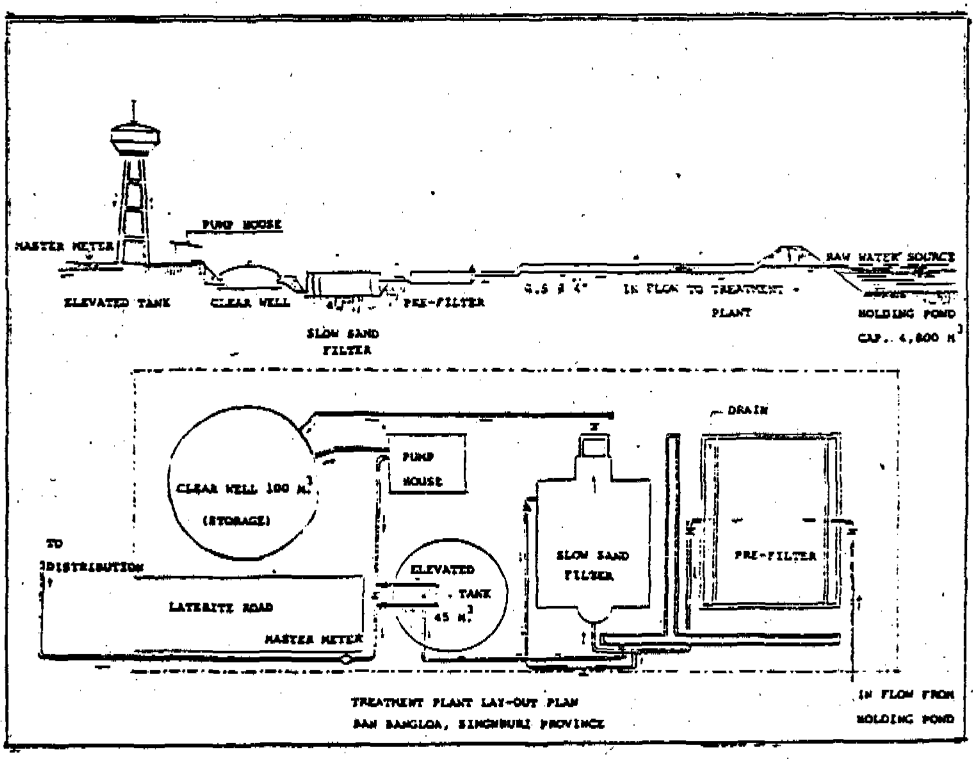

Fig. 20 Showing the treatment plant lay-out of Ban Bangloa Water Supply Treatment , Singhburi Province.

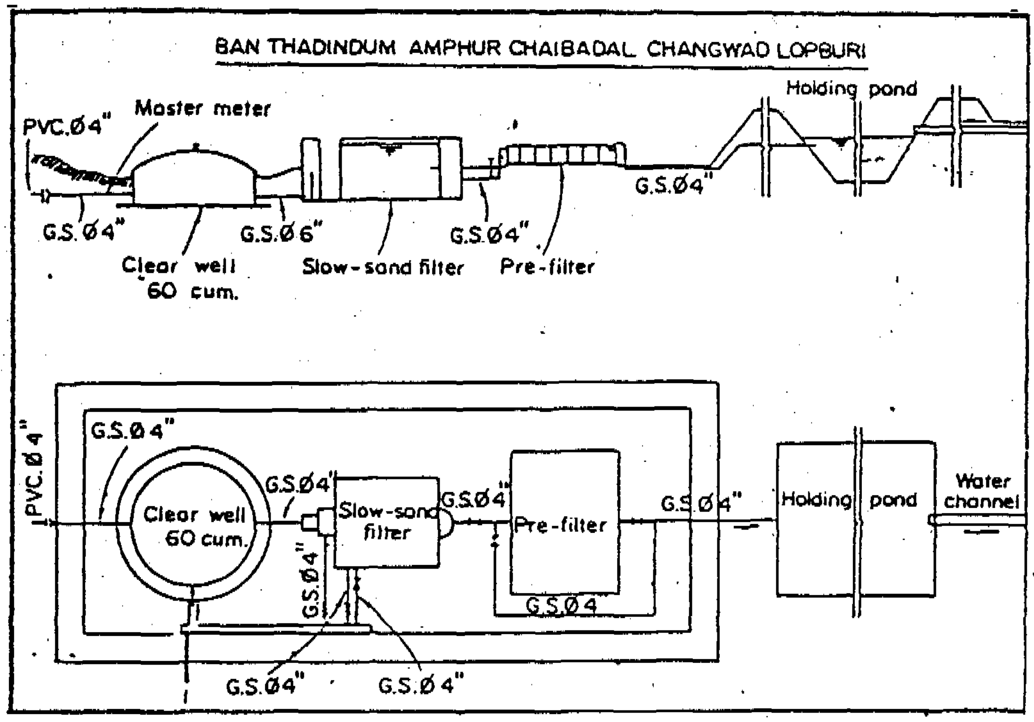

Fig. 21 Showing treatment plant lay-out of Ban Thadindam Water Supply Treatment, Lopburi Province.

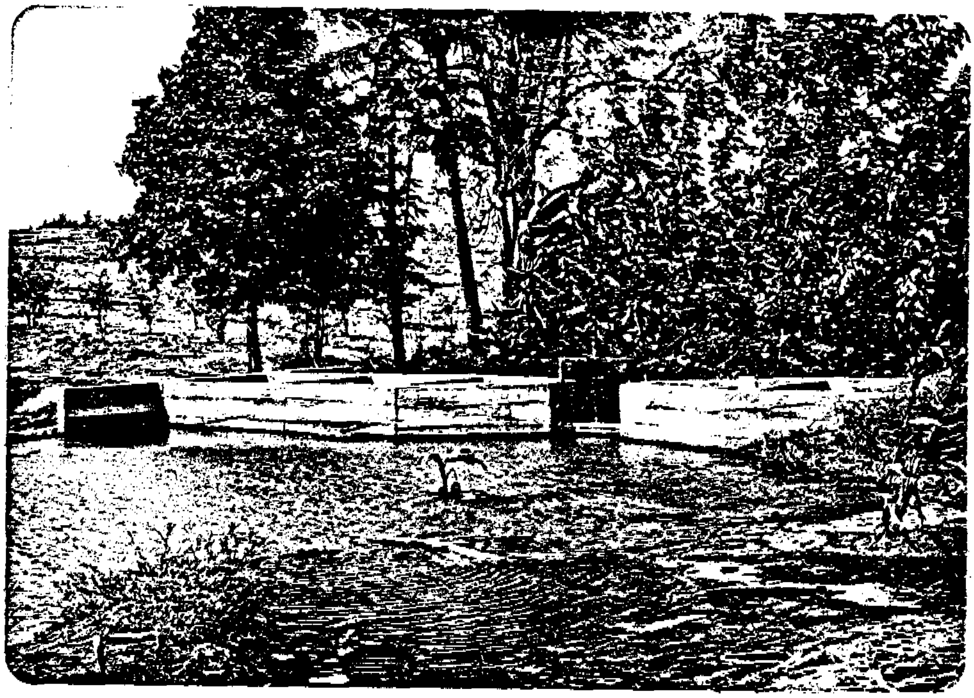

Fig. 22 A concrete dam constructed on a hill to block the way of the natural stream, Ban Thadindam, Lopburi Province.

Fig. 23 View of a trough dug to convey water from the dam into the holding pond at Ban Thadindam, Lopburi Province.

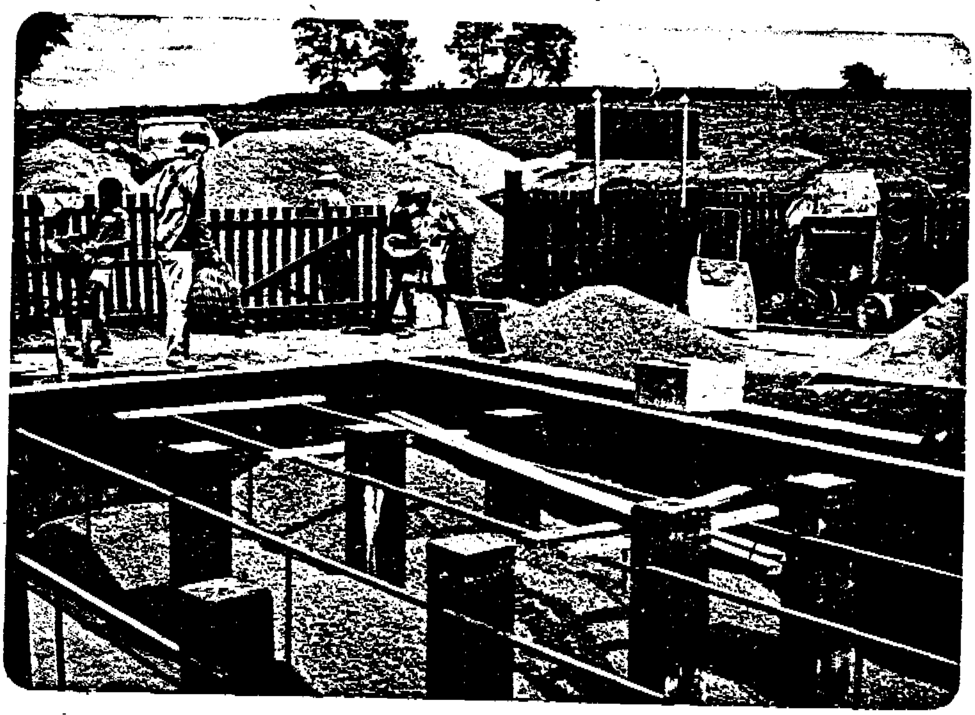

Fig. 24 A horizontal-flow pre-filter being filled with gravels of various graded sizes at Ban Thadindam, Lopburi Province.

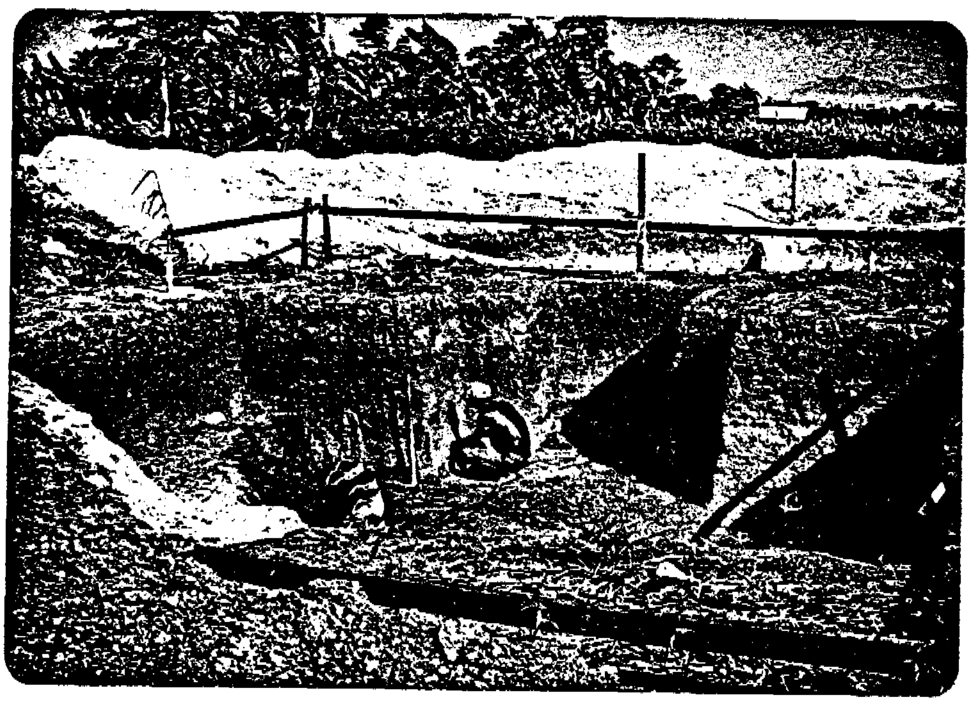

Fig. 25 Excavating the soil into the slow sand filter shape at Ban Thadindam, Lopburi Province.

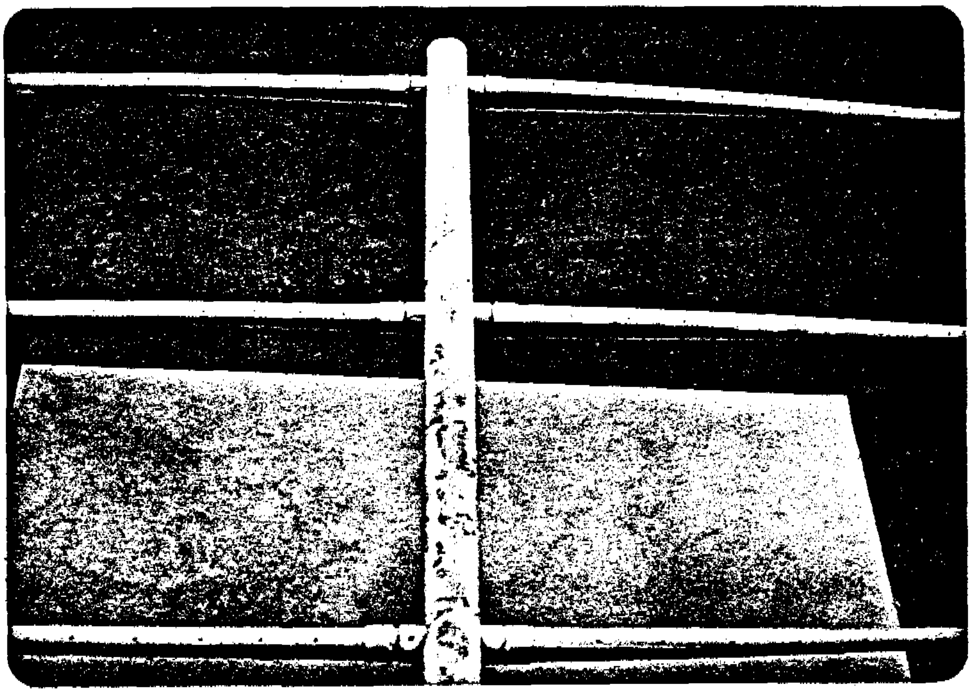

Fig. 26 The underdrain system of the slow sand filter using PVC pipes.

