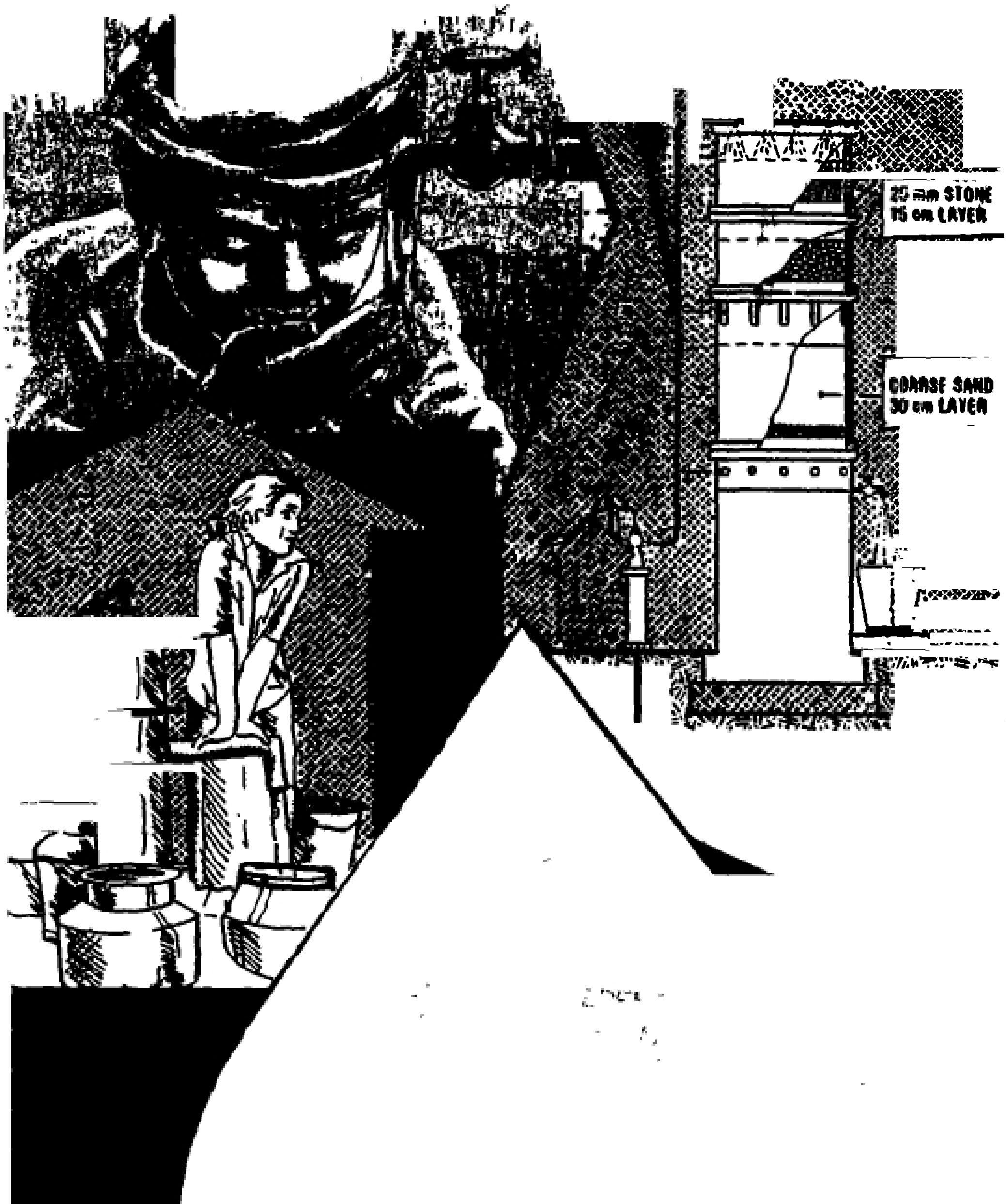

TECHNOLOGY PACKAGE ON
IRON REMOVAL

TECHNOLOGY MISSION ON
DRINKING WATER IN VILLAGES
AND RELATED WATER MANAGEMENT

TECHNOLOGY PACKAGE ON
IRON REMOVAL

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INTRODUCTION

Iron may originally be present in a water as derived from the source or be acquired from metals with which the water subsequently comes in contact. To decide this important point it is necessary to examine samples collected directly from the source on the spot. If the latter is a deep bore-hole and samples can only be obtained from the pump delivery, a series of samples should be collected at intervals throughout several hours' continuous pumping at maximum capacity. Should the examination of these samples show that the amount of iron present in the water decreases rapidly as pumping proceeds, it is fairly certain that some, if not all, of the iron is derived from the metal of the bore-hole tubing, strainer and rising main. This is required to be ascertained before further action.

OCCURRENCE OF IRON

Iron is one of the most important and valuable of all the elements. It is essential for the nutrition and healthy development of most plants and animals, and also man, and is very widely, distributed in nature. Iron is present in practically all soils, gravels, sands and rocks, sometimes in considerable amounts, but often only in traces. It is usually found in the form of oxides. Other common forms are ferrous carbonate and iron pyrites. Rain in percolating through soils and rocks, acquires iron in addition to other mineral constituents according to the character of geological formation, and there are very few waters, whether from surface or deep sources, which do not contain atleast traces of iron. Iron in surface waters is mostly in insoluble or colloidal form. In deep sources, it is in dissolved state and exposure to atmosphere results in oxidation of soluble to insoluble or colloidal forms.

