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SEATEC INTERNATIONAL

610050 ENSIC Abstr. 1981, 3(1)
22pp. (1977).

MANUAL FOR DESIGN AND OPERATION OF THE COCONUT FIBER/BURNT RICE HUSK FILTER IN VILLAGES OF SOUTHEAST ASIA

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October 1977

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I INTRODUCTION

1.1 Potable Water Sources

Ground water sources should be given priority over surface water for potable water supply in small communities (villages) whenever it is available in sufficient quantity and acceptable quality. Generally, ground water taken from a depth of below 10 m can be used directly for drinking without treatment. This is of course a tremendous advantage, but the water must be lifted to the surface by pumping or manual methods. However, due to the higher mineral content of ground water, many sources are sometimes unacceptable to the users. Demineralization of mineral content is a very expensive and complex process.

Contaminants in raw waters include both (a) dissolved minerals and organic materials (including compounds causing color, tastes, and odors), and (b) particulate matter, including turbidity (soil particles) and bacteria. Whereas surface waters usually have less than 500 ppm total dissolved solids, ground water sometimes have much more. Generally, a water is not usable if the total dissolved solids exceed 1000 ppm.

Surface water generally has relatively low dissolved solids but may be high in turbidity, color, tastes, odors, and bacteria concentration. The technology for removing of turbidity, color, tastes, odor and bacteria is well developed for large treatment works and has been applied to small communities with some success in recent years.

1.2 Ground Water Systems (Wells)

Wells may be either deep (more than 10 m depth to water) or shallow. Shallow wells obtain their water not from underground aquifers but from surface drainage. Hence shallow well water needs to be treated before use to remove turbidity, bacteria, etc., similar to treatment requirements for surface water. A shallow well is best constructed with concrete walls to prevent cave-ins and a concrete cover to prevent the introduction of foreign matter. The concrete walls may have open sections below the water

table to facilitate the passage of water. In most instances in rural communities no wall linings nor cover are used making the system unsafe.

The water may be drawn from the well by a simple hand pump. This system works well in supplying the water needs for a small group of houses.

1.3 Surface Water Treatment Process

Slow sand filters, rapid sand filters, infiltration galleries, and two-stage filtration using coconut husk fibers and burnt rice husks have been used for removing turbidity, bacteria, and color from surface waters. The operating and physical characteristics of these systems are summarized in Table 1.

Although the utilization of surface water involves more complex treatment processes, the pumping requirements are lower than for wells. Also, the mineral quality is usually better.

1.4 Choice of Treatment Processes

In choosing the proper treatment process, the following aspects should be considered:

(a) Mechanical know-how (technological capability) of the residents to manage, repair, and maintain the equipment and treatment plants.
(b) Availability of funds and labor (the resources) required for construction, operation, and maintenance of the treatment system.
(c) Social acceptability of the water treatment plant to the users.
(d) Financing considerations including both the community's ability to pay and the government's willingness to subsidize community water supply construction and operation.
(e) Education of the community regarding the need and importance of clean water.

For small communities, it is important that the plant can be operated and maintained with minimal external help as it is too expensive to hire specially trained workers to manage small water treatment systems.

In choosing the required treatment process, it is useful to refer to Table 1 and determine whether the materials and technical skills required to construct, operate and maintain the treatment plant are available in the community. The choice should be decided on the least cost alternative and the most acceptable process to the community. It is very desirable to take the community's opinion into account for the successful implementation of a system.

1.5 Principles of Two-stage Filtration

Research and development have shown the combination of shredded coconut fiber and burnt rice husks, operating in series, will in many instances effectively remove particulate matter from water and also to some extent remove certain dissolved materials. The first stage of the process serves as a roughing filter and the second stage is similar to that of a sand filter. Also, the presence of the burnt carbon in the second stage serves to some extent to absorb organic materials similar to absorption by activated carbon.

It is believed that the first stage, through surface phenomena, serves a role similar to that of coagulation/flocculation, hence for many waters no coagulating chemicals need be used. However, for some waters small dosages of coagulating chemicals may be necessary to complete the coagulation/flocculation process in the first stage. The first stage can be omitted if ground waters or relatively turbid free surface waters are used as the raw water source. The second stage filter, utilizing burnt rice husks as the filter medium, will oxidize the dissolved iron and manganese and remove these precipitates and residual turbidity. Clogging of the medium will occur as a result of precipitates building up on the surface of the burnt rice husks. The service life of the medium thus depends upon the quality characteristics of the raw water.