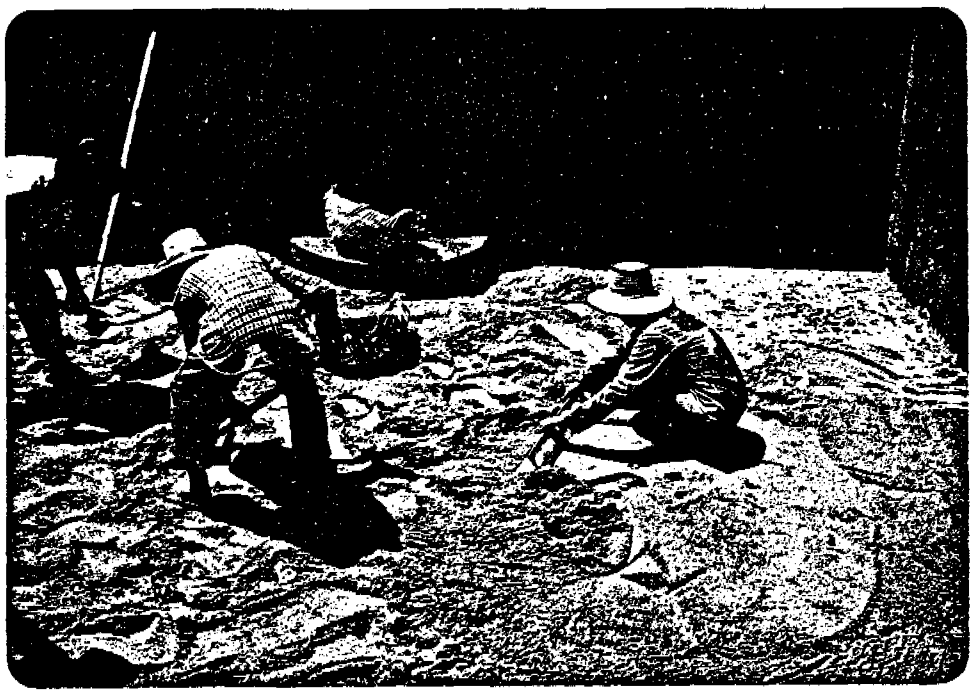

Fig. 27 The slow sand filter is being filled with graded sand at Ban Thadindam, Lopburi Province.

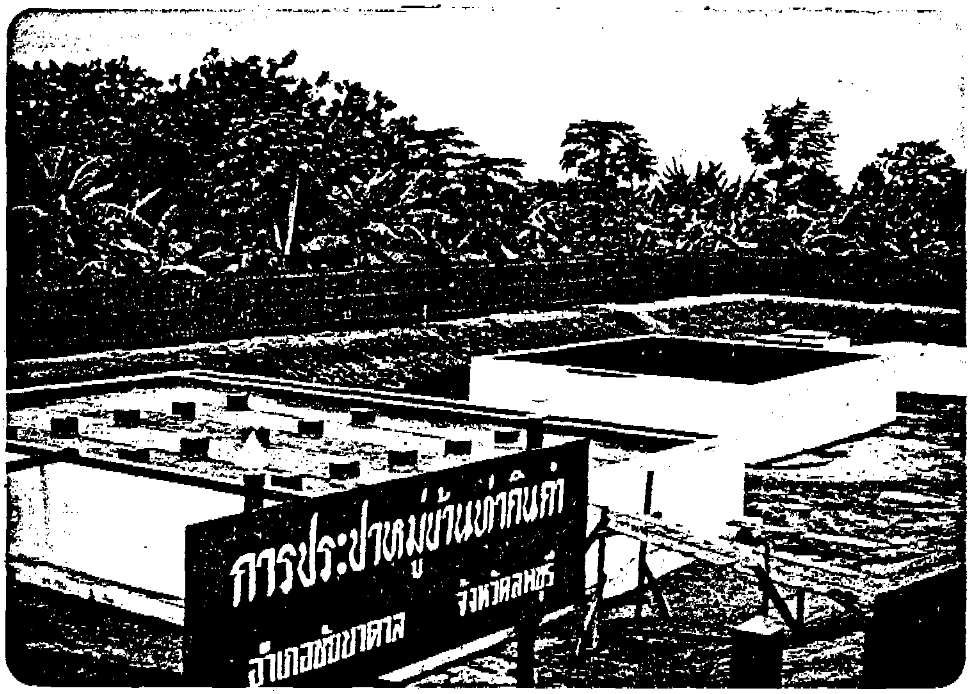

Fig. 28 View of the slow sand filtration system at Ban Thadindam, Lopburi Province.

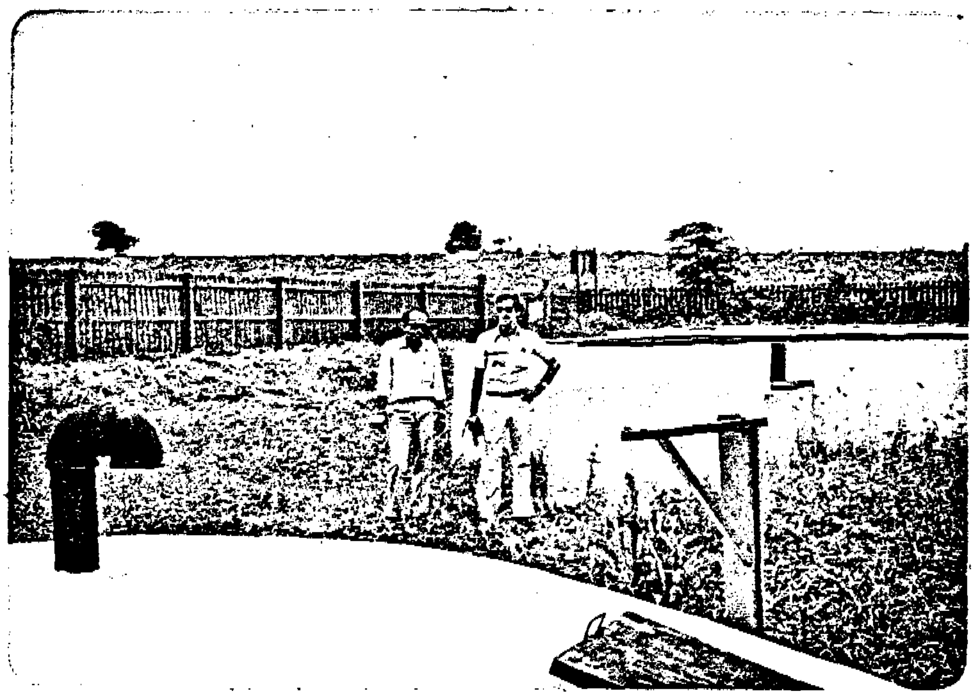

Fig. 29 The IRC Director visited the progress of the Project at Ban Thadindam, Lopburi Province, September, 1981.

6. ECONOMIC COMPARISON BETWEEN SLOW AND RAPID SAND FILTRATION SYSTEMS

6.1 Ban Bangloa, Singhburi Province

6.1.1 Construction cost

If the slow sand filtration system (SSF) had been replaced by a rapid sand filtration system (RSF) at Ban Bangloa, various units of such replacement would have been constructed. The cost of each unit of both systems is compared and presented in Table 1.

It can be noticed that the cost difference between those systems depends on the cost of filtration unit. The total cost of the slow sand filter is higher than the rapid sand filter for ฿ 112,000 or 6-7 %.

TABLE 1 : Comparison of construction cost breakdown between SSF and RSF

	Description	SSF units - ฿ (US$ 1 = ฿23)	RSF units - ฿ (US$ 1 = ฿23)
1.	Raw water pump house	51,000	51,000
2.	Electrical pump for raw water	60,000	60,000
3.	Clear water pump house	39,000	39,000
4.	Electrical pump for clear water	60,000	60,000
5.	Pipe connection within raw water pump house	14,000	14,000
6.	pipe connection within clear water pump house and treatment plant	61,000	61,000
7.	Pre-filter	112,000	-
8.	Slow sand filter	390,000	-
9.	Rapid sand filter	-	380,000
10.	Clear well	162,500	162,500
11.	Elevated tank	247,500	247,500
12.	Raw water distribution & delivery system	343,500	343,500
13.	Chlorination tank	10,000	10,000
14.	Tools for repair of engine & pipe connection	15,000	15,000
15.	Miscellaneous items, fence, name plate, etc.	123,000	123,000
16.	Land	free	free
	Total cost	1,688,500	1,566,500

6.1.2 Cost of operation and maintenance

The SSF plant has been operated since March 1980. A village water supply committee, consisting of seven members, has been formed to advise on the management of the water supply system. A local man has been selected and trained as an operator to carry out the routine running and maintainance proper function of the system. The revenues and the cost of operation and maintenance have been recorded since April 1980 as shown in TABLE 2.

TABLE 2 : Operation and Maintenance costs of Ban Bangloa Water Supply Treatment Plant

Month 1980	Revenue	Operation & maintenance costs						Total Expences
		Salary	Fuel	Oil	Chlorine	Cleaning	Maintainance	
Dry season								
April	5,965	600	1,900	158	185	-	-	2,843
May	4,799	600	1,747	160	165	200	255	3,127
Rainy season								
June	3,050	600	1,468	132	150	-	275	2,625
July	2,550	600	1,554	125	140	200	315	2,932

Note : Water rate is ฿ 3 for first 10 M^3 and ฿ 2 for each additional cubic meter.

It will be noticed that the revenues average ฿ 4,000 per month, while the average monthly expenses are ฿ 3,000. This leaves approximately ฿ 1,000 per month as prefits. A rapid sand filter would have increased the cost of operation by ฿ 1,650 per month ; about ฿ 1,200 for alum and about ฿ 450 worth of filtered water which would have been wasted due to back-washing. At the current price level, the initial higher cost of construcion of the slow sand filter would be balanced by the higher cost of operation and maintenance of the rapid sand filter in about 6 years.

For his work, the operator receives a salary of ฿ 600 per month. Other expenses of water supply management include fuel and lubricant costs for two engine pumps of 14 hp. and 17.5 hp., the 14 hp. pump being used to draw water from the irrigation canal to the holding pond, and the

17.5 hp. pump to lift treated water from the clear well into the elevated tank. Cost of such expenses was ฿ 1,982 per month in dry season and ฿ 1,640 per month in rainy season.

Incurred maintenance was mostly directly to the two diesel engine pumps. It is fortunate that the committee chairman himself knows how to repair the pump engine, otherwise maintenance cost would be higher. Other maintenance costs include repairs of pipe leakage and breakage, which are not substantial for the time being.

6.2 Ban Thadindam, Lopburi Province

6.2.1 Construction cost

If the slow sand filtration system had been replaced by a rapid sand filtration system, various units of such replacement would have been constructed. The cost of each unit is compared and presented in TABLE 3. The high initial cost depends upon the filtration unit only. The construction cost of the rapid sand filtration higher than the slow sand filtration system for ฿ 19,800 or 2.3 %.

TABLE 3 : Comparison of construction cost breakdown between SSF and RSF

Description	SSF units - ฿	RSF units - ฿
1. Pre-filter	108,200	-
2. Slow sand filter, cap.5 m^3/hr.	242,600	-
3. Rapid sand filter, cap. 10 m^3/hr.	-	331,000
4. Clear well, cap. 60 m^3	130,700	130,700
5. Main distribution system	327,000	327,000
6. Miscellaneous items, fence, name plate, etc.	54,500	54,500
7. Land	free	free
Total cost	863,000	843,200

6.2.2 Cost of operation and maintenance

The management of Ban Thadindam Water Supply Treatment Plant is done through a water supply committee established by the villagers.

This committe is consisted of four persons who are responsible for the treatment plant operation and maintenance, income and expenses, recruitment of operators, etc. They receive ฿ 25 each per month as honourarium. The operator with basic training from Rural Water Supply Division undertakes the daily operation of the plant. He has to keep the plant area clean, control the filtration rates and maintain the distribution system, clean the filter at the end of filter run and collect water bills. At the time of report writing, his salary was ฿ 500 per month. Water costs ฿ 1 per cubic meter, which is cheap. TABLE 4 summarizes operating and maintenance costs of Ban Thadindam Water Treatment Plant.