OBJECTIONS TO IRON

The presence of iron in water is objectionable owing to production of discoloration, turbidity, deposit, and taste. Iron bearing waters have an astringent, metallic or bitter taste, and by combination of the iron with tannin impart an inky-color to tea infusions. Water containing iron is undesirable for culiniary use, causing brown-coloured deposition on the vegetable during washing and cooking. It is also objectionable for laundry purposes and gives rise to 'iron-moulding' on linen and other white fabrics being washed. For may industrial purposes such as paper-making, dyeing, photographic film manufacture and beverages, the water must be entirely free from iron. Even small traces of iron in water lead to accumulation of appreciable deposits in distribution mains and reservoirs, and these often troublesome to water authority and objectionable to consumers. Under such conditions, growths of iron bacteria often develop in the distribution system, when difficulties such as blocking of mains, meters, pipes, etc. are accentuated, and complaints of discoloured, turbid and unpalatable water becomes more serious. The iron bacteria are nuisance organisms, and transform or deposit iron in the form of objectionable slime, resulting in fouling and plugging of wells and distribution systems. The bacteria also cause odour, taste, frothing, colour and turbidity in waters (Fig.1).

LIMITS OF IRON

A toxic dose of iron for a child has been given as 1500 mg of $FeCl_2$. Instead of physiological reasons, therefore, the limits for iron are based upon aesthetic and taste considerations. Growth of iron bacteria is experienced when iron concentration exceeds 0.2 mg/l. Ministry of Health, considering the inconvenience that may arise from the presence of such small amounts of iron in public water supplies, Ministry of Health, Government of India and Indian Standard Institution suggested the following guidelines for iron in mg/litre.

Permissive	..	0.3
Excessive	..	1.0

When this amount is exceeded, some form of treatment is usually advisable.

IRON BACTERIA

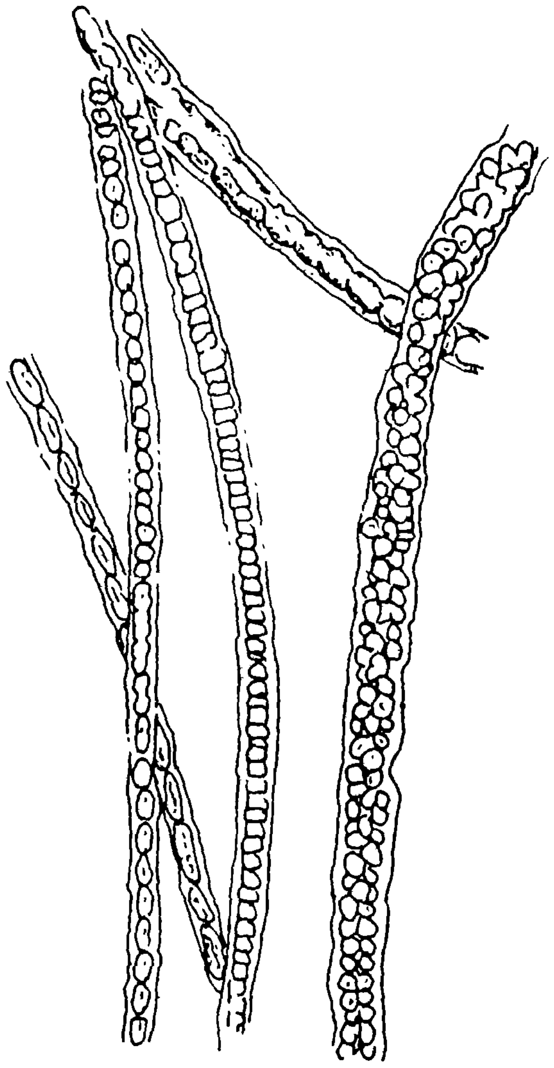


FIG. 1

CHEMISTRY OF IRON REMOVAL

Ferrous iron, Fe(II)

In the pH range of natural waters, soluble bivalent iron, Fe (II), consists of Fe^{++} and $Fe(OH)^+$. The solubility of ferrous iron in all carbonate bearing waters(C_T, total carbonic species, exceeding 0.0001 M) within the common pH range (pH 6 to 9) is governed by the solubility product of siderite, $FeCO_3$ ($Ksp=10^{-15.1}$). The solubility product of $Fe(OH)_2$ governs the solubility of Fe(II) only in waters that contain no carbonate or their pH is very high.

For a water saturated with air with E_H of 0.7171 v and pH 7.0, the equilibrium concentration of Fe^{++} can be obtained from Peter-Nernst equation. According to it at pH 7.0 the calculated equilibrium concentration of Fe^{++} amounts to approximately 5×10^{-14} M. Thus, no iron should exist in solution in equilibrium with atmosphere.

Ferric iron, Fe(III)

In oxygenated water, Fe(II) is oxidised to Fe(III). The solubility of Fe(III) in natural water is controlled by the solubility of ferric oxide hydroxide, $Fe(OH)_3$. For a water saturated with air and pH 7 total Fe(III) constituent comprising, Fe^{+++}; $Fe(OH)_2^+$; & $Fe(OH)^-$ is of the order of only 1 microgram per litre.

Over the entire pH range of natural waters, Fe(II) is thermodynamically unstable in the presence of dissolved oxygen.

$$4\,Fe^{++} + O_2 + 10\,H_2O \longrightarrow 4\,Fe(OH)_3 + 8\,H^+$$

This reaction is thus accompanied by a reduction in pH.