The two-stage filter serves much the same function as a conventional water treatment plant and achieves removals similar to rapid sand filtration, i.e., removal of particulates including turbidity, bacteria, and chemical

precipitates (such as dissolved iron in well water which may precipitate out when the water is exposed to atmospheric conditions), plus some removal of dissolved constituents.

For most of the villages in Southeast Asia, using surface waters for their water source, the two-stage filter can be utilized to treat the raw waters for domestic water supply. Where groundwaters are used, a single stage filter of burnt rice husks will probably suffice. Typical sketches of the two-stage and single stage filters are given in Figures 1 and 2. This training manual is written to provide sufficient technical information for the design, construction, operation and maintenance of both types of filters.

1.6 Potable Water Consumption

Based on surveys conducted in Thailand (Ref. 1) and in the Philippines (Ref. 2), the consumptive use for drinking in a typical household was found to average 3 liters per capita per day (lpcd). Cooking and other consumptive uses averaged less than 7 lpcd. Washing of cooking and eating utensils and other household articles utilized 10 to 15 lpcd. Bathing for personal hygiene utilized 10 to 20 lpcd.

A 30 percent allowance may be allowed for the peak daily demand, i.e., spillages, holidays, very hot days, etc. This brings the maximum daily consumption for potable water to 30 to 40 lpcd, and for total domestic water consumption to 40 to 70 lpcd.

1.7 Population Projections

The population growth rate in most of Southeast Asia averages about 3.0 percent per annum. For design purposes, a 3 percent annual increase appears sufficient unless sufficient data are available to calculate the actual population growth rate. It is suggested that the units be installed as a first stage water supply system for the village, which can be updated and modified further as the standard of living in the community progresses, and as demand for better services grows. A five year design period is considered reasonable. Hence, the design population is 1.16 times the existing population.

1.8 Plant Location

The people in the community will be more inclined to use the treated water when it is readily accessible from their houses. The public tap or filter should not be more than 200 meters from the most distant user. When using mechanical or electrical pumps, it is best to construct one treatment plant and connect the rest of the community by means of public taps. One public tap can serve a population of 100 persons without causing long queues at the service area.

1.9 Filter Design

Due to the loose configuration of the shredded coconut husk fibers, the suspended solids which are filtered out penetrate deeply into the medium. The depth of the coconut fiber is usually 60 - 80 cm.

Due to the compact configuration of the wetted burnt rice husks, the suspended solids which are filtered out penetrate only into the first 5-10 cm of the medium. The depth of the burnt rice husks is also 60-80 cm. For construction purposes it is better to use tanks of equal size for interchangeability and ease in purchasing. Although the shredded coconut fiber could sustain a higher filtration rate, it was found that the ideal filtration rate through the burnt rice husk filter is from 1.2 to 1.5 m^3/m^2-hr. The upper 2 cm of the burnt rice husk filter is the medium which will clog during use. Each time the BRH filter tank overflows due to clogging and building up of head loss, the topmost 10 cm layer is scrapped off and replaced with fresh burnt rice husks.

A freeboard of 1.0 m is allowed in each filter tank. When the filter media is new, at normal filtration rates the water depth will be much below the 1.0 m freeboard. However, as the media clogs, it will take a higher hydrostatic head to drive the water through the filter. When the water overflows the tank, then the head loss in the filter is greater than 1.0 m, which calls for a change of the media or scrapping off of the top layers of the burnt rice husks filter.

1.10 Underdrain, Maindrain, and Laterals

The laterals and maindrain are provided so that the flow of the water across and through the media will be uniform. The rate at which the filtration capacity of media is used up will be likewise uniform. For design purposes, the criteria recommended by Fair, Geyer, and Okun (Ref. 3) have been used. These criteria are as follows:

Spacing between orifice: 0.3m

Spacing between laterals: 0.3m

Diameter of orifice: 1/4" (0.63 cm)

Ratio of area of orifice to lateral: 1:2

Ratio of area of lateral to maindrain: 1:1.5

The maindrain and laterals may be constructed of G.I. pipes or PVC pipes. The latter is preferred whenever it is available as the laterals are continually immersed in water.