TABLE 4 : Operation and maintenance costs of Ban Thadindam Water Supply Treatment Plant.

Season 1980	Operation & maintenance costs				
	Revenue (average)	Salary	Expenses for committee members	Maintenance cost	Total expenses
Dry season	1,550	500	100	100	700
Rainy season.	1,046	500	100	100	700

Note : 1. Charge for water is ฿ 1 per Cu.M.

2. Number of families using water supply is 288.

As this water treatment plant is situated on a hilly area, the water flows to consumers by gravity. There is no other operating cost, except the operator's salary. No machinery is used, the maintenance is minimum. The only maintenance incurred is towards the repair of pipe leakages.

The average monthly revenue in the dry season was ฿ 1,500, but in the rainy season the revenue decreased to ฿ 1,000. After deduction of salaries and cost of operation and maintenance profits are between ฿ 300-800 per month . These funds will be used for further improvement of the water supply system.

The cost of operation of a rapid sand filter is estimated to be about ฿ 200 per month higher than the operational expenses of the slow sand filter ; ฿ 140 for alum and ฿ 60 due to wasting of treated water. The initial construcion cost of the slow sand filter would again balance the cumulative cost of the rapid sand filter and its operation and maintenance in about 8 years.

6.3 Conclusions and recommendations

The following conclusions can be drawn in relation to the economic comparison between slow and rapid sand filters : -

a) The cost of construction of a slow sand filter is about 2-7 % higher than that of a rapid sand filter.

b) Depending on the degree of turbidity of the raw water, the cost of operation and maintenance of a slow sand filtration plant may well be lower by 25-55 % than that of a rapid sand filtration plant.

c) If both the slow and rapid sand filters have been operated continuously for about 6-8 years, the construction costs plus the costs of operation and maintenance of both systems would be about the same.

d) One of the factors that has hampered the application of the slow sand filter in the past is the high initial cost of construction as compared with the initial cost of rapid sand filter. Generally, a water supply system is designed to function for at least 10 years.

This study clearly shows that the slow sand filtration system within the standard design period, is not more expensive than the rapid sand filtration system and may well turn out to be even cheaper in the long run. Therefore, it is considered worthwhile to invest in the construction of the slow sand filter. Moreover, the slow sand filtration system has more advantageous than the rapid sand filtration system because of its simplicity in operation and maintenance.

7. MONITORING PROGRAMME

After the two water supply treatment plants at Ban Bangloa, Singhburi Province and Ban Thadindam, Lopburi Province had been completed and put into operation, the monitoring programme was carried out from January to August, 1980. Samples were collected and analyzed at the AIT's Environment Engineering Laboratory. The results of water quality are discussed below.

7.1 Ban Bangloa, Singhburi Province

7.1.1 Raw water characteristics

An irrigation canal passing by the village is the raw water source for Ban Bangloa water supply system. The irrigation canal water is taken from Chao Phya River for agricultural purpose. The embankments and the canal bed are made of earth loosely compacted, imparting high turbidity to the water. Raw water characteristics during the monitoring programme are shown in TABLE 5.

TABLE 5 : Raw water characteristics of Ban Bangloa Water Supply System

Parameters	Concentration range mg/l
pH	7.3 - 8.3
Turbidity, NTU	67 - 275
Colour, ^{o}Hazen	200 - 750
BOD_5	2.4 - 3.2
D.O.	6.3 - 8.3
Total hardness, mg/l as $CaCO_3$	64 - 116
Total solids	203 - 362
Total iron	0.40 - 0.67
Manganese	0.08 - 0.10
Chloride	6.0 - 6.8
Sulphate	7.4 - 9.6
Nitrate	0.28 - 0.35
Total coliform, MPN / 100 ml	2,200 - 5,400
E.coli, MPN / 100 ml	90 - 170

It can be seen that the irrigation canal water has very high turbidity and colour, although other parameters are within the acceptable ranges. Biochemical oxygen demand (BOD_5) was determined from time to time to detect the pollution contamination and the extent of algal development. Some important parameters are discussed below. All parameters determinations are reported in TABLES A 1 - 12 in Appendix A.

7.1.2 Flow rate and filter run

The designed plant capacity is 5 m^3/hr. The measured influent flow to the pre-filter was about 4.5 m^3/hr. Flow measurement was carried out by means of a bucket and stop watch by a skilled operator.

It was almost impossible to measure the filtration rate of the slow sand filter as the weir was submerged under water most of the time. Measurement was possible only twice with an average value of 3.3 m^3/hr. which is well below the designed filtration rate.

TABLE A 1 in Appendix A shows that the slow sand filter was stopped after 103 days of operation for cleaning, due to poor quality of treated water. One inch of the top layer of sand bed was scraped off, and the sand filter was restarted. The monitoring continued under the supervision of the operator in the village.

7.1.3 Discussion on important parameters

(a) Turbidity and colour

Fig. 30 shows variations of turbidity in raw water and in effluents of the pre-filter and slow sand filter of Ban Bangloa Water Supply Treatment Plant. In the dry season when raw water turbidity was relatively low, say about 100 NTU, the system produced water of acceptable quality of about 25 NTU. When turbidity in raw water rose above 200 NTU in rainy season, the quality of treated water deteriorated and was not acceptable in terms of turbidity.

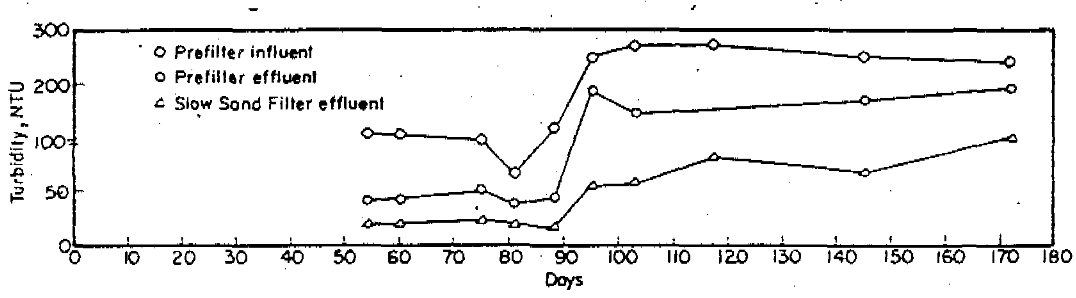

Fig. 30 Turbidity in influent and effluents of Ban Bangloa Water Supply Treatment Plant.

Fig. 31 shows variations of colour in raw water and effluents of pre-filter and the slow sand filter. At present, colour is "apparent colour" and closely associated with turbidity.

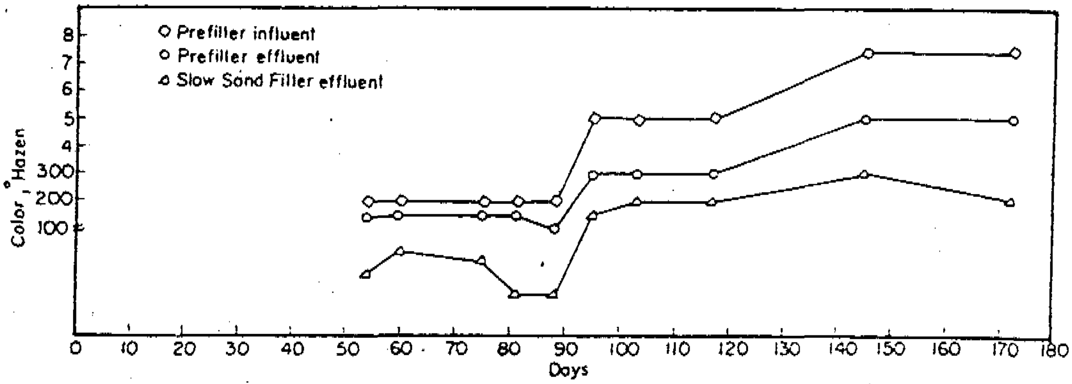

Fig. 31 Colour in influent and effluents of Ban Bangloa Water Supply Treatment Plant.

(b) Sand size

The examination of the grain size distribution of sand in the slow sand filter, it was found that the effective size "E" varied between 0.45 - 0.58 mm. and uniformity coefficient "U" between 1.45 - 1.82, which were far different from recommended values for grain size used in the slow sand filter, E = 0.23 mm. and U = 1.8. A smaller grain size of sand would do a better job in removing turbidity and colour.

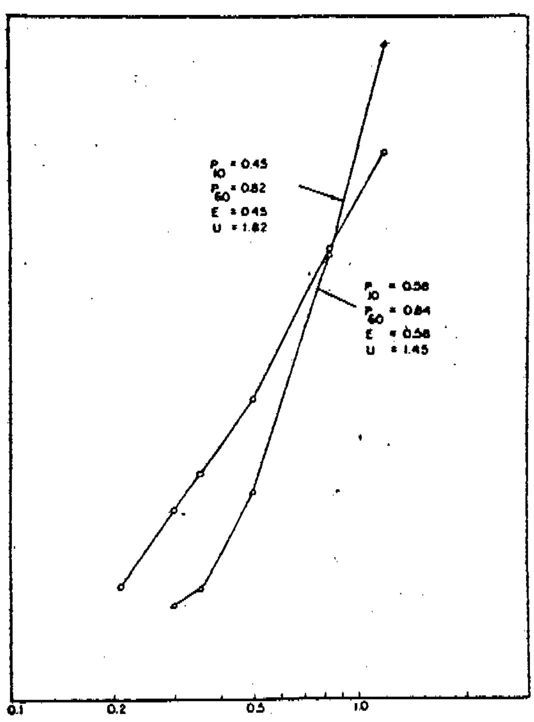

Fig. 32 Grain size distribution of sand in the slow sand filter at Ban Bangloa (5 June 1980).

(c) Coliform organisms

Fig. 33 shows the results of total coliform count in raw water and effluents from the pre-filter and the slow sand filter. The most probable number (MPN) of raw water total coliform varied from 2,200 to 5,400 per 100 ml. of sample. The effluent from the pre-filter had a coliform count varying from 49 to 93 MPN/100ml. In general, the horizontal pre-filter accounted for 95 % removal of coliform organisms while the slow sand filter accomplished 55 % removal of the remaining coliform organisms resulting in an overall removal of 96 - 99 %.

There was presence of E.coli organisms in the holding pond (90 - 170 MPN/100 ml.). The horizontal pre-filter removed 80 % of E.coli organism whereas the slow sand filter accounted for 100 % removal of the remaining E.coli organism (Fig. 34).

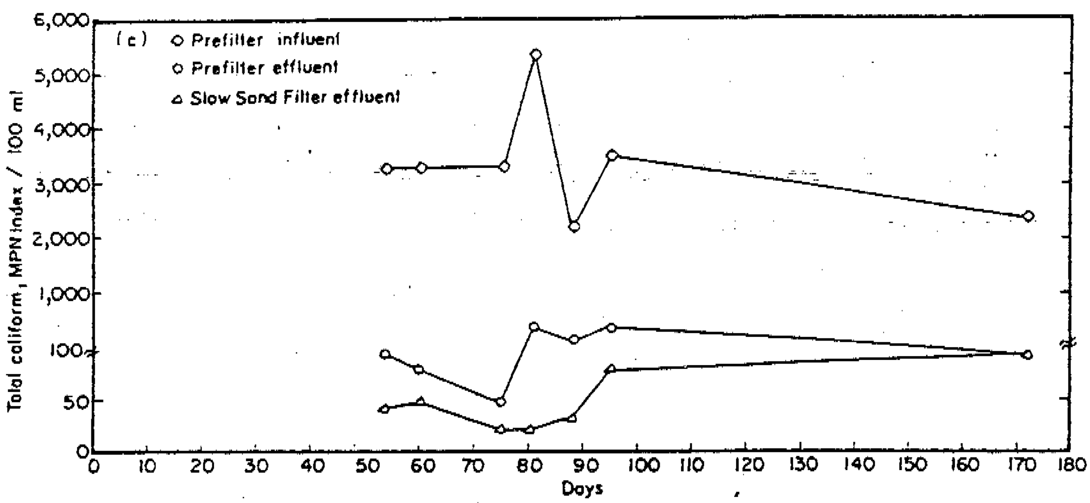

Fig. 33 Coliform organisms counts in influent and effluents of Ban Bangloa Water Supply Treatment Plant.

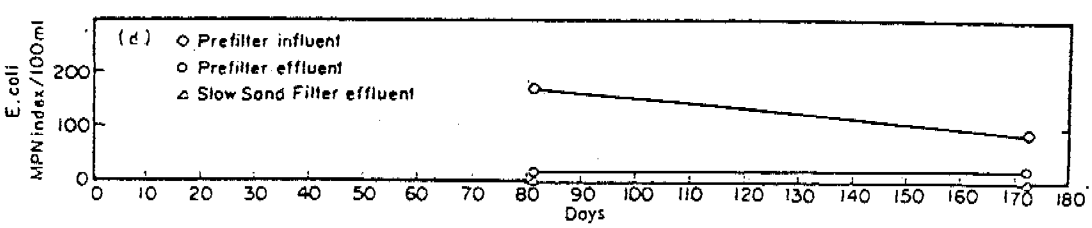

Fig. 34 E.coli counts in influent and effluents of Ban Bangloa Water Supply Treatment Plant.