Kinetics of Oxygenation

The reaction rates of ferrous iron is strongly pH dependent. Oxidation of Fe(II) is very slow at pH values below 6. The oxygenation kinetics follow the rate law :

$$-\frac{d\ Fe(II)}{dt} = k\ Fe(II)\ P_{O_2}\ (OH^-)^2$$

The rate of oxygenation of ferrous iron to ferric iron is second order with respect to the concentration of $(OH)^-$. Thus, a 100 fold increase in the rate of reaction occurs for a unit increase in pH of water.

Complex Formation

The solubility characteristics of aqueous iron can be influenced by complex formation. Complex formation of Fe(II) with ligands other than $(OH)^-$ however, does not appear to be extensive or prevalent in natural waters. The stability constants of bicarbonate or sulphate complexes do not exceed roughly 10 and thus neither HCO_3^- nor SO_4^{--} within the common concentration range affect the solubility relations markedly. Ferric ions, generally, have a stronger tendency to form complexes than ferrous ions.

Analytical Limitations

Analytically, it is rather difficult to distinguish between dissolved and colloidal or suspended iron. Centrifugation at 93,000 g for 180 minutes removes suspended iron between pH 5 and 12. The size of $Fe(OH)^3$ particulates can be as small as 100 A^o and will vary with pH.

ANALYTICAL METHODS

Phenanthroline Method (for total iron)

The phenanthroline method is adequate and suitable for the analysis of both natural and treated waters. The complexing agent 1, 10-phenanthroline is specific to ferrous iron and is pH dependent. In view of this, some chemical treatment is essential before the analysis of iron. Initially iron is brought into solution by acidification and then all the iron is reduced to ferrous state by boiling with hydroxylamine. Ferrous iron produced reacts with phenanthroline at pH between 2.9 and 3.5 to form an orange-red complex having absorption maxima at 510 nm.

Equipment

Either a spectrophotometer for use at 510 nm providing a light path of 1 cm or a filter-photometer providing a light path of 1 cm and a green filter having maximum transmittance at 510 nm.

Reagents

Hydrochloric acid - Concentrated HCl containing less than 0.00005% Fe.

Hydroxylamine solution (10%) - Dissolve 10 g NH_2 OH.HCl in 100 ml distilled water.

Ammonia acetate buffer solution - Dissolve 250 g NH_4OOCCH_3 in 150 ml distilled water and add 700 ml glacial acetic acid to it.

Phenantroline solution - Dissolve 100 mg of 1.10 phenanthroline mono-hydrate in 100 ml distilled water by stirring and heating to $80^{o}C$. Add 2 drops of concentrated HCl and store in a glass bottle.

Iron stock solution - Dissolve 1.404 g of $Fe\ (NH_4)_2.(SO_4)2.6H_2O$ in 50 ml distilled water and add 20 ml concentrated H_2SO_4 slowly with stirring. Add 0.1 N $KMnO_4$ dropwise till faint pink colour persists. Dilute to 1000 ml with distilled water.

Standard iron solution - Prepare standard solutions of 0.5 mg/l; 1.0 mg/l; 2.0 mg/l; & 5.0 mg/l of iron by taking 0.25 ml; 0.50 ml; 1.00 ml; & 2.50 ml of iron stock solution in 100 ml volumetric flasks and diluting to 100 ml with distilled water.

Preparation of Calibration Curve:

- Take 50 ml of each standard solution in separate 125 ml conical flasks
- Add 2 ml conc. HCl and 1 ml hydroxylamine solution.
- Add few glass beads and heat the solution to boiling; continue boiling until the volume is reduced to 15-20 ml.
- Cool the solution and then add 10 ml ammonia acetate buffer solution.
- Add 4 ml phenanthroline reagent & dilute to 50 ml with distilled water. Mix thoroughly and allow 10 minutes for maximum colour development.
- Measure the absorbance of the developed colour at 510 nm against blank prepared by taking 2.5 ml of distilled water and subjected it to treatment similar to standards. Plot a curve of concentration of iron versus absorbance.

Determination of iron in water :

- Take 50 ml water samples (representative) in 125 ml conical flasks.
- Repeat steps of treatment from addition of 2 ml of conc. HCl through measurement of absorbance of the developed colour.
- Find the level of iron from the calibration curve.

NEERI'S Field Testing Method

A field testing method is developed by NEERI, which is easy to use for routine estimation, at places where elaborate facilities are not available to perform analysis by phenanthroline method for total iron.

Procedure :

- Take 50 ml of water sample (representative) in a Nessler tube.
- Break-open a NEERI-made 'Ferro Ampoule' and transfer the contents into the Nessler Tube and swirl to mix.
- Allow the colour to develop for 10 minutes. If iron is present, an orange-red colour will appear.
- Transfer the developed colour solution into the test tube provided in the NEERI-made colour comparator kit.
- Match the colour in the adjacent compartment and note the iron value.

AREAS SHOWING IRON WATERS

High concentrations of iron is associated with waters from shale, sandstone, and other rocks. Iron is dissolved by ground waters containing free carbondioxide but no dissolved oxygen. Occasionally some very deep wells in such areas also yield slightly ferruginous waters. The experience of NEERI with bore-holes is that apart from dossolved iron, such waters are also characterised by very low pH, excessive dissolved carbondioxide, trace metals such as copper, zinc, arsenic, etc, which require specific treatment to render them suitable for public supply purposes. It is, therefore, essential that all waters confirmed ferruginous require to be screened for other toxic substances before deciding on the type of iron removal treatment.