Support medium or an underdrain is provided to prevent the burnt rice husk particles from clogging up the laterals. The underdrain consist of pea gravel ranging from 1/8 inch to 1/4 inch in diameter, 5 to 10 cm deep.

1.11 Storage Tank

In using any type of pump (electric, mechanical or hand pump), it is not advisable to operate the pump continuously for long periods of time nor for very short periods of time (on-off - on-off sequences). Storage tanks are used to smooth out the minute-to-minute and hourly fluctuations in water demand and pump operation. The storage tank may also be used as a measuring tank for batch chlorination and for reserve in the event the system breaks down or is under repair. For design purposes, the storage tank should be at least sufficient to hold half of the maximum daily demand. The two-stage filter with storage tank is shown in Figure 1.

1.12 Chlorination

Chlorination kills any bacteria which are able to pass through the media of the filter. Calcium hypochlorite (HTH) is a handy chemical for chlorinating water supplies in small communities, and is far more convenient

to use than chlorine gas. Calcium hypochlorite should be stored in dark dry places.

To achieve effective chlorination, the chlorine powder must be mixed into the water and a sufficient contact period allowed. A simple porous earthen pot, coconut shell, or jar can be suspended in the storage tank to dispense the chlorine solution. The HTH solution should be mixed with an equal proportion of fine sand and placed inside the container. Using a suspended coconut shell three (3) holes approximately one-quarter inch in diameter are provided for the chlorine solution to pass through to the filtered water. Such a chlorinator needs to be refilled every 2-3 weeks. Chemical feed pumps, although far more accurate, are expensive and complicated so that they are not recommended for use in small communities.

The filtered water storage tank is often used as the chlorination chamber, because it serves as a measuring chamber for estimating the quantity of water passing through the system. Chlorine powder or chlorine solution should be added when the tank is empty. The required quantity of HTH powder, calculated as shown in Sec. 3 7, is dissolved in a pail of water and poured inside the tank. The pump is operated until the tank is full. Water supply should be taken only when the tank is filled, which allows time for the chlorine to accomplish disinfection of the water and to disperse so there will be no residual chlorine taste.

II DESIGN PROCEDURE

2.1 Plant Layout

Prepare a sketch, drawn to scale, of the village showing the houses, the stream, and possible sites for the treatment plant and public taps. Estimate the distances between the houses and the points mentioned. With the aid of a compass draw circles with radii of 200 m with the treatment plant and the public taps as the centers of the circles. Eliminate public tap locations where adequate coverage is taken care of by other public taps.

Distances measured by pacing will be accurate enough for this step.

2.2 Population Estimate

Count the number of houses to be served by the system and multiply by six or seven to estimate the present population of the village. Multiply this population by 1.16 to get the estimated population five years from now. The population five years from now is the design population.

If an area is to be served by a public tap, count the number of houses within 200 meters. Multiply the number of houses by seven and by 1.16 and then divide by one hundred. This gives the number of faucets that must be installed at this particular public tap. Round off to the next highest integer.

2.3 Distribution System

Most villages will eventually want a distribution system to serve distant public taps from the treatment plant. In choosing the route of the pipeline(s), see to it that the line will not pass through depressed and flooded areas or near the toilets of the houses. Choose the shortest route which satisfies the constraints mentioned above.

2.4 System Selection

The raw water source and the resources of the barangay will dictate the type of filter to be chosen and whether public fountains are to be built or not. Choose the system which best suits the financial, social, technical, and political character of the community.

2.5 Water Consumption

Multiply the design population by 30 lpcd to determine the minimum plant design capacity. Divide this value by 1.000 to express the plant capacity in m^3/day.

2.6 Filter Area Required

Assume a pumping period of six hours. This will normally be between 5:00 to 8:00 am and 4:00 to 7:00 pm. Divide the plant capacity by 9 (equal to 1.5 m^3/m^2-hr x 6 hr) to obtain the filter area required. The plant capacity should be expressed in m^3.

2.7 Filter Tank Height

One meter freeboard should be allowed for the filter tank. This brings the total depth of the coconut fiber and burnt rice husk filters to 1.8 m each.