7.1.4 Comments

The following comments and recommendations are made at the conclusion of the monitoring programme excuted by AIT.

a) In general, the design of the treatment plant is acceptable.

b) The area of the treatment plant is muddy and dirty. The working area of the site must be properly paved.

c) The pre-filter, the slow sand filter and the clear well are immerged under the flood during inundation period. Two alternatives are recommended, either close the plant during flood season or build protective concrete wall around the vulnerable parts of the plant.

d) Remove pre-filter medium, properly wash it and repack.

e) Change the existing filter medium to proper size, and apply correct initial commissioning of the slow sand filter according to techniques universally accepted.

f) The proposed horizontal flow pre-filter constructed at Ban Bangloa is feasible for the slow sand filtration. But the availability of the pre-filter surface is insufficient to remove turbidity during the rainy season. Therefore, another unit of either a pre-filter or a holding pond is recommended otherwise a chemical coagulation unit is needed.

g) Close supervision and inspection must be provided by a PWA engineer who could visit the plant at least once in three months in order to collect data, give additional instruction and provide on the job training to the operator. Frequent meetings between him and the committee chairman are suggested.

h) It is felt necessary to give additional education of public health to the villagers, emphasize them the significance of good water quality.

i) Finally, reasonable increasing in water rate charge is necessary in order to properly operate and maintain the water treat-plant.

within 50-60 mg/l. Nitrate concentration, in terms of nitrogen, should not exceed 10 mg/l or 44 mg/l as NO_3 in pulic water supplies.

TABLE 7 : International standards for drinking water

Substances	Highest desirable level	Maximum Permissible level
pH range	7.0 - 8.5	6.5 - 9.2
Turbidity	5 units[a]	25 units
Colour	5 units[b]	25 units
Total hardness	100 mg/l as $CaCO^3$	500 mg/l as $CaCO_3$
Total solids	500 mg/l	1,500 mg/l
Iron (total as Fe)	0.1 mg/l	1.0 mg/l
Manganese as Mn	0.05 mg/l	0.5 mg/l
Sulphates (as SO_4)	200 mg/l	400 mg/l
Chloride (as Cl)	200 mg/l	600 mg/l

[a] = Turbidity units
[b] = Platinum-cobalt scale

7.2.2 Flow rate and filter run

It was found that calculated influent flow of water to pre-filter was about 7.1 m^3/hr., which was higher than the design value. It is necessary to provide a gate valve to control this flow. However, filtration rate in the slow sand filter was maintained at about 0.15 m^3/m^2/hr., the calculated discharge was 4.4 m^3/hr., which is well in the range of the design plant capacity. It is then important to recirculate the pre-treated water back to the inlet of the pre-filter.

The slow sand filter was in continuous operation for over 6 months before it was stopped for cleaning. The monitoring programme also ended, and it is now under the supervision of the operator.

7.2.3 Discussion on important parameters

Quality of treated water was excellent in terms of turbidity and colour. During the monitoring period, turbidity of treated water was always less than 1 unit and colour was less than 5 units on the Platinum-Cobolt scale. As expected, total solids and total hardness are not much affected by the filtration system and remained unchanged after treatment. However, the water quality is in the permissible levels for drinking purpose. Total iron and manganese were removed to great extent and their concentrations in treated water were well below the highest desirable level for drinking water standard.

Discussion below involves the parameters of nitrate and coliforms.

a) Nitrate

Fig. 35 shows nitrate contents in raw water and in the treated water. Nitrate was not removed at all by this mode of treatment. The treated water still had a nitrate content of 30 mg/l, which is still of relatively high concentration for water supply. Measures have to be taken to control high concentraions of nitrate in raw water used as a source of water supply to avoid undesirable public health effects.

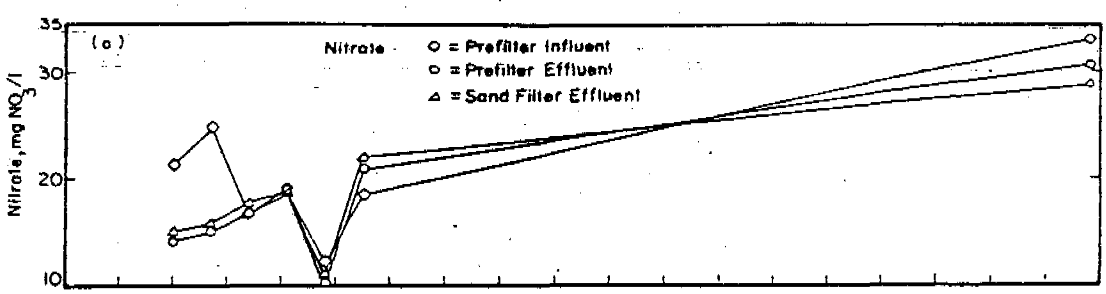

Fig. 35 Show nitrate content in influent and effluent of Ban Thadindam Water Supply Treatment Plant

b) Coliform organisms

Fig. 36 shows the results of total coliforms count in raw water and effluents from the pre-filter and the slow sand filter. MPN of total coliform in raw water varied from 2,400 - 35,000 per 100 ml of sample. The pre-filter accounted for 96 % removal of coliform organisms, while the slow sand filter increased to 99 % removal.

For E.coli, raw water contained 2,300 - 7,900 counts per 100 ml of sample (Fig. 37). Pre-filter accounted 99 % removal of E.coli and there was no presence of E.coli in treated water, which is considerably safe for drinking water supply.

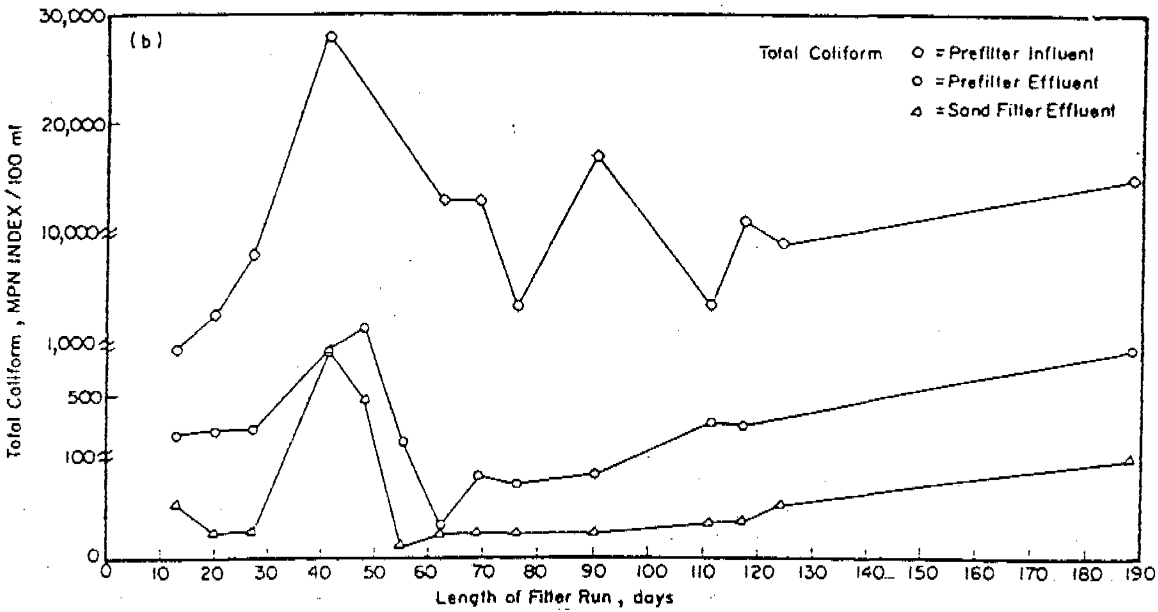

Fig. 36 Total coliform organisms in the influent and effluent of Ban Thadindam Water Supply Treatment Plant.

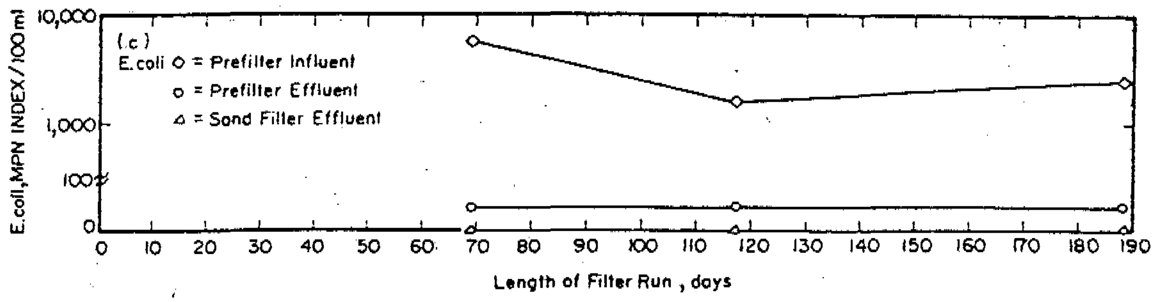

Fig. 37 E.coli organisms in the influent and effluent of Ban Thadindam WaTer Supply Treatment Plant.

7.2.4 Comments

The selection of raw water source was successfully conducted in case of Ban Thadindam Water Supply Treament Plant. This source is ideal for slow sand filtration system as the raw water contains very low turbidity content. The treated water is suitable for domestic purpose. Special attention must be given to nitrate content which could be cause of disease when its concentration is more than 40 mg/l.

The following recommendations can be made :

a) Promptly repair pipe leakages.

b) Cover the pre-filter and the slow sand filter to protect sun light and thus minimize the algal growth.

c) Reduce hydraulic loading at the inlet of the pre-filter by installing a float valve at the pre-filter inlet pipe.

d) Install manometer to show the headloss of the slow sand filter so as the operator will know when to stop and clean the slow sand filter.

e) Frequent visits of the village committee and PWA engineers are encouraged to provide technical and moral support to the operator, and to promote better participation of the villagers in the project.

f) As the raw water quality is very ideal for the slow sand filtration system, only a holding pond is sufficient to reduce turbidity , thus a pre-filter unit can be omitted.

8. HEALTH EDUCATION AND COMMUNITY PARTICIPATION PROGRAMME

8.1 Activities

The health education programme of the Slow Sand Filtration Research Project has been conducted into three phases as follows : -

Phase 1 : Pre-construction

It is neccessary to study the socio-economic condition of the community before one initiates a rural water supply project. The characteristics of the community such as social behaviour, education, occupation, etc. are important factors that will ensure the positive result of the project development.

The success of the project also depends on the interest of the influential villagers, such as the headman, a religious leader, a head master, etc. This group of people can easily generate the interest in such a programme. Nevertheless, the degree of community interest most certainly depends on the need of the new facility. Furthermore, the willingness to participate in the water supply project also depends on the economic status of the community.

A set of questionaires was developed for collection of data. The results of the baseline survey are summarized in TABLE 8.

TABLE 8 : Summary of the baseline survey on socio-economic aspects of Ban Bangloa and Ban Thadindam.

Description	Ban Bangloa	Ban Thadindam
1. Percentage of houses surveyed	50 %	50 %
2. Population, total	314 families	159 families
	1,884 people	850 people
- male	46.5 %	50 %
- female	53.5 %	50 %
3. No. of people per family	2 -13	2 - 13
- average	5	5
4. Owner status of the premises	99.0 %	99.0 %
5. Education		
- no. of schools	2	1
- literacy rate (age above 10 yrs.)	83 %	86 %
6. Occupation distribution		
- farming	43.6%	58.9 %
- stock-raising	3.7 %	0.2 %
- handicraft	2.4 %	4.3 %
- labour	9.7 %	8.0 %
- trading	6.3 %	2.0 %
- working outside the village	5.6 %	0.8 %
- house-wife	2.9 %	1.0 %
- student	15.9 %	18.6 %
- unemployed	3.2 %	1.5 %
- unidentified	6.7 %	4.5 %
7. Sources of income		

- rice farming	44.0 %	1.0 %
- other crop farming	4.0 %	47.0 %
- stock-raising	4.0 %	1.0 %
- handicraft	2.0 %	17.0 %
- wage-earner	46.0 %	34.0 %
8. Average income/fam/month	฿ 1,850	฿ 2,420
Average national income/fam/month	฿ 1.930	฿ 2.400
Average national expense/fam/month	฿ 2,400	฿ 2,400
9. Existing water sources	1. Chao Phya River 2. Irrigation canal	1. Spring
10. Before installation of SSF		
- drinking water	rain	rain & spring
- for other purposes	river, well	spring
11. Treatment of drinking water		
- from rain water	direct 32 % boiling 11 %	direct 84 % boiling 10 %
- from river & well	alum 57 %	alum 6 %
12. Treatment of water for other purposes	alum 73 %	alum 7 %
- no treatment	27 %	93 %
13. Refuse disposal		
- put into open pit & burn	94 %	95 %
- other method	6 %	5 %
14. Having private latrine	92 %	83 %
15. Participation in		
- village affairs meeting	81 %	92 %
- health affairs meeting	67 %	39 %
16. Priority of village needs in relation to other needs	1. water supply 2. good road	1. good road 2. electricity 3. water supply
17. Need for water supply	93 %	85 %
18. Willingness to participate in SSF Project		
- through digging a holding pond	97 % yes	93 % yes
- through labour for laying pipes	97 % yes	97 % yes
- through purchase of water meter	97 % yes	97 % yes
19. Willingness to pay for water charge		
- ฿ 1 per cubic meter	32 %	-
- ฿ 2 per cubic meter	35 %	18 %
- ฿ 3 per cubic meter	8 %	-
- not willing to pay	25 %	82 %

20. Preference on chlorine addition		
- agree	96 %	76 %
- disagree	4 %	24 %

The results of the survey have revealed that the villagers under the leadership of the village headman are willing to contribute free labour and materials for digging a holding pond and laying pipelines. Their contribution is summarized in TABLE 9 & 10.