States of Assam, Meghalaya, Tripura, West Bengal, Orissa, Bihar, Uttar Pradesh, Madhya Pradesh, Maharashtra, Tamil Nadu and Kerala have been found to have ground waters bearing iron in varying concentrations requiring appropriate treatment to make them potable. (Fig 2) There are an estimated 2900 villiages/hamlets in India, which have problem of excessive iron. Various practices of iron removal are inter-related and hence must be coordinated in the process concept and in the design.

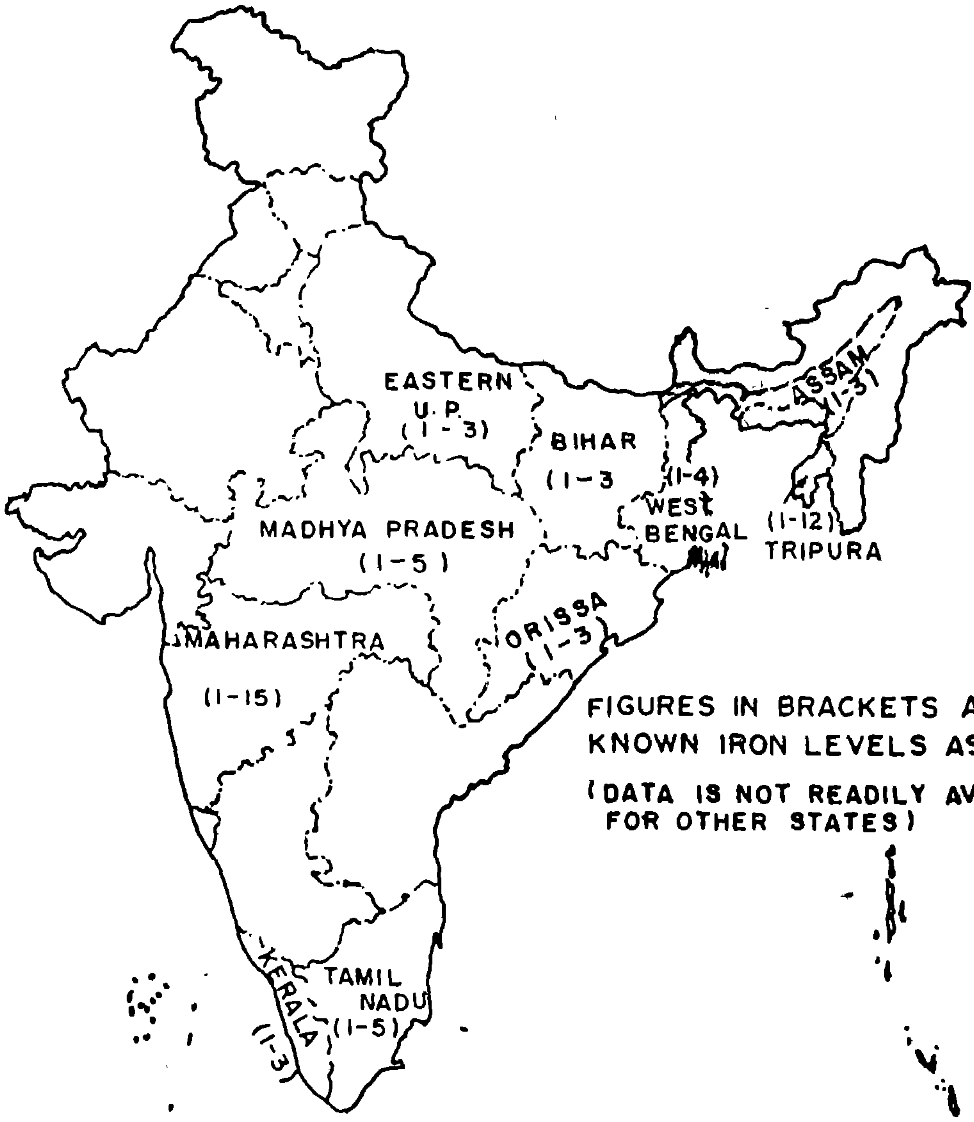
PRINCIPLES OF IRON REMOVAL

The literature on iron removal is confusing, because the characteristics of various waters and varying chemical composition of iron and other health related parameters make it necessary to select one of the several processes to meet the specific local conditions. The structures needed for specific processes are discussed under treatment.

The processes employed at water works for the purification of water, such as storage, coagulation, and filtration, satisfactorily remove the small amounts of iron which are present in the many deep wells in the cretaceous water-bearing formations.

TECHNOLOGY MISSION ON DRINKING WATER

IRON PROBLEM STATES



FIGURES IN BRACKETS ARE KNOWN IRON LEVELS AS mg/l Fe

(DATA IS NOT READILY AVAILABLE FOR OTHER STATES)

FIG. 2

Oxidation :

Oxidation is only one step in the removal process. Coagulation and sedimentation (and/or filtration) co-determines the overall removal efficiency in the removal of Fe(II). Coagulation of Fe(III) is fast within neutral or slightly acidic pH ranges. Hydrous oxides of Fe(III) have extensive sorption capacities for Fe(II), which is significant and even sometimes most important part of the oxidative deferratisation process.