2.8 Laterals, Maindrain and Underdrain

Fix the orifice diameter at 0.25 inches diameter and 0.3 m apart. The laterals should be placed 0.3 m apart to provide equal areas of drainage for the orifice. Calculate the total area of orifices for the longest lateral, and multiply by 2 to determine the lateral area. Calculate the lateral diameter and round off to the nearest commercial pipe size.

Count the number of laterals required and multiply by its area to determine the total lateral area. Multiply the total lateral area by 1.5 to obtain the maindrain area. Calculate the maindrain diameter and roundoff to the nearest commercial pipe size.

The pea gravel for the underdrain should be sufficient to cover the laterals and to prevent the carryover of burnt rice husk particles. Set the thickness of the underdrain equal to the diameter of the maindrain.

For Example:

Spacing between orifice is fixed at 0.3 m. If the longest lateral is 1.5 m then there will be five orifices in this lateral. If the orifice diameter is 0.25 inches, then the total orifice area is

(3.14 x 1/4 x 1/4 x 5/4) = 0.245 in^2. The required lateral area is (0.245 x 2) = .49 in^2. The lateral diameter is then $\sqrt{\frac{4 \times .49}{3.14}}$ = .79 in.

The nearest commercial size pipe is a 3/4' pipe.

If the tank diameter is 1.5 m and the laterals are spaced 0.3 m apart, then there will be 5 laterals for the filter. The total lateral area is (3.14 x 3/4 x 3/4 x 5/4) = 2.2 in^2. The maindrain area is then (2.2 x 1.5) = 3.31 in^2. The maindrain diameter is ($\sqrt{4 \times 3.31/3.14}$) = 2.05 in. The nearest commercial size pipe is 2".

2.9 Storage Tank Design

Divide the daily water consumption by two. This gives the volume required for the storage tank. Determine the distance between the farthest public tap and the treatment plant. Divide the distance by 100 to allow for 1% hydraulic head loss. This gives the minimum tank height that will be sufficient to supply the farthest tap when full.

If the tank is less than 6 m^3 and the required tank height is more than 5 m, it will be best to construct a tower to support the storage tank. At a later stage of development, economics might dictate the use of standpipes for the nearby areas and elevated towers for the far-off areas. This will give a more uniform pressure and distribution time throughout the community but will require two pumps instead of one.

2.10 Plumbing and Tank Hydraulics

The burnt rice husk media should always be submerged to operate effectively. Hence, the bottom of the burnt rice husk filter should be 0.8 m below the top of the standpipe storage tank. Similarly, the bottom of the coconut fiber filter should be at least 0.8 m below the top of the burnt rice husk filter if a two-staged filter is used. The schematic diagrams of the arrangement of both types of filters are shown in Fig. 1 and Fig. 2.

The tanks will be connected by G.I. or PVC pipes with a diameter equal to the diameter of the maindrain determined Sec. 2.8. An outlet

should be provided at the bottom of each tank to drain off the water for purposes of maintenance. A stopper is preferred over a valve, because the maintenance may take place once every three or four months depending on the turbidity and suspended solids concentration of the raw water.

The piping between the raw water source, pump, and coconut fiber filter will depend on the flow rate. The following rules of thumb are recommended:

Water flow rate	Pipe diameter
less than 3 m^3/hr	3/4"
3 to 6 m^3/hr	1"
6 to 10 m^3/hr	1 1/2"
above 10 m^3/hr	2"

2.11 Pump Selection

Divide the daily demand by 611 (equal to 35.31 ft^3/m^3 x /3600 sec/hr x 6 hrs pumping) to obtain the flow rate in ft^3/sec. Sum up the height of the coconut fiber and burnt rice husks filters, the distance between the filter and the raw water source, and the depth of the water source. Multiply the sum by 2 to take care of the losses in the pipe, bends, elbows, valves, and reducers. This gives the total pumping head required.

The pump horsepower requirements are as follows:

$$Hp = \frac{62.4\ QH}{550\ e}$$

in which Q is the water flow rate in ft^3/sec, H is the pumping head, Hp is the pump horsepower, and e is the pump efficiency. The pump efficiency may vary from 0.6 to 0.8. When in doubt use the smaller value.

The pump capacity is often expressed in terms of gpm. In which case, multiply Q by 448.E (equal to 7.48 x 60). A reducer might be required to fit the pump bore to the piping between the raw water source and coconut fiber filter as discussed in Sec. 2.10.