TABLE 9 : Community contribution towards the water supply construction at Ban Bangloa, Singhburi Procince

Description	Baht (1 US$ = ฿ 23)
1. Cash	10,000
2. Sand & gravel	10,000
3. Labour for digging a holding pond	10,000
4. Land for treatment plant	60,000
Total contribution	90,000

Percentage of contribution to the total cost of construction = 4.4 %

TABLE 10 : Community contribution towards the water supply treatment plant at Ban Thadindam, Lopburi Province

Description	Baht (1 US$ = ฿3)
1. Labour for digging a holding pond	10,000
2. Land for treatment plant	10,000
3. Pipes for distribution system	80,000
Total contribution	100,000

Percentage of contribution to the total cost of construction = 10.1 %.

Fig. 37 The PMC chairman regularly organised an informal meeting to encourage the local government officials and villagers to pay much attention to SSF Project.

Fig 38 Health education is promoted in school at Ban Thadindam, Lopburi Province.

Phase 2 : During construction

The district health workers organised the movie show in the demonstration villages. During the intermission, the health workers informed them the harmfulness of the intestinal worms especially hook-worms. Some slides and specimens were shown in order to draw their attention. A laxative liquid was prepared and used to remove those worms. It was noticed that very few people were willing to cooperate in such a campaign since they felt that there was no need to do so.

When the construction of the water supply system was nearly finished , the villagers were informed that they had to dig the ground for laying pipe from the main pipe line to their house vicinity under the water supply authorities' supervision. It was found that each family was eager to dig the ground , lay pipe line for his own connection (Fig. 39). In many houses,there were no men at home during such a period, women had to do the work instead. It was noticed that those women enjoyed themselves digging the ground and laying the pipes.

Fig. 39 Villagers participating in laying pipe line under closed attention of the village headman at Ban Thadindam, Lopburi Province.

Phase 3 : Post-construction

When the slow sand filtration systems in Ban Bangloa and Ban Thadindam were completed, the water supply have been operated and supplied to villagers. Since then there are changes in living conditions which reflect the result of the demonstration projects. Another set of questionaires was developed to evaluate the impacts of the water supply on the communities. The number of houses interviewed at Ban Bangloa and Ban Thadindam were 190 and 100 respectively. The results of the evaluation are shown in TABLE 11 , and the correlation studies between important topics were chosen and presented in TABLE 12 - 21.

TABLE 11 Evaluation on health education after water supply had been operated for a year.

Description	Ban Bangloa	Ban Thadindam
A. Consumption		
1. What kind of water do you drink, when rain water is not available ?		
- water supply	68.4 %	91.0 %
- well water	15.3 %	8.0 %
- others	16.3 %	1.0 %
2. Could you tell me how to treat the raw water if you don't drink water supply ?		
- boil	1.0 %	5.0 %
- alum coagulation	27.4 %	0.0 %
- filtration	0.0 %	1.0 %
- sedimentation	2.6 %	3.0 %
- no answer	69.0 %	91.0 %
3. Why do you choose to drink water supply ?		
- palatable	3.7 %	0.0 %
- economic	0.0 %	2.0 %
- convenient	31.1 %	22.0 %
- safe	4.2 %	19.0 %
- every item above	7.3 %	48.0 %
- no answer	53.7 %	9.0 %

Description	Ban Bangloa	Ban Thadindam
4. What do you really mean when you say water supply is clean and safe ?		
- free from germs	5.3 %	41.0 %
- clear and free from germs	12.6 %	23.0 %
- no answer	82.1 %	36.0 %
5. Why don't you drink water supply ?		
- unpalatable	0.0 %	1.0 %
- cannot afford for connection	10.0 %	1.0 %
- has not applied for connection yet	2.6 %	1.0 %
- no answer	87.4 %	97 %
6. What kind of water do you use to wash vegetables and prepare food when rain water is not available ?		
- water supply	67.4 %	93.0 %
- well water	14.2 %	4.0 %
- river	17.4 %	0.0 %
- no answer	1.0 %	3.0 %
7. How do you treat raw water taken from other sources before washing vegetables and cooking ?		
- boil	0.0 %	4.0 %
- alum coagulation	31.6 %	0.0 %
- sedimentation	1.6 %	1.0 %
- no answer	66.8 %	95.0 %
8. Reasons for using water supply for cooking.		
- convenient	45.3 %	37.0 %
- not destroy food palatability	0.0 %	2.0 %
- safe	1.6 %	8.0 %
- every item above	20.5 %	48.0 %
- no answer	32.6 %	5.0 %
9. What do you really mean when you say that using water supply for cooking because it is safe ?		
- free from germs	4.7 %	30.0 %
- clear	8.4 %	19.0 %
- no answer	86.9 %	51.0 %

Description	Ban Bangloa	Ban Thadindam
10. Reasons for using well, river waters for cooking.		
- economic	9.0 %	3.0 %
- not access to water supply	2.6 %	0.0 %
- no answer	88.4 %	97.0 %
11. What kind of water do you use for bathing ?		
- water supply	39.0 %	95.0 %
- well water	25.8 %	5.0 %
- river water	32.6 %	-
- others	2.6 %	-
12. Reasons for using water supply for bathing.		
- convenient	28.4 %	34.0 %
- clean	0.5 %	4.0 %
- safe	0.0 %	10.0 %
- every item above	11.6 %	47.0 %
- no answer	59.5 %	5.0 %
13. What do you really mean when you say that using water supply for bathing because it is safe ?		
- free from germs	3.7 %	36.0 %
- others	0.0 %	5.0 %
- no answer	96.3 %	59.0 %
14. Reasons for using well, river waters for bathing.		
- convenient	16.8 %	5.0 %
- economic	36.3 %	1.0 %
- every item above	15.3 %	2.0 %
- no answer	31.6 %	92.0 %
15. Do you use water supply ?		
- yes	71.0 %	93.0 %
- no	29.0 %	7.0 %
16. When did you use water supply ?		
- since its start	66.9 %	87.0 %
- 3 - 12 months later	2.6 %	5.0 %
- no answer	30.5 %	8.0 %

Description	Ban Bangloa	Ban Thadindam
10. Reasons for using well, river waters for cooking.		
- economic	9.0 %	3.0 %
- not access to water supply	2.6 %	0.0 %
- no answer	88.4 %	97.0 %
11. What kind of water do you use for bathing ?		
- water supply	39.0 %	95.0 %
- well water	25.8 %	5.0 %
- river water	32.6 %	-
- others	2.6 %	-
12. Reasons for using water supply for bathing.		
- convenient	28.4 %	34.0 %
- clean	0.5 %	4.0 %
- safe	0.0 %	10.0 %
- every item above	11.6 %	47.0 %
- no answer	59.5 %	5.0 %
13. What do you really mean when you say that using water supply for bathing because it is safe ?		
- free from germs	3.7 %	36.0 %
- others	0.0 %	5.0 %
- no answer	96.3 %	59.0 %
14. Reasons for using well, river waters for bathing.		
- convenient	16.8 %	5.0 %
- economic	36.3 %	1.0 %
- every item above	15.3 %	2.0 %
- no answer	31.6 %	92.0 %
15. Do you use water supply ?		
- yes	71.0 %	93.0 %
- no	29.0 %	7.0 %
16. When did you use water supply ?		
- since its start	66.9 %	87.0 %
- 3 - 12 months later	2.6 %	5.0 %
- no answer	30.5 %	8.0 %

Description	Ban Bangloa	Ban Thadindam
17. Why did you make a decision late ?		
- no money	0.5 %	2.0 %
- no answer	99.5 %	98.0 %
18. Why don't you use water supply ?		
- no money	7.9 %	5.0 %
- no distribution line nearby	3.7 %	-
- no answer	88.4 %	95.0 %
19. When will you use it ?		
- uncertain	24.7 %	5.0 %
- no answer	75.3 %	95.0 %
B. Effect on health		
20. Have you ever been sick severely with diarrhea ?		
- once a year	10.0 %	13.0 %
- twice a year	3.7 %	11.0 %
- more than three times a year	5.3 %	8.0 %
- never	81.0 %	68.0 %
21. Have you ever been sick with diarrhea but not to the extent to take medicine ?		
- once a year	4.7 %	12.0 %
- twice a year	4.2 %	8.0 %
- more than three times a year	-	7.0 %
- never	91.1 %	73.0 %
22. Has anyone in your family ever been sick severely with diarrhea ?		
- one people	13.7 %	19.0 %
- two people	6.3 %	7.0 %
- more than three people	3.2 %	5.0 %
- none	76.8 %	69.0 %
C. Participation		
23. Contribution towards the demonstration project.		
- labour	1.6 %	37.0 %

Description	Ban Bagloa	Ban Thadindam
- money	44.2 %	6.0 %
- both labour & money	53.1 %	51.0 %
- no contribution	1.1 %	6.0 %
24. How do you feel when you participated in the project ?		
- pround	31.6 %	63.0 %
- convenient and safe	18.9 %	21.0 %
- improve the village prosperity	13.7 %	6.0 %
- no idea	35.9 %	10.0 %
25. How do you involve in operation and maintenance of water supply system ?		
- pay for water consumed	53.7 %	60.0 %
- not steal water or destroy pipes	11.6 %	3.0 %
- every item above	14.2 %	33.0 %
- no answer	20.5 %	4.0 %
D. Knowledge about water supply		
28. Could you tell me where is the water supply treatment plant located ?		
- right answer	96.3 %	98.0 %
- wrong	3.7 %	2.0 %
29. Where is the raw water taken from ?		
- right answer	95.3 %	97.0 %
- wrong	4.7 %	3.0 %
30. Could you tell me the process used to treat the raw water ?		
- right answer	73.2 %	64.0 %
- wrong and no answer	26.8 %	36.0 %
31. Who takes care of water supply operation ?		
- right answer	88.4 %	98.0 %
- wrong	11.6 %	2.0 %
32. From whom did you know the water supply project ?		
- health worker	12.1 %	26.0 %
- headman	46.3 %	1.0 %

Description	Ban Bangloa	Ban Thadindam
- village committee	37.4 %	43.0 %
- no answer	4.2 %	30.0 %
33. In fact, who is responsible for water supply management ?		
- operator only	8.4 %	5.0 %
- water supply committee	58.4 %	35.0 %
- village committee	4.2 %	12.0 %
- every villager	10.0 %	25.0 %
- operator & water supply committee	4.7 %	21.0 %
- every item above	13.8 %	2.0 %
- no answer	0.5 %	0.0 %
E. Attitude towards water supply		
34. Are you really fond of drinking water supply ? Why ?		
- yes because	71.6 %	33.0 %
- convenient	(35.8 %)	(15.0 %)
- clean & safe	(21.1 %)	(9.0 %)
- every item above	(14.7 %	(9.0 %)
- no because	11.0 %	50.0 %
- unpalatable	(4.2 %)	(19.0 %)
- unclean	(6.8 %)	(31.0 %)
- no answer	17.4 %	17.0 %
35. Are you really fond of using water supply ? Why ?		
- yes because	90.0 %	93.0 %
- convenient	(81.1 %)	(76.0 %)
- clean & safe	(2.6 %)	(2.0 %
- every item above	(6.3 %)	(15.0 %)
- no because	4.7 %	1.0 %
- unpalatable	(1.6 %)	(0.0 %)
- uneconomic	(2.6 %)	(0.0 %)
- no answer	5.3 %	6.0 %

Description	Ban Bangloa		Ban Thadindam	
36. What will you do when you have noticed any damage or leakage ?				
- inform				
- operator	24.7 %		39.0 %	
- water supply committee	26.3 %		37.0 %	
- any person of the above mentioned	42.2 %		20.0 %	
- no answer	6.8 %		4.0 %	
37. What will you do when someone lets animals into the water source ?				
- warn the owner	25.8 %		86.0 %	
- chase the animals	12.6 %		1.0 %	
- inform water supply committee	7.4 %		6.0 %	
- inform operator	15.2 %		2.0 %	
- no answer	39.0 %		5.0 %	
38. Should the village water supply be constructed in other villages ?				
- yes	92.6 %		98.0 %	
- no answer	7.4 %		2.0 %	
F. Problems				
39. Problems concerned with	Yes	No	Yes	No
- pump	5.8	94.2	0.0	100.0
- water is unclear	34.3	65.7	12.0	88.0
- water is turbid	16.8	83.2	28.0	72.0
- odour	1.0	99.0	21.0	79.0
- high water rate	6.8	93.2	3.0	97.0
- operator unreliable	1.0	99.0	0.0	100.0
- water supply committee unreliable	0.0	100.0	0.0	100.0
- quality is doutful	5.3	94.7	19.0	81.0

The correlation studies between some important topics are as follows :-

TABLE 12 The correlation study between source of water supply information and degree of participation, Ban Bangloa, Singhburi Province.