Contact beds :

In practice, removal of iron is generally accelerated and rendered more effective by providing interfacial contact areas, ie. the water is allowed to trickle over some contact material like coke, lime-stone, marble, calcite, or crushed stone. The contact surfaces gets coated with hydrous oxides of Fe(III) and the subsequent removal of Fe(II) becomes more effective. It is for these reasons, the contact surfaces in filters have to be matured (to allow coating with hydrous oxides) before they efficiently remove iron.

Spray Aeration :

This is usually intended to remove dissolved carbondioxide. In the opinion of NEERI, it is usually cheaper to neutralise with an alkali than to employ aeration when the carbondioxide content of the water is below 10 mg/l.

Alkali treatment :

The lime-soda process of softening is effective in removing iron from water. The process is valuable where carbondioxide levels are low and waters are hard. Laboratory tests will alone decide the suitability of alkali treatment for the specific water. The alkali should be applied in such dose that the final pH of the water, after settlement and filtration, is in the 7.5 to 8.5 range, and thorough mixing of alkali and water should take place.

Chlorination :

Chlorination can be employed to control growths of iron bacteria. Before adopting this process, it is essential to determine whether chlorine, in the absence of dissolved oxygen, will be effective in oxidising iron in the specific water supply design.

METHODS OF TREATMENT

Troubles due to iron are avoided by : (i) treatment of the water before distribution, if it contains more than permissible iron, or if it is unduly corrosive to metals; (ii) use of specially selected mains, such as uPVC (iii) avoidance of 'dead-end' mains; and(iv) periodical flushing of mains.

The means by which iron is removed from water consists substantially of its precipitation by oxidation and removal of free carbondioxide by aeration, followed by separation of the suspension by sedimentation and/or filtration. Aeration may suffice for the preliminary precipitation, but, when the amounts of free carbondioxide and iron are high, or relatively soluble and complex compounds of iron are present, the addition of chemicals is necessary. Sedimentation tanks, for the removal of the bulk of the precipitate prior to filtration, are usually required when the amount of iron in the water is high. Filters will become overloaded and impossible to operate efficiently if fed with unduly turbid water.

The systems available for specific iron removal requirements are discussed below.

- Domestic treatment.
- Rural water supply.
- Community water supply.

The supervision and operation depends on the system.

Domestic Treatment

This is for individual house-hold purpose for treatment of water with high iron content. The following are the alternatives.

- Shallow Dug Wells.
- Chemical treatment with suitable doses of sodium carbonate and sodium phosphate.
- Hand-operated domestic Aeration/Filtration Unit.
- Muscle-powered Dissolved Air Floatation Unit.

Shallow Dug Wells : Dug wells are made by digging a hole in the ground. To provide working space for the digger at the bottom of the hole, a diameter of atleast 1.3 m is necessary so as to allow two men working together. For private use this minimum diameter is adequate to supply the required amounts of water, while for larger rates of abstraction the diameter may be increased to 2-3 m. The depth of the well primarily depends on local geo-hydrologic condition and is limited by the cost and technical difficulties of excavation. Private wells usually have a depth less than 10 m. The construction should ensure protection against the incursion of surface drainage. The water inside the well should be chlorinated thoroughly using NEERI pot-chlorinator to guard against bacteriological contamination. The top must not be closed with water-tight cover. Water should remain in contact with air and sunlight to the extent possible. This facilitates water getting nearly saturated with air so that no iron should exist in solution. Pulley and bucket system ensures aeration of the water in the well. The dug wells will not prevent precipitated iron being carried into the water drawn and it is necessary to use domestic filters to have these precipitates removed. (Figure No.3).

Chemical Treatment : Iron present in all forms is removed by the addition of a mixture of sodium carbonate and sodium phosphate. The technique developed in NEERI comprises of addition of the chemicals to precipitate iron as insolubles followed by settling and filtration. The treatment is carried out in a bucket of 60 litres capacity containing