In the simpler single stage filter design, only jet-o-matic hand pumps are suggested. These will supply sufficient water for the size filters shown and the size of village considered in the standard design. Pumping should be done by the water users as water is required or by one (paid) village resident who has responsibility for the filter project.

III START UP

3.1 Coconut Fiber Preparation (for Two-Stage Filters)

Shredded coconut fiber may be prepared manually by soaking the husk for 2-3 days in water, then shredding the husk by pulling off the individual fibers one by one and removing the solid particles which bind the fibers. Mechanically, shredded coconut husks may be purchased from upholstery stores or coir factories. Both long and short fibers are satisfactory.

The shredded fiber should be immersed in water for three days. During each day, the water should be poured off and changed until the fiber does not impart any more color to the water. At the initial stage, the fibers may be greasy but generally this can be removed after three days of soaking.

3.2 Burnt Rice Husk Preparation (for Both Two-Stage and Single-Stage Filters)

Using a 1/8 inch mesh wire screen (mosquito nets or screens), sieve the partially burnt rice husk taken from the drier furnace of a rice mill. Discard the unburnt rice husks. Place the sieved burnt husks in water and mix slowly with a paddle or piece of wood. Discard the supernatant water with the suspended ashes and repeat the procedure three times. (Note that the supernatant has a high concentration of lye which could be used for cleaning plates and other glassware.)

3.3 Laterals and Underdrain Preparation

Place the laterals and maindrain as described in Sec. 2.8. Add 1/8 inch to 1/4 inch pea gravel until the maindrain is almost covered. The orifice should be facing the bottom of the tank.

3.4 Placing the Coconut Fiber in the Filter Tank

Place the clean or new coconut fiber into the coconut fiber filter up to a depth of 0.8 m above the underdrain. Add water and apply slight pressure with the palm of the hand to remove any entrapped air bubbles.

For large treatment plants, place the media in layers 10 cm thick at a time cover with water, and remove the entrapped air bubbles by the same procedures.

3.5 Placing the Burnt Rice Husk in the Filter Tank

Place the burnt rice husk prepared as described in Sec. 3.2 up to a depth of 0.6 - 0.8 m above the underdrain in the second tank. With a paddle or a flat piece of wood swirl the media after adding some water to remove entrapped air bubbles. After five minutes allow the particles to settle and apply slight pressure with the palm of the hand to seal cracks and make the filter surface flat.

3.6 Pumping

Pump some water into the coconut fiber filter then through the burnt rice husk filter. The yield during the first hour is to be used for cleaning the storage tank. Subsequent water yields can be used for drinking after chlorination.

3.7 Chlorination

Commercial calcium hypochlorite contains 60-70 percent available chlorine. During normal operation, the chlorine dosage should be about 0.3 ppm, which will be sufficient to achieve disinfection and not enough to cause taste problems. In the event of an epidemic in the village which may possibly be water-borne, the chlorine dosage should be increased to levels above 1.0 ppm.

The amount of chlorine required for each storage tank can be calculated as follows:

$$W = \frac{0.3 \times V}{0.6} = 0.5\ V$$

in which W is the weight of chlorine in gms of the chlorine compound (HTH), V is the volume of the storage tank in m^3, and 0.6 is the percent active chlorine in the compound (HTH).

For batch chlorination, dissolve the required weight of bleaching powder in a bucket of water. Pour the mixture into the empty storage tank. Run the pump until the storage tank is full. The quantity of water to dissolve the HTH powder is not important. Nobody should use the water until the tank is full to prevent drinking a highly chlorinated water at the start and a weakly chlorinated water at the end of the pumping operation.

For chlorination using a porous pot the frequency required for chemical replenishment must be carefully noted. The amount of HTH powder is then multiplied by the frequency of HTH replenishment and the number of times the storage tank is emptied per day. An equal portion of fine sand is usually mixed with the HTH powder and placed inside the pot type chlorinators.

IV OPERATION AND MAINTENANCE

4.1 Daily Operation and Maintenance Routine

The daily operation and maintenance routine involves starting the pump at the early hours of the morning to assure that the tank is full to meet the peak morning demand. Generally by late morning, the storage tank will be empty, in which case it will be time to start the pumping again.