Source of information	Degree of participation				
	Labour	Labour & money	No participation	Various contribution	Total
Health worker	15	2	3	3	23
Village headman	52	7	18	2	79
Village committee	10	13	13	3	39
Unknown	0	3	4	1	8
Others	7	6	10	18	41
Total	84	31	48	27	190

Null hypothesis : Source of water supply information and degree of participation are independent.

Chi-square calculated = 74.97

X^2 at 0.01 level of significant (df_{12}) = 26.22

The value obtained for X^2 is significant at level of 0.01, thus the null hypothesis is rejected.

Therefore, the degree of participation depends on the characteristics of the person who disseminated the information on water supply information.

TABLE 13 The correlation study between source of water supply information and degree of participation, Ban Thadindam Lopburi Province.

Source of information	Degree of participation					
	Labour	Labour & money	Labour & persuation	Various contribution	No participation	Total
Health worker	4	12	4	5	1	26
Village committee	28	8	4	10	1	41
Headman	15	5	9	0	4	33
Total	37	25	17	15	6	100

Null hypothesis : Source of water supply information and type of participation are independent.

Chi-square calculated = 25.58

X^2 at 0.01 level of significant (df_8) = 20.09

The value obtained for X^2 is significant at level of 0.01, thus the null hypothesis is rejected.

Therefore, the degree of participation depends on the characteristics of the person who disseminated the information on the water supply project.

TABLE 14 The correlation study between knowing the process of water supply system and using water supply, Ban Bangloa, Singhburi Province.

Knowing the process	Using water supply			
	Immediately	Do not use	Use later	Total
Known	102	33	4	139
Unknown	24	25	2	51
Total	126	58	6	190

Null hypothesis : Knowing the process of water supply system and using water supply are independent.

Chi-square calculated = 10.65

X^2 at 0.01 level of significant (df_2) = 9.21

The X^2 calculated is higher than X^2 at 0.01 level of significant thus the null hypothesis is rejected.

It is expected that if villagers knew the process of water supply system that it is free from germs they would decide to use it. From the study of Chi-square above shows that villagers' decision to use water supply depends on their knowledge of water supply process. It would also be some other reasons for them to make a decision to use water supply.

TABLE 15 The correlation study between knowing the process of water supply system and using water supply, Ban Thadindam, Lopburi Province.

Knowing the process	Using water supply			
	Immediately	Do not use	Use later	Total
Known	54	6	4	64
Unknown	33	2	1	36
Total	87	8	5	100

Null hypothesis : Knowing the process of water supply system and using water supply are independent.

Chi square calculated = 1.37

X^2 at 0.05 level of significant (df_2) = 5.99

The Chi-square at 0.05 level of significant is higher than X^2 calculated, thus the null hypothesis is accepted.

The result of the above studied shows that whether villagers' decision to use water does not depend on the knowledge of water supply.

TABLE 16 The correlation study between the owner status of water tap and type of drinking water, Ban Bangloa, Singhburi Province.

Owner status	Type of drinking water			
	water supply	well water	river water	Total
Owner	129	5	0	134
Non-owner	1	24	31	56
Total	130	29	31	190

Null hypothesis : Owner status of water tap and type of drinking water are independent.

Chi-square calculated = 168.1

X^2 at 0.01 level of significant (df_2) = 9.21

The value obtained for X^2 is significant at level of 0.01, thus the null hypothesis is rejected.

This means that those who own water tap will drink water supply, while the others who have not connected to the distribution line will take other type of water for drinking.

TABLE 17 The correlation study between the owner status of water tap and type of drinking water.

Owner status	Type of drinking water			
	water supply	well water	river water	Total
Owner	89	3	1	93
Non-owner	2	5	0	7
Total	91	8	1	100

Null hypothesis : Owner status of water tap and type of drinking water are independent.

Chi-square calculated = 41.06

X^2 at 0.01 level of significant (df_2) = 9.21

The value obtained for X^2 is significant at level of 0.01, thus the null hypothesis is rejected.

This means that those who own water tap will drink water supply while the others who have not access to water supply will have to take other types of water for drinking.

TABLE 18 The correlation study between owner status and responsibility for operation and maintenance of water supply system, Ban Bangloa, Singhburi Province.

Owner Status	Responsibility for operation & maintenance				
	a	a + b + c	b + c	No response	Total
Owner	99	26	8	1	134
Non-owner	3	3	12	38	56
Total	102	29	20	39	190

Note : a = paying for water consumption

b = not stealing water

c = not damaging pipes

Null hypothesis : Owner status of water tap and responsibility for operation and maintenance are independent.

Chi-square calculated = 135.34

X^2 at 0.01 level of significant (df_3) = 11.34

The X^2 calculated is higher than the X^2 at 0.01 level of significant, thus the null hypothesis is rejected.

It explains that those who have connected to distribution line have to be responsible for operation and maintenance of water supply system by paying for water consumption, not stealing water and not damaging pipes.

TABLE 19 The coreelation study between owner status and responsibility for operation and maintenance of water supply system, at Ban Thadindam, Lopburi Province,

Owner status	Responsibility for operation and maintenance			
	a	a + b + c	No response	Total
Owner	60	33	0	93
Non-owner	0	3	4	7
Total	60	36	4	100

Note : a = paying for water consumption
b = not stealing water
c = not damaging pipes

Null hypothesis : Owner status of water tap and responsibility for operation and maintenance are independent.

Chi-square calculated = 57.76
X^2 at 0.01 level of significant (df_2) = 9.21

The X^2 calculated is higher than the X^2 at 0.01 level of significant, thus the null hypothesis is rejected.

It explains that those who have connected to the distribution line have to be responsible for operation and maintenance by paying for water consumption, not stealing water and not damaging the pipes.

TABLE 20 The correlation study between type of drinking water and its effect on the interviewee's health, Ban Bangloa , Singhburi Province.

Type of drinking water	Have you ever been sick severely with diarrhea ?		
	Yes	No	Total
Water Supply	17	117	134
Others	19	37	56
Total	36	154	190

Null hypothesis : Types of drinking water and its effect on the interviewee's health are independent.

Chi-square calculated = 11.57

X^2 at 0.01 level of significant (df_1) = 6.64

The X^2 calculated is significant at level of 0.01, thus the null hypothesis is rejected.

This means that the types of drinking water is likely to be cause of diarrhea. There is a tendency for people who take other types of water for drinking to be sick with diarrhea.

TABLE 21 The corrclation study between type of drinking water and its effect on the interviewee's health, Ban Thadindam, Lopburi Province.

Type of drinking water	Have you ever been sick severely with diarrhea ?		
	Yes	No	Total
Water supply	30	63	93
Others	2	5	7
Total	32	68	100

Null hypothesis : Types of drinking water and its effect on the interviewee's health are independent.

Chi-square calculated = 0.03

X^2 at 0.05 level of significant (df_1) = 3.84

The X^2 calculated is not significant at level of 0.05, thus the null hypothesis is accepted.

This means that the types of drinking water is independent with the occurence of diarrhea in the village of Ban Thadindam.

8.2 Impacts of water supply on the communities

The slow sand filtration system at Ban Bangloa was completed in March, 1980 and the one at Ban Thadindam in December, 1979. The water supply systems have been operated and water has been supplied to the villagers. Since then there are changes in living conditions which reflect the result of the demonstration projects. Some observations were made as follows : -

8.2.1 Water usage pattern

After the installation of water supply, it was found that the consumption during the dry season is 58 lpcd. while the rate of consumption during the rainy season decreased to 26 lpcd. This resulted in an average charge of ฿ 2.30 per person per month during the rainy season and ฿ 5.20 per person per month during the dry season. This is because during the rainy season the inhabitants use rain and well water.

8.2.1 Increase in connection

It is noticed that one tap in each house for general use is neither sufficient nor convenient. There is a tendency to increase the number of taps in a house, for example, one in the kitchen and one on the second floor. The use of plastic hoses connected to the existing tap has become very popular since it can supply the water to any place within the compound.

8.2.2 Level of education of the operator and his interest

The operator must have, at least, a fourth grade level of education and some additional experience of mechanical work in order to be eligible for our training course. It is believed that anyone who satisfies these requirements can be trained to operate the slow sand fitler.

Success and failure, with respect to the operation and maintenance of the slow sand filtration system, do not much depend on the operator's level of education but far more on his interest. This has been clearly demonstrated in the case of Ban Thadindam.

Despite the simplicity of the slow sand filtration system, it would have failed through the poor interest of the operator. The construction of a rapid sand filtration sytem would, in this case, most certainly have led to a complete failure of the water supply.

8.2.3 Community leader

The role of the village headman (or leader) is one of the utmost important for the success of the project. He must encourage the villagers to cooperate in the development project of the community. In case of rural water , he will determine the location of the plant site which is usually a compromise between the engineering recommendations and the land availability in the community. The extent of the community participation depends on his motivation. Therefore the active interest of the headman will greatly enhance the success of the project.

8.2.4 The need to form a village committee for water supply

In Ban Thadindam, a village committee for water supply has been formed consisting of four people. This committee is responsible for reading the water meters and collecting revenues. Each of the four people receives ฿ 25 per month for his work. The full-time operator is responsible for operation and maintenance of the system. He is paid ฿ 500 per month.

In Ban Bangloa, the village committee for water supply consists of seven persons but their duties and responsibilities differ from the committee at Ban Thadindam. They only give advice on the policy and management of the water supply and make decisions on such topics such as water rates and the charges for new house connections.

8.2.5 Simplicity of slow sand filtration system enhances continued operation

At Ban Thadindam, the raw water is taken from a spring, The slow sand filter is constructed on a slope providing sufficient head to supply the consumers by gravity. The operator of this plant has paid very poor attention to his work because he complained that the salary paid to him is too low. Most of his time, he spends outside the village working on his farm. In spite of this, his absence does not trouble the villagers since the water is supplied by gravity and the system has automatically continued to function. This is very ideal situation for a village water supply.

8.2.6 Familiarity

The villagers have become familiar with the water supply. It is now difficult for them to return to the old way of life, travelling to fetch water from far distance. The owner of one grocery store said that after her family had used tap water for a few months, her son refused to fetch water from a pond, he complained that the pond was too far and the tap water is readily available.

8.2.7 Influence of rain water during the rainy season

People who have their private well will use water from it during the rainy season. In summer months, the wells are almost dry so they have to resort to water from other sources. The water supplied from tap is obviously the most convenient source. The rainy season brings the water levels in the well back within easy reach. As a result, some of the consumers go back to use well water again. Besides, rain water is still considered better for drinking. It is noticed that the revenue has decreased to about half during the rainy season.

8.3 Comments on health education and community participation programme.

The study of health education and community participation programme on water supply demonstration projects has been noticed as follows : -

8.3.1 It was one of the most important techniques for study the health education and community participation in connection with water supply in Thailand. The questionaires set up for use in the pre-construction phase was improved and concentrated on water supply in particular. But some weakpoints still existed with the result that many questions elicited no response.

8.3.2 In the pre-construction phase, the public health workers from Rural Water Supply Division associated with public health workers from Provincial Public Health Bureau were assigned to interview the villagers. Those health workers have some experiences in their work more than 3-5 years before. As a result, their results of interview were mostly satisfied.

In the post-contruction phase, the public health workers from Provincial Public Health Bureau and local people were assigned to run the job. The health workers had just graduated from the health training school before they joined the health education programme. The results of those two groups revealed that local people had done better job than the health workers. It would be possible to conclude that the local people are able to communicate better with their neighbours than the health workers. This is because most local people are closely familiar with their neighbours and some of them have been living there long enough to know alomost every person in the village. In contrary, the health workers are very young and most of them came from other villages their visit was understood as an official investigation on the Government Project, with the result that sometime the atmosphere of their meeting was tense. It would take them time to improve themselves to grow accustomed to the villagers.

8.3.3 Having joined the health education programme the health workers of the Provincial Public Health Bureau said that such a programme should be implemented in other villages too, so as they will be able to contact more closely with the villagers. Moreover, they will be able to identify the health education problems. And it is hoped that the more effective health education programmes will be evantaully formulated and implemented in the future.

9. COMMENTS ON THE RESEARCH PROJECTS

9.1 The outstanding characteristics of operation that distinguish the slow from the rapid sand filter are the rates of filtration, the method of washing the filters and the absence of chemical treatment in the slow sand filtration. In comparing the two types of filter it is found that the slow sand filter under inexperienced operator is less likely to function uneffectively. It does not require such skilled attendance as the case of Ban Thadindam Water Supply Treatment Plant. From this operation point of view the slow sand filter is most appropriate to the developing countries especially in the rural areas in which skilled labours are scarce.

9.2 One of the important features of the slow sand filter involves the great reliability in removal of bacteria. It is less effective when the filter is applied with raw water of high turbidity. From the results of the demonstration projects the employment of a pre-treatment such as a holding pond and/or a horizontal flow pre-filter is succesfully accomplished the high turbidity of raw water. The pre-treatment greatly helps reducing the turbidity to the acceptable level which can be passed to the slow sand filter. In addition, such pre-treatment employed in the projects requires no chemicals, therefore the operating cost is less per unit of volume of water treated.

9.3 Among the features of rapid sand filter that makes it more desirable than slow sand filter is the lower initial cost. It is due to the smaller area of land required. But the Rural Water Supply Project in Thailand the land for construction is received by donation. So the capitalized cost of the plant is not as high as one has expected.