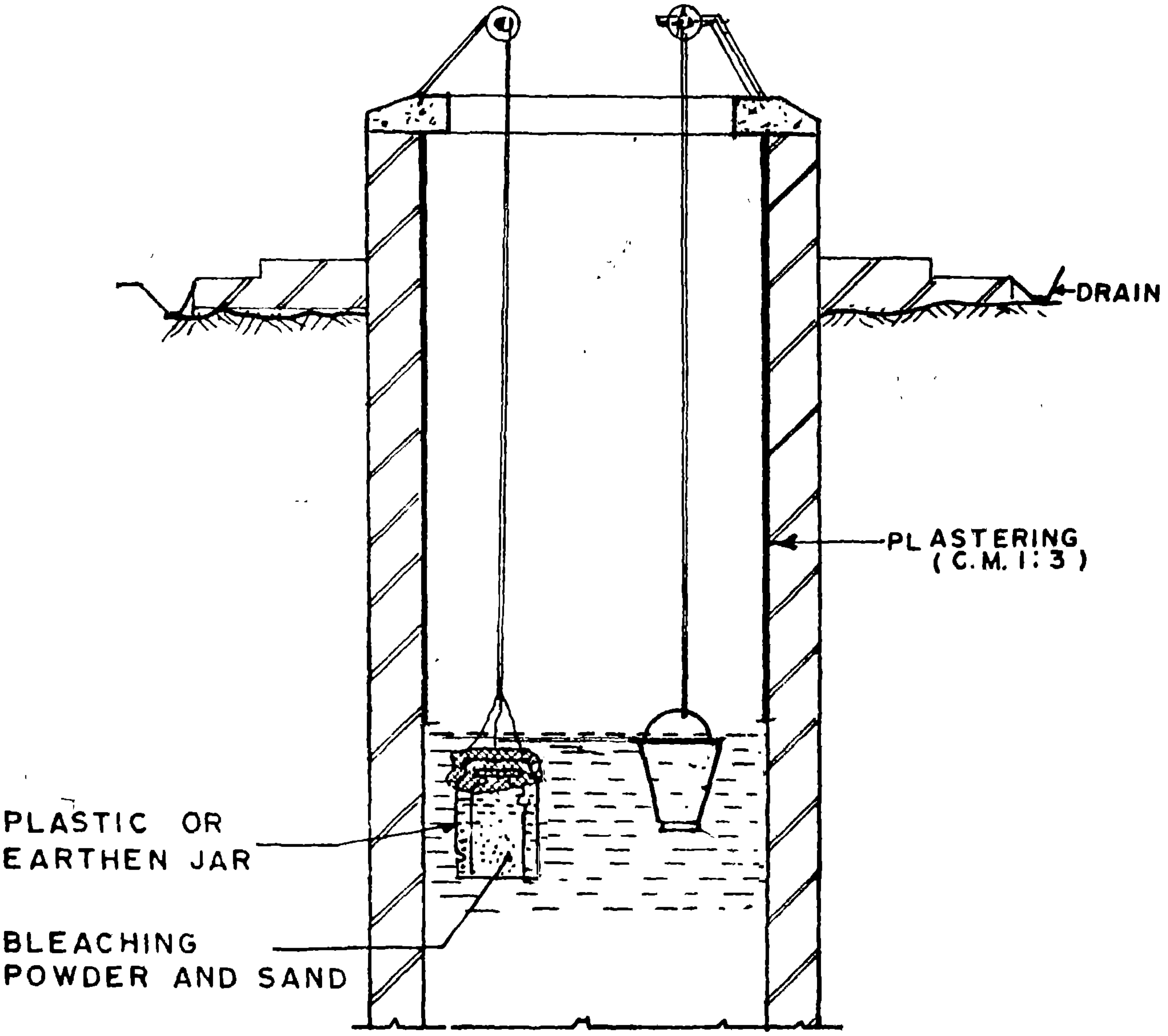


FIG 3 : SHALLOW DUG WELL

40 litres water with a tap at 10 cm above the bottom of the bucket for removal of the settled water. (Figure 4). The steps involved are:

- take 40 litres water in the bucket and stir with a stick for 10 minutes;
- add the chemical-mix and stir again for 10 minutes;
- settle the water for 2 hrs. and withdraw it from the tap to pass through a sand filter to be collected in another bucket.
- the settled precipitates from the first bucket are removed periodically; the filtered water is free of iron.

The concept can be extended to larger volumes of water using suitable masonary tanks that can be built in each house.

Hand-operated Domestic Aeration/Filtration Unit :

This Unit was developed by NEERI and internationally referred as 'Domestic Iron Removal Unit (DIRU)'. The unit is suitable for rural purposes, and can be built from locally available skill. Aeration of the raw water over a series of coke marble/calcite beds is followed by slow sand filtration. After sometime a catalytic oxidation bed is formed which hastens the removal process. No chemicals are needed. The unit can be worked directly by an elevated hand-pump. Raw water containing 1-6 mg/l Fe(II) iron and 0.1-0.3 mg/l Mn (IV) manganese is treated in this way at the rate of 200 litres per hour. (Figure 5).

Muscle-powered Dissolved Air Floatation Unit :

The Unit comprising of air saturator, and floatation tank with in-built filter can be fabricated with local talent. The unit is attached to a hand pump of capacities upto 500 l per operation. (Figure 6). The desired treatment of water is achieved through the following sequence of plant operation :

- Raw water is filled in the air-saturator to approximately three-fourth of its volume and the screw-cap is tightened. The pneumatic hand-pump is operated to attain a pressure of 3.5 kg/cm^2. Water becomes saturated with air at this pressure, which is then led into the floatation tank through a distributor, regulated by hand-controlled shut-off valve attached to a flexible hose and on to the distributor manifold.