For a system using batch chlorination, chlorine powder (HTH) should be added into the storage tank every time it is empty. The procedure is described in Sec. 3.7.

4.2 Cleaning the Coconut Filter Media (for Two-Stage Filters)

There will come a time when the coconut fiber will be clogged with suspended solids. The duration of the filter run depends on the suspended solids concentration in the raw water. As the media clogs the head loss increases. However, as the head loss increases, the water level in the tank increases to a point that the incoming water flow will equal the filtration rate. The maximum head loss is equal to the freeboard above the media which is 1 m.

Therefore, when the filter tank overflows, it is time to clean the filter. If the fibers can be readily obtained at an inexpensive price, it would be better to throw away the media after it has clogged. If purchase of new fiber is difficult or expensive, the entrapped particles can be removed by soaking and pounding the media then rinsing with clean water. This process might have to be done once every three or four months.

New media when required should be prepared as described in Sec. 3.1 and placed in the filter tank as described in Sec. 3.4.

For reused washed fiber, place the fibers in the filter tank as described in Sec. 3.4. There is no need to go through the color removal process described in Sec. 3.1.

4.3 Cleaning the Burnt Rice Husk Media

As the burnt rice husk filter is used, it clogs with suspended solids and colloids. When the filter tank overflows then the head loss in the media is higher than the allowable head loss of 1 m to maintain a filtration rate of 1.25 to 1.5 $m^3/m^2/hr$. The colloidal and suspended solids are mostly entrapped in the upper 2 to 3 cm of the media.

In this case, stop the pumping and drain off the water in the tank. Scrape off the top most 10 cm layer of the media. Then start the operation in the usual way.

If the media thickness is less than 0.6 m after the scraping-off operation, it is best to prepare new media as described in Sec. 3.2. The newly prepared media is placed inside the tank as described in Sec. 3.5.

The scraping operation may take place once every three to four months depending on the turbidity of the raw water. The change of the whole media may be required once a year.

4.4 Cleaning the Storage Tank

It is advisable to clean the storage tank once a year to remove any solids which may have precipitated inside the tank. Cleaning could be done by scrubbing the sides and floor of the tank with a brush, and then rinsing the tank thoroughly with water.

V REFERENCES

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TABLE 1: CHARACTERISTICS OF ALTERNATIVE WATER TREATMENT METHODS

Parameters	Infiltration Gallery	Slow Sand Filter	Rapid Sand Filter	Two-Stage Filtration
1. Land requirements	Large	Large	Small	Average
2. Skilled operator required	No	No	Yes	No
3. Cost of construction	Average	Average if proper sand size is available	High	Low
4. Cost of maintenance	Low	Average	High	Low
5. Materials of construction	Wall supports of brick, concrete block in weak soil	Concrete lined either tanks or concrete tanks	Concrete tanks	Wooden support structure; concrete or G.I. ja for filter tank
	Covering material optional	Sand of effective dia 0.45-0.55 mm uniformity coefficient 2 to 3	Sand of effective dia 0.45-0.55 mm uniformity coefficient 1.6	Coconut fiber shredded and washed. Burnt rice husks of effective dia 0.3-0.5 mm uniformity coef. 2.3 to 2.6
	Hand pumps	Mechanical or electrical pump Primary settling tank may be required	Mechanical or electrical pump Alum dosing system Flocculation Sedimentation Elevated tank for back-washing filters	Hand or mechanical pump
6. Supplementary treatment	Chlorination	Chlorination	Chlorination	Chlorination
7. Special requirements	Near the river or water source	None	Proper pH control for flocculation	None
8. Ease in operation	Simple	Simple	Complicated	Simple

TABLE 1 (CONT'D)

Parameters	Infiltration Gallery	Slow Sand Filter	Rapid Sand Filter	Two-Stage Filtration
9. Ease in construction	Difficult	Less Difficult	Very Difficult	Simple
10. Technical aspects	Simple	Simple	Highly Complicated	Simple
11. Size of Community per unit	Unlimited	Unlimited	Greater than 5,000 persons	Less than 1,000 persons
12. Raw water characteristics	Not specified	Turbidity less than 50 ppm otherwise pre-treatment required	Highly turbid waters	Turbidity less than 200 ppm otherwise mul stage unit or coagulant required.
		Low-medium level pollution source	Average level pollution source	Low-medium le pollution source