9.4 The selection of site for construction has affected to the ease of operation and its operation cost. It is obviously seen that the Ban Thadindam Water Supply Treatment Plant located on a hill from which sufficient pressure head is provided, is very ideal for site selection. No mechanical equipments are needed, thus reducing both the initial construction and operation costs. And also the hardship of the operation of Ban Thadindam Water Supply Treatment Plant has not occured.

9.5 It has been found that there exists a wide gap of the communication of health knowledge between health workers and the villagers. Many factors are involved, but the most important one seems to be the failure of health workers themselves to adequately utilize the existing resources and opportunities in dissemination of health knowledge with regard to water supply and sanitation. The demonstration projects survey has shown that the communication gap can be filled with the active involvement of health education activities. The success of such activities of the well-informed public. It will be the right opportunity for the health workers during the construction to disseminate the health knowledge.

In connection with the health education programme, the failure of the project also depends on the ignorance of the village headman. Fortunately, the two demonstration villages have the strong and energetic headmen who are eager and willing to develop more public facilities provided in their villages. When the construcion is finished they have formed a water supply committee to be responsible for planning and managing of water supply operation. The leadership of the village headman and the readiness of the community willing to participate in the project much support to the project success.

APPENDIX A

DATA OF BAN BANGLOA
WATER SUPPLY TREATMENT PLANT

TABLE A 1 : Operating report

Date	Inf. flow rate of pre-filter, m^3/hr	Filtration rate of SSF, m^3/hr	Length of filter run days
17-4-80	4.9	-*	54
8-5-80	4.6	-*	75
14-5-80	4.9	3.3	81
21-5-80	4.5	3.3	88
28-5-80	4.0	-*	95
5-6-80	4.0	-*	103
			(Filter cleaning)
Average	4.5	3.3	

Note : Flow rate could not be measured because the weir was submerged.

Inf. = influent

Eff. = effluent

TABLE A 2 : Turbidity (NTU) of raw water and effluents

Date	Raw water	Holding pond eff. (a)	Pre-filter eff. (b)	SSF eff. (c)	Tap water	Removal efficiency %		
						b VS a	c VS b	c VS a
17-4-80	130	110	42	20	20	61.8	52.4	81.8
23-4-80	-	110	45	22	-	59.1	51.1	80.0
8-5-80	-	100	52	25	-	48.0	51.9	75.0
14-5-80	-	67	39	22	-	41.8	43.6	67.2
21-5-80	-	120	45	18	50	62.5	60.0	85.0
28-5-80*	260	250	190	58	-	24.0	69.5	76.8
5-6-80	-	275	150	60	-	45.4	60.0	78.9
19-6-80	-	275	-	85	-	-	-	69.1
16-7-80	-	250	170	68	-	32.0	60.0	72.8
13-8-80	255	240	190	100	70	20.8	47.4	58.3
Average	215	180	103	48	47	43.9	55.1	74.5

Note * = Heavy rain on 27-5-80

TABLE A 3 : Colour (^{o}Hazen) of raw water and effluents

Date	Raw water	Holding pond eff. (a)	Pre-filter eff. (b)	SSF eff. (c)	Tap water	Removal efficiency, %		
						b VS a	c VS b	c VS a
17-4-80	200	200	140	60	-	30.0	57.1	70.0
23-4-80	-	200	150	80	60	25.0	46.7	60.0
8-5-80	-	200	150	70	-	25.0	53.3	65.0
14-5-80	-	200	150	40	-	25.0	73.3	80.0
21-5-80	-	200	100	40	-	50.0	60.0	80.0
28-5-80*	500	500	300	150	150	40.0	50.0	70.0
5-6-80	-	500	300	200	-	40.0	33.3	60.0
19-6-80	-	500	300	200	-	40.0	33.3	60.0
16-7-80	-	750	500	300	-	40.0	33.3	60.0
13-8-80	750	750	500	200	150	33.3	60.0	73.3
Average	483	400	299	134	120	34.2	50.7	67.8

Note * = Heavy rain on 27-5-80

TABLE A 4 : pH of raw water and effluents

Date	Raw water	Holding pond eff	Pre-filter eff.	SSF eff.	Tap water
17-4-80	8.3	8.2	7.8	7.7	-
23-4-80	-	8.1	7.7	7.6	7.6
8-5-80	-	8.2	7.8	7.8	-
14-5-80	-	8.3	7.9	7.8	-
21-5-80	-	7.8	7.8	7.7	-
28-5-80*	8.0	8.0	7.8	7.7	7.5
5-6-80	-	8.3	7.9	7.8	-
16-7-80	-	7.3	7.9	7.8	-
13-8-80	7.8	7.8	7.9	7.8	7.7
Average	8.0	8.0	7.8	7.7	7.6

Note * = Heavy rain on 27-5-80

TABLE A 5 : D.O (mg/l) of raw water and effluents

Date	Raw water	Holding pond eff.	Pre-filter eff.	SSF eff.	Tap water
17-4-80	7.9	7.9	3.7	2.6	-
23-4-80	-	7.7	4.0	2.8	-
8-5-80	-	8.3	3.3	4.8	-
14-5-80	-	7.5	4.3	2.6	-
21-5-80	-	6.3	3.2	2.7	-
28-5-80*	6.0	6.5	4.1	2.3	-
13-8-80	-	6.5	3.6	2.4	-
Average	6.9	7.2	3.7	2.9	

Note * = Heavy rain on 27-5-80

TABLE A 6 : BOD_5 (mg/l) of raw water and effluents

Date	Raw water	Holding pond eff.	Pre-filter eff.	SSF eff.	Tap water
17-4-80	-	2.4	1.6	1.2	0.5
23-4-80	-	3.2	1.5	1.5	-
Average	-	2.8	1.6	1.4	0.5

TABLE A 7 : Total solids (mg/l $CaCO_3$) of raw water and effluents

Date	Raw water	Holding pond eff.	Pre-filter eff.	SSF eff.	Tap water
17-4-80	260	242	149	123	-
23-4-80	-	251	152	142	142
8-5-80	-	203	126	110	-
14-5-80	-	247	127	92	-
21-5-80	-	230	121	106	-
28-5-80*	295	298	185	168	-
13-8-80	-	362	306	263	236
Average	278	262	166	143	189

Note * = Heavy rain on 27-5-80

TABLE A 8 : Hardness (mg/l as $CaCO_3$) of raw water and effluents

Date	Raw water	Holding pond eff.	Pre-filter eff.	SSF eff.	Tap water
17-4-80	116	104	94	88	-
23-4-80	-	116	104	104	104
8-5-80	-	76	80	76	-
14-5-80	-	84	84	80	-
21-5-80	-	88	86	84	-
28-5-80*	104	104	96	88	-
16-7-80	-	64	80	80	-
13-8-80	-	84	80	68	66
Average	110	90	88	84	85

Note * = Heavy rain on 27-5-80

TABLE A 9 : Iron and manganese, mg/l of raw water and effluents

Date	Raw water	Holding pond eff.	Pre-filter eff.	SSF eff.	Tap water
Iron					
23-4-80	-	0.67	0.58	0.45	0.40
14-5-80	-	0.53	0.47	0.38	-
28-5-80*	-	0.50	0.35	0.30	0.34
13-8-80	-	0.40	0.28	0.20	0.18
Average	-	0.53	0.42	0.33	0.31
Manganese					
17-4-80	-	0.08	nil	nil	-
13-8-80	-	0.10	nil	nil	nil
Average	-	0.09	nil	nil	-

Note * = Heavy rain on 27-5-80

TABLE A 10 : Chloride, mg/l of raw water and effluents

Date	Raw water	Holding pond eff.	Pre-filter eff.	SSF eff.	Tap water
17-4-80	-	6.8	6.3	6.8	-
23-4-80	-	6.1	6.6	6.3	6.3
8-5-80	-	6.5	6.5	6.2	-
28-5-80*	-	6.8	6.8	6.7	-
13-8-80	-	6.0	5.5	5.5	5.5
Average	-	6.4	6.3	6.3	5.9

Note * = Heavy rain on 27-5-80

TABLE A 11 : Sulphate and nitrate, mg/l of raw water and effluents

Date	Raw water	Holding pond eff.	Pre-filter eff.	SSF eff.	Tap water
Sulphate					
17-4-80	-	9.6	7.9	3.0	-
13-8-80	-	7.4	5.2	2.6	2.6
Average	-	8.5	6.6	2.8	2.6
Nitrate					
17-4-80	-	0.28	0.27	0.27	-
13-8-80	-	0.35	0.32	0.30	0.30
Average	-	0.315	0.295	0.285	0.30

TABLE A 12 : Total coliform and E.coli (MPN index/100 ml) of raw water and effluents

Date	Raw water	Holding pond eff- (a)	Pre-filter eff. (b)	SSF eff. (c)	Tap water	Removal efficiency, %		
						b VS a	c VS b	c VS a
Total coliform								
17-4-80	-	3,300	94	43	-	97.2	54.3	98.7
23-4-80	-	3,300	79	49	43	97.6	38.0	98.5
8-5-80	-	3,300	49	23	-	98.5	53.1	99.3
14-5-80	-	5,400	350	23	-	93.5	93.4	99.8
21-5-80	-	2,200	110	33	-	95.0	70.0	98.5
28-5-80	-	3,500	350	79	33	90.0	77.4	97.7
13-8-80	-	2,400	93	93	43	96.1	0	96.1
Average	-	3,343	161	49	40	95.4	55.2	98.4
E. coli								
14-5-80	-	170	17	nil	-	90.0	100	100
12-8-80	-	90	23	nil	nil	74.4	100	100
Average	-	130	20	nil	nil	82.2	100	100

APPENDIX B

DATA OF BAN THADINDAM
WATER SUPPLY TREATMENT PLANT

TABLE B 1 : operating report

Date	Inf. flow rate of pre-filter, m^3/hr	Filtration rate of SSF, m^3/hr	Length of filter run days
27-1-80	10.1	8.6	41
5-2-80	9.7	3.8	48
12-2-80	8.2	3.8	55
19-3-80	-	5.9	62
26-3-80	5.4	3.8	69
3-4-80	5.5	3.8	76
17-4-80	5.8	3.8	90
8-5-80	6.9	3.8	111
14-5-80	5.8	3.8	117
28-5-80	-	3.8	124
13-8-80	6.5	3.8	188
Average	7.1	4.4	89.2

TABLE B 2 : Turbidity of raw water and effluents

Date (days)	Raw Water	Before entering the holding pond	Holding Pond eff. (a)	Prefilter eff. (b)	SSF eff. (c)	Clear Well	Tap-Water	Removal Efficiency, % b vs a	c vs b	c vs a
21/1/80	1.0	1.0	0.95	0.50	0.23	-	-	47.4	54	75.8
30/1/80	1.1	1.1	1.20	0.50	0.25	-	-	58.3	50	79.2
6/2/80	1.3	1.2	1.20	1.00	0.35	-	-	16.7	65	70.8
13/2/80	1.2	1.3	1.00	0.35	0.20	-	-	65	42.9	80
20/2/80	2.0	2.0	1.50	0.48	0.30	-	-	68	37.5	80
27/2/80	2.1	-	4.30	0.70	0.33	0.35	-	83.7	52.9	92.3
5/3/80	2.6	-	3.20	0.70	0.35	-	0.37	78.1	50	89.1
12/3/80	3.0	3.1	3.40	1.40	0.50	-	-	58.8	64.3	85.3
19/3/80	3.5	-	3.20	0.31	0.25	0.28	-	90.3	19.35	92.2
26/3/80	2.3	-	2.50	1.00	0.70	-	0.90	60	30	72
3/4/80	3.4	-	2.40	0.50	0.25	0.26	-	79.2	50	89.6
17/4/80	-	-	1.50	0.30	0.20	-	-	80	33.3	86.7
8/5/80	-	-	2.00	0.40	0.30	-	0.28	80	25	85
14/5/80	-	-	2.20	0.28	0.17	0.19	-	87.3	39.3	92.3
28/5/80	-	-	12.00	-*	0.70	-	-	-	-	-
5/6/80	-	-	3.40	0.80	0.50	-	-	76.5	37.5	85.3
13/8/80	-	-	4.50	0.70	0.70	-	0.7	84.5	0	84.4
Average	2.1	1.6	3.1	0.62	0.37	0.27	0.56	69.6	40.7	83.8

Note: * Raw water did not flow into the holding pond because of collapse of dam's neck. Therefore the water level in the holding pond was too low to give the enough head to allow water to flow through the prefilter. Water from the holding pond flowed directly through the slow sand filter.

Collapse of dam's neck had happened since 20/5/80 and was repaired by 29/5/80.