IRON REMOVAL
AT DOMESTIC LEVEL

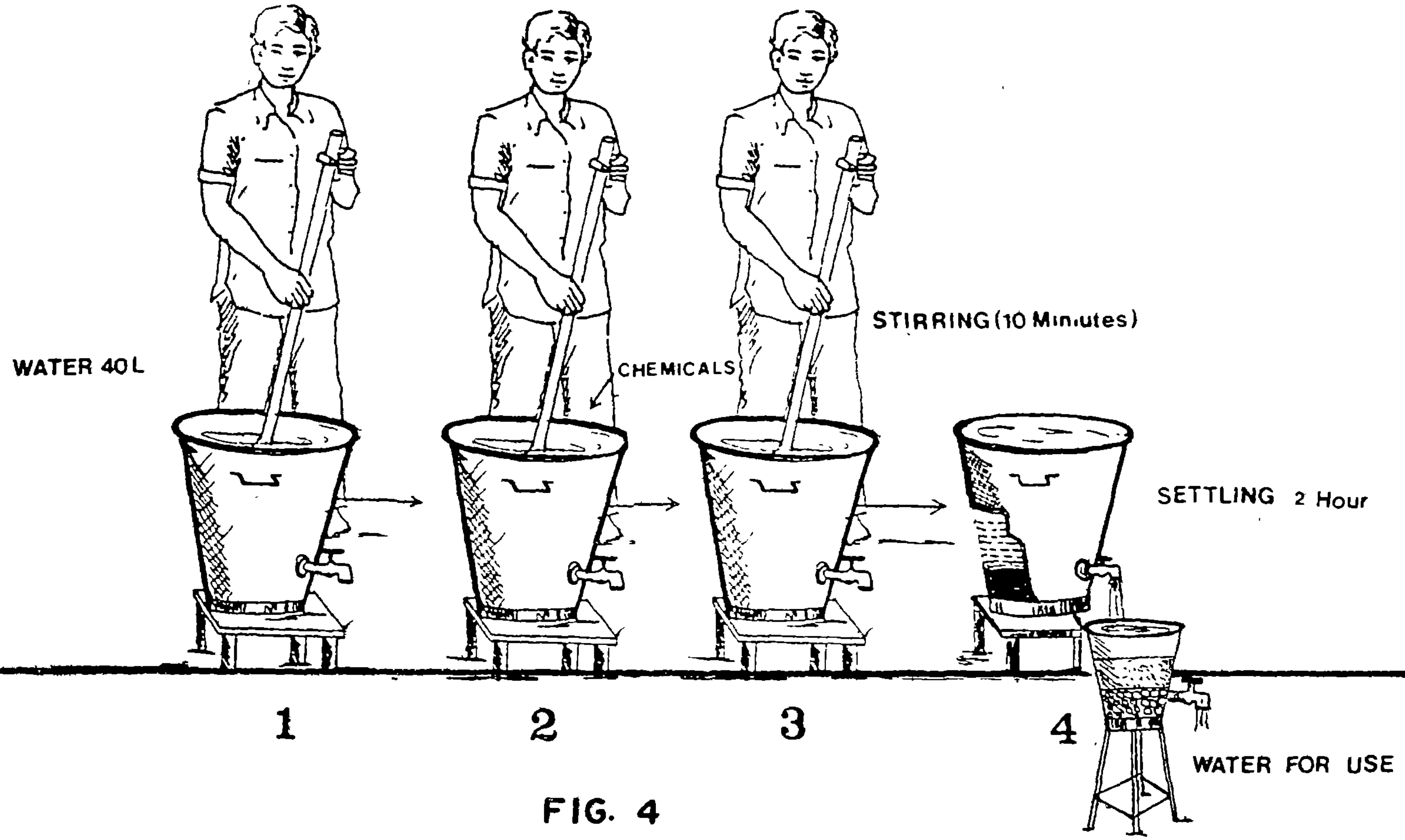


FIG. 4

HAND OPERATED DOMESTIC AERATION/ FILTRATION UNIT (NEERI)