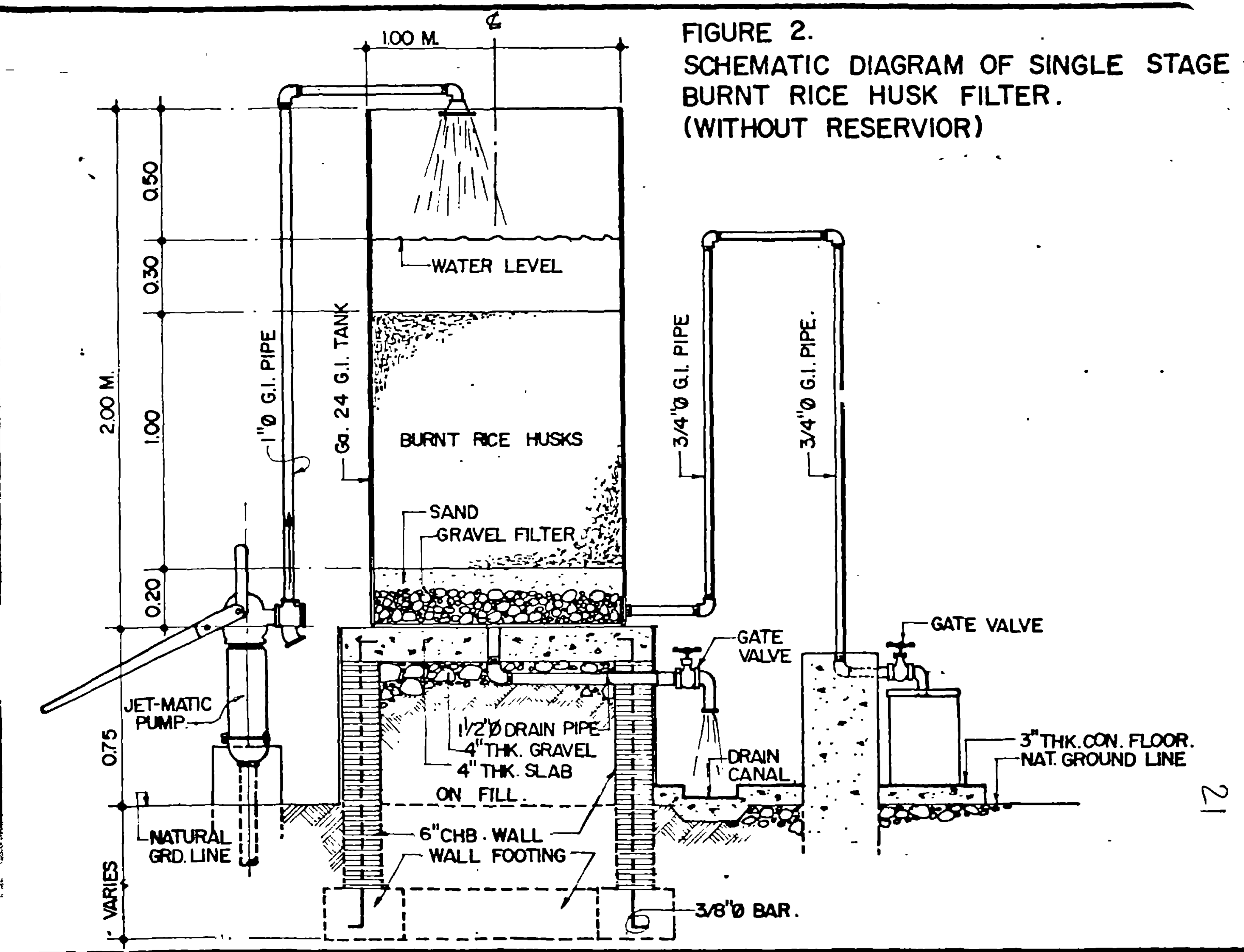
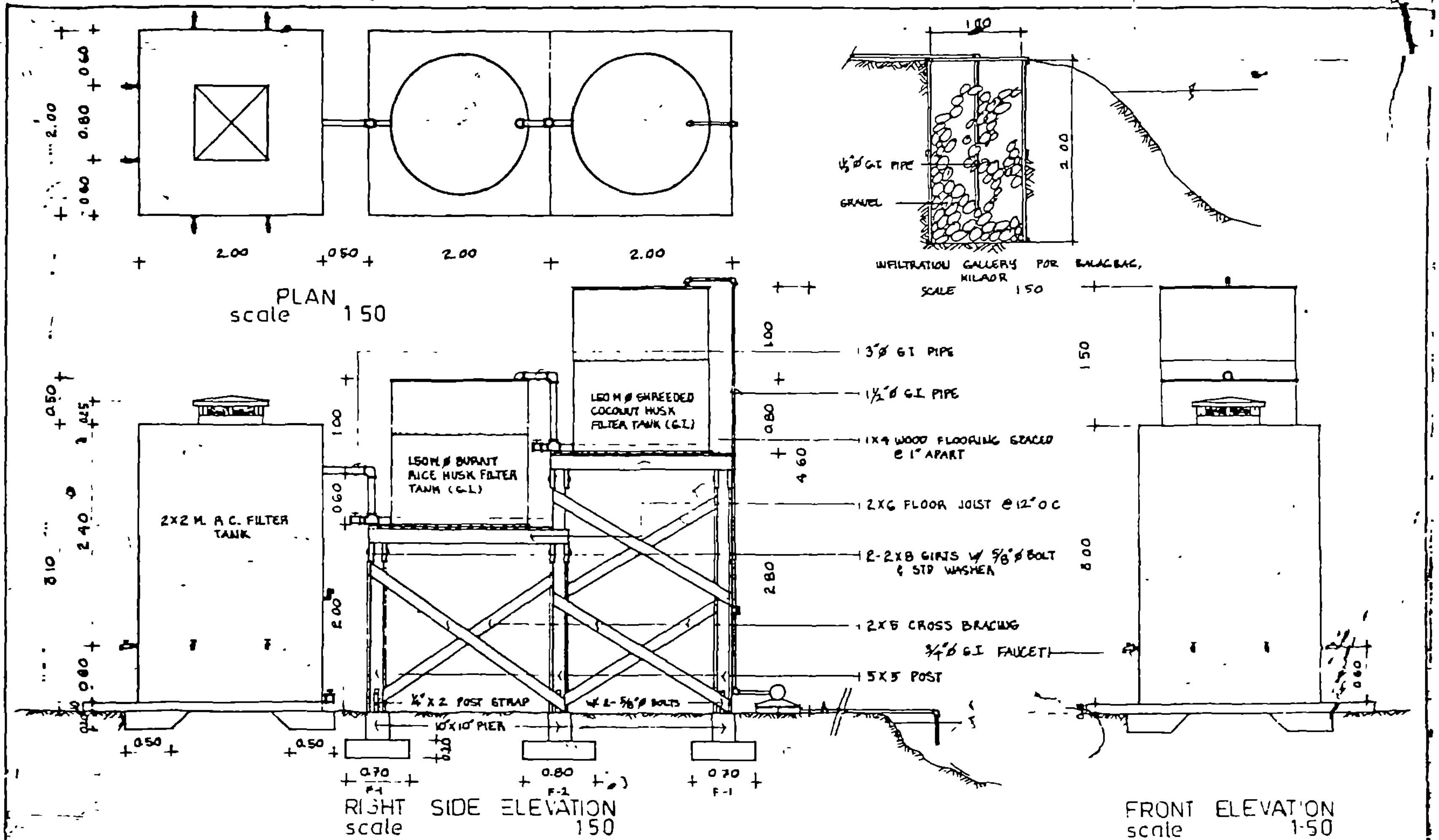


FIGURE 2.
SCHEMATIC DIAGRAM OF SINGLE STAGE BURNT RICE HUSK FILTER.
(WITHOUT RESERVIOR)



SHEET NO. ½	PROPOSED: FRANKEL FILTRATION SYSTEM LOCATION: BALAGBAG, MILAOR/~~MAGABAO~~, CAM SUR	BICOL RIVER BASIN COUNCIL PROGRAM OFFICE ~~BARAS CANAMAN, CAMARINES SUR~~			FIGURE I. SCHEMATIC DIAGRAM OF TWO-STAGE FILTER.
		SHEET CONTENTS PLAN AND ELEVATIONS	DESIGNED BY STRUCTURAL BY	DRAWN BY CHECKED BY	DATE SEPT '75