TABLE B 3 : Colour of raw water and effluents

Date	Raw water	inf. into holding pond	Holding pond eff.	Pre-filter eff.	SSF eff.	Clear well	Tap water
21-1-80	5	5	5	< 5	< 5	-	-
30-1-80	5	5	5	< 5	< 5	-	-
6-2-80	5	5	5	< 5	< 5	-	-
13-2-80	5	5	5	< 5	< 5	-	-
20-2-80	5	5	5	< 5	< 5	-	-
27-2-80	10	-	50	30	20	15	-
5-3-80	5	-	10	10	5	-	< 5
12-3-80	5	15	15	5	< 5	-	-
19-3-80	5	-	10	5	< 5	< 5	-
26-3-80	5	-	5	5	< 5	-	< 5
3-4-80	5	-	5	< 5	< 5	< 5	-
17-4-80	-	-	10	5	< 5	-	-
8-5-80	-	-	5	< 5	< 5	-	< 5
14-5-80	-	-	10	< 5	< 5	< 5	-
28-5-80	-	-	20	-	10	-	-
5-6-80	-	-	15	< 5	< 5	-	-
13-8-80	-	-	10	< 5	< 5	-	< 5
Average	6	6.7	11.2	< 5	< 5	-	< 5

TABLE B 4 : pH of raw water and effluents

Date	Raw water	inf. into holding pond	Holding pond eff.	Pre-filter eff.	SSF eff.	Clear well	Tap water
21-1-80	7.8	7.9	7.7	7.5	7.4	-	-
30-1-80	7.6	7.7	7.7	7.4	7.3	-	-
6-2-80	7.5	7.6	7.7	7.3	7.3	-	-
13-2-80	7.6	7.7	7.5	7.3	7.3	-	-
20-2-80	7.6	7.7	7.7	7.3	7.4	-	-
27-2-80	7.8	7.7	8.0	7.4	7.4	7.5	-
5-3-80	7.5	-	7.6	7.5	7.3	-	7.4
12-3-80	7.6	-	7.8	7.5	7.4	-	-
19-3-80	7.6	-	7.8	7.3	7.3	7.4	-
26-3-80	7.5	-	7.6	7.4	7.3	-	7.3
3-4-80	7.5	-	7.5	7.3	7.2	7.3	-
17-4-80	-	-	7.6	7.5	7.5	-	-
8-5-80	-	-	7.5	7.3	7.3	-	7.3
14-5-80	-	-	7.6	7.6	7.5	7.4	-
28-5-80	-	-	7.7	-	7.6	-	-
5-6-80	-	-	7.9	7.8	7.5	-	-
13-8-80	-	-	7.6	7.6	7.4	-	7.4
Average	7.6	7.7	7.7	7.4	7.4	7.4	7.4

TABLE B 5 : D.O of raw water and effluents

Date	Raw water	inf. into holding pond	Holding pond eff.	Pre-filter eff.	SSF eff.	Clear well
21-1-80	8.43	9.02	9.31	8.13	7.74	-
30-1-80	12.45	10.88	12.05	7.25	6.91	-
6-2-80	9.26	11.17	11.66	6.08	6.57	-
13-2-80	9.80	9.41	10.24	7.21	7.74	-
20-2-80	12.05	10.54	12.50	7.01	7.15	-
27-2-80	9.69	-	12.80	3.03	0.90	2.5
5-3-80	6.70	-	8.90	2.90	0.50	-
12-3-80	12.10	10.50	12.10	6.50	0.80	-
19-3-80	7.67	-	10.90	3.70	6.10	4.5
26-3-80	4.88	-	10.90	8.50	3.32	-
3-4-80	7.00	-	9.07	3.11	1.04	4.8
17-4-80	-	-	9.50	2.00	4.50	-
8-5-80	-	-	9.50	5.70	5.00	-
14-5-80	-	-	9.90	5.20	3.40	5.2
28-5-80	-	-	7.00	-	1.20	-
13-6-80	-	-	8.20	3.50	2.50	-
Average	9.1	10.3	10.3	5.3	4.1	4.3

TABLE B 6 : BOD_5 of raw water and effluents

Date	Raw water	inf. into holding pond	Holding pond eff.	Pre-filter eff.	SSF eff.	Clear well	Tap water
21-1-80	1.96	3.27	2.09	1.76	1.48	-	-
30-1-80	1.18	0.93	0.88	1.28	0.74	-	-
6-2-80	1.27	0.83	1.67	0.49	0.59	-	-
13-2-80	1.78	1.39	1.52	0.62	0.56	-	-
20-2-80	1.56	1.43	1.33	0.71	0.62	-	-
27-2-80	2.54	-	2.79	1.32	0.44	0.39	-
5-2-80	2.19	-	2.36	1.43	1.09	-	0.85
12-3-80	2.35	2.06	2.30	1.91	1.42	-	-
19-3-80	2.25	-	1.95	0.60	0.59	0.30	-
26-3-80	2.30	-	2.15	0.95	0.62	-	0.59
3-4-80	2.60	-	2.30	1.23	0.65	0.29	-
17-4-80	1.20	-	1.20	0.95	0.60	-	-
Average	1.9	1.7	1.9	1.1	0.8	0.3	0.7

TABLE B 7 : Total solids of raw water and effluents

Date	Raw water	Inf. into holding pond	Holding pond eff.	Pre-filter eff.	SSF eff.	Clear well	Tap water
21-1-80	684	685	648	638	627	-	-
30-1-80	730	693	676	664	657	-	-
6-2-80	695	710	697	664	642	-	-
13-2-80	753	760	687	668	659	-	-
20-2-80	935	818	848	839	806	-	-
27-2-80	865	-	654	550	552	567	-
5-3-80	870	-	708	678	638	-	666
12-3-80	865	701	606	609	619	-	-
19-3-80	823	-	673	685	607	663	-
26-3-80	696	-	680	606	573	-	668
3-4-80	753	-	678	625	598	556	-
17-4-80	-	-	621	605	589	-	-
8-5-80	-	-	-	-	580	-	595
14-5-80	-	-	548	512	495	505	-
28-5-80	-	-	612	-	521	-	-
13-8-80	-	-	590	558	519	-	508
Average	788	728	663	636	605	573	609

TABLE B 8 : Hardness of raw water and effluents

Date	Raw water	Inf. into holding pond	Holding pond eff.	Pre-filter eff.	SSF eff.	Clear well	Tap water
21-1-80	320	315	315	311	307	-	-
30-1-80	437	402	394	366	355	-	-
6-2-80	405	396	372	372	370	-	-
13-2-80	414	401	367	347	358	-	-
20-2-80	430	386	372	367	356	-	-
27-2-80	418	-	329	386	386	371	-
5-3-80	453	-	382	382	382	-	370
12-3-80	437	437	457	387	394	-	-
19-3-80	473	-	374	382	363	366	-
26-3-80	485	-	361	374	359	-	359
3-4-80	477	-	374	370	358	374	-
17-4-80	-	-	344	340	344	-	-
8-5-80	-	-	352	348	328	-	316
14-5-80	-	-	304	304	292	285	-
28-5-80	-	-	395	-	311	-	-
5-6-80	-	-	408	404	396	-	-
13-8-80	-	-	380	367	364	-	362
Average	432	390	366	363	354	349	352

TABLE B 9 : Iron and manganses, mg/l of raw water and effluents

Date	Raw Water	Before entering the holding pond	Holding Pond eff. (a)	Prefilter eff. (b)	SSF eff. (c)	Clear Well	Tap Water	Removal Efficiency, %		
								b vs a	c vs b	c vs a
Iron										
30/1/80	0.11	-	0.08	0.06	0.05	-	-	25.0	16.7	37.5
6/2/80	0.15	0.10	0.09	0.05	0.04	-	-	44.4	20.0	55.6
13/2/80	0.26	0.21	0.19	0.13	0.11	-	-	31.6	15.4	42.1
20/2/80	0.30	0.32	0.18	0.11	0.07	-		38.9	36.4	61.1
27/2/80	0.20	-	0.26	0.10	0.07	0.06		53.8	30.0	73.1
12/3/80	0.14	0.13	0.12	0.07	0.06	-		41.7	14.3	50.0
26/3/80	0.18	-	0.15	0.04	0.04	-	0.06	73.3	0	73.3
3/4/80	0.27	-	0.05	0.02	0.02	0.01		0	0	60.0
13/8/80		-	0.24	0.13	0.07	0.06		46.2	46.2	70.8
Average	0.20	0.19	0.15	0.09	0.06	0.04	0.06	39.4	19.9	58.2
Manganese										
6/2/80	0.59	0.58	0.60	0.46	0.14	-				
13/2/80	0.32	0.42	0.40	0.20	0.02	-				
20/2/80	0.35	0.28	0.33	0.10	0.03	-	-			
27/2/80	0.60	-	0.18	0.18	0.06	0.02	-			
19/3/80	0.29	-	0.30	0.19	0.02	0.04				
3/4/80	0.09	-	0.10	0.02	nil	nil				
13/6/80		-	0.12	0.06	nil	-	nil			
Average	0.37	0.43	0.29	0.17	0.04	0.02				

TABLE B 10 : Chloride, mg/l of raw water and effluents

Date	Raw water	Inf. into holding pond	Holding pond eff.	Pre-filter eff.	SSF eff.	Clear well	Tap water
21-1-80	91.7	91.9	93.3	91.4	90.9	-	-
30-1-80	92.6	91.9	91.9	91.9	90.9	-	-
6-2-80	90.0	90.2	92.1	92.6	92.4	-	-
13-2-80	90.0	90.0	89.0	90.5	90.9	-	-
20-2-80	80.5	80.5	100.5	86.2	93.3	-	-
27-2-80	95.2	-	96.7	96.5	98.6	95.4	-
5-3-80	93.8	-	94.3	93.8	98.2	-	92.9
12-3-80	92.5	91.4	95.1	93.5	91.5	91.4	-
19-3-80	91.4	-	95.2	92.4	93.8	-	-
26-3-80	96.7	-	91.9	98.1	95.7	-	92.9
3-4-80	96.4	-	90.9	92.6	92.4	91.2	-
17-4-80	-	-	93.0	93.0	94.0	-	-
14-5-80	-	-	95.0	-	91.0	-	-
28-5-80	-	-	98.0	43.0	93.0	-	-
13-8-80	-	-	101.0	100.0	98.0	-	98.0
Average	91.9	89.3	95.5	93.3	93.4	92.7	94.6

TABLE B 11 : Sulphate and nitrate, mg/l of raw water and effluents

Date	Raw water	Inf. into holding pond	Holding pond eff.	Pre-ffilter eff.	SSF eff.	Clear well	Tap water
Sulphate							
30-1-80	24.5	25.0	23.8	20.0	18.5	-	-
6-2-80	25.0	22.0	21.3	19.0	18.0	-	-
13-2-80	22.3	17.4	17.0	19.0	16.4	-	-
20-2-80	24.5	23.3	27.7	23.3	20.6	-	-
27-2-80	35.4	-	38.3	36.0	35.5	33.4	-
12-3-80	22.0	20.7	26.0	21.3	20.0	-	-
26-3-80	32.0	-	28.0	23.0	26.0	-	20.5
14-5-80	-	-	19.0	13.0	12.7	-	-
13-8-80	-	-	22.0	18.5	18.5	-	18.5
Average	26.5	21.7	24.8	21.5	20.7	-	-
Nitrate							
6-2-80	16.8	18.6	21.3	14.2	15.1	-	-
13-2-80	21.3	23.0	24.8	15.1	15.9	-	-
20-2-80	17.7	18.6	16.8	16.8	17.7	-	-
27-2-80	18.5	-	19.2	19.5	18.4	17.4	-
5-3-80	13.3	11.5	12.4	10.2	11.1	-	12.0
12-3-80	15.0	-	18.5	21.0	22.0	-	-
13-8-80			33.2	30.8	29.8	-	29.8
Average	17.1	17.9	20.9	18.2	18.6	17.4	20.9

TABLE B 12 : Total coliforms and E.coli of raw water and effluents

Date	Raw Water	Before entering the holding pond	Holding Pond eff. (a)	Prefilter eff. (b)	SSF eff. (c)	Clear Well	Tap Water	Removal Efficiency, %		
								b vs a	c vs b	c vs a
30/1/80	>2,400	>2,400	920	130	49	--	-	85.9	62.3	94.7
6/2/80	7,000	7,900	>2,400	170	23	--	-	92.9	84.5	99
13/2/80	7,900	7,000	7,900	170	23	--	-	97.8	86.5	99.7
27/2/80	11,000	-	28,000	920	920	920	-	96.7	-	96.7
5/3/80	17,000	-	-	1,300	490	-	170	-	-	-
12/3/80	16,000	16,000	9,200	110	13	-	-	98.8	88.2	99.9
19/3/80	-	-	13,000	33	23	23	-	99.7	30.3	99.8
26/3/80	35,000	-	13,000	79	23	-	8	99.4	70.9	99.8
3/4/80	27,000	-	3,000	70	23	-	-	97.9	67.1	99.3
17/4/80	-	-	17,000	79	23	-	-	99.5	70.9	99.9
8/5/80	-	-	3,300	280	33	-	17	91.5	88.2	99
14/5/80	-	-	11,000	240	33	33	-	97.8	86.3	99.7
28/5/80	-	-	9,200	-	49	-	-	-	-	-
13/8/80	-	-	15,000	920	93	-	33	93.9	89.9	99.4
Average	>15,413	>8,325	>10,248	346	130	-	-	96.0	75.0	98.9
26/3/80	2,100		7,900	23	nil	nil		99.7	95.7	99.9
14/5/80	-		2,300	23	nil	nil		99	95.7	99.9
13/8/80			4,300	23	nil	nil		99.3	95.7	99.9
Average			4,833	23	nil	nil	-	99.4	95.7	99.9