DIRU

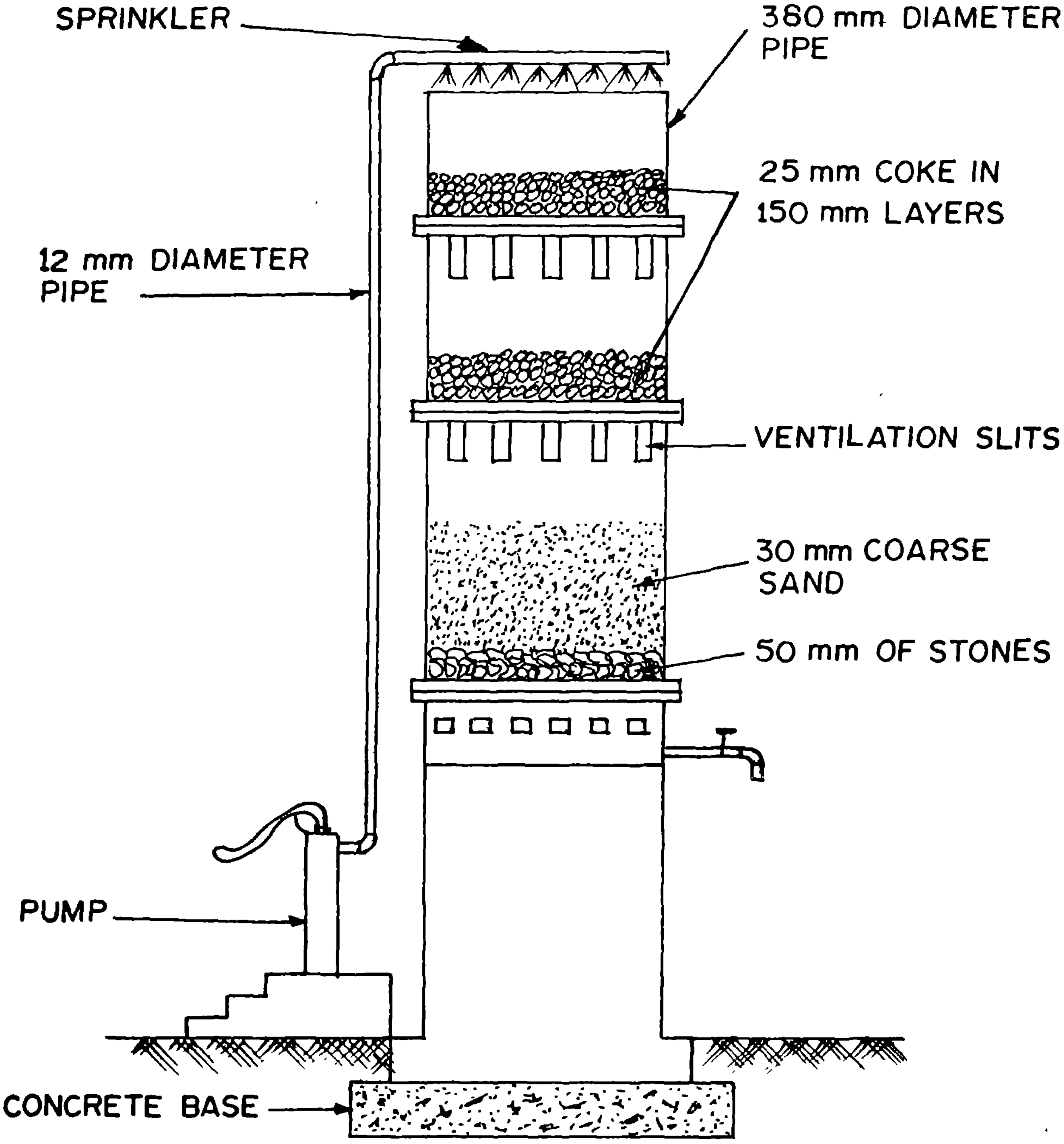
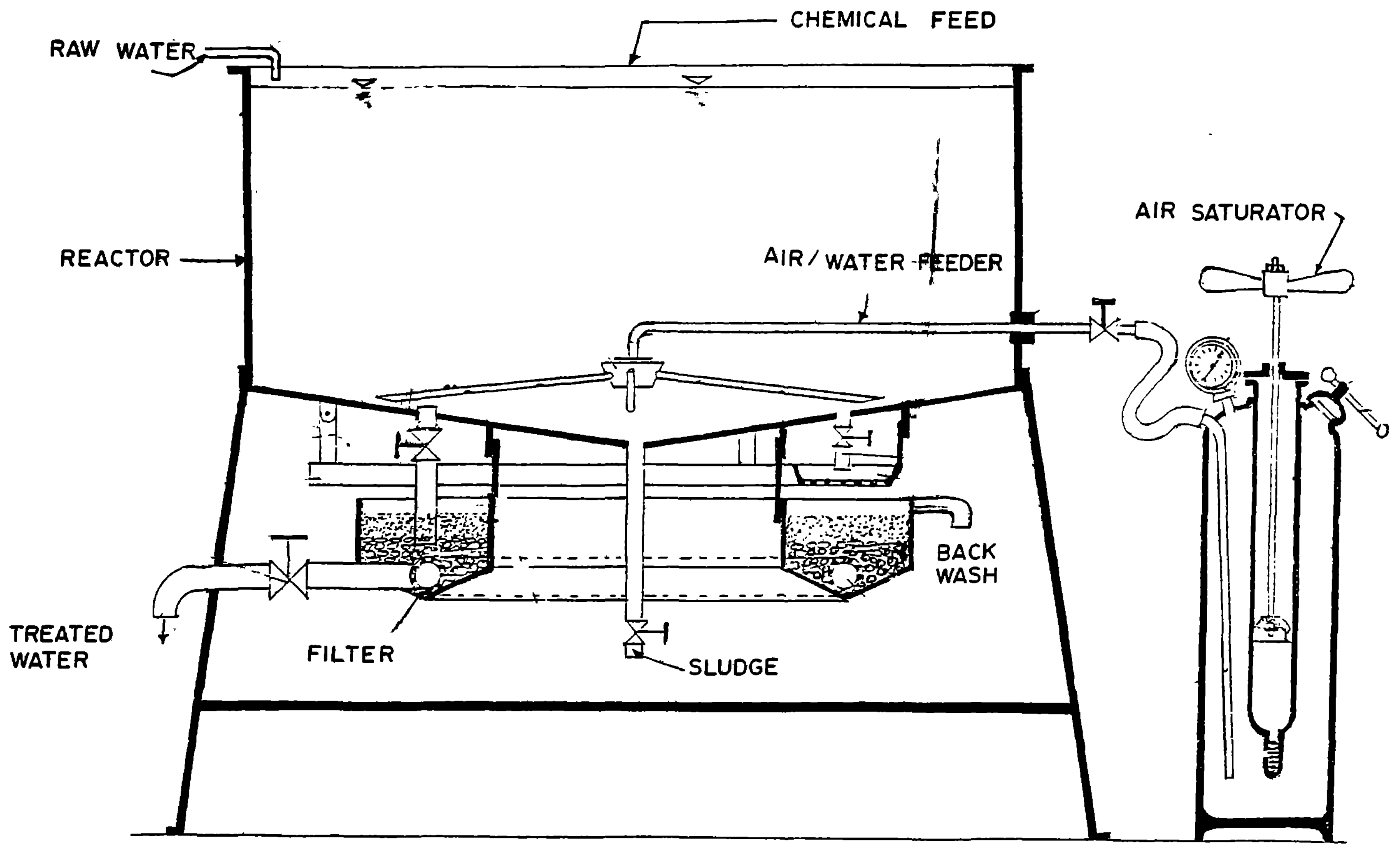


FIG.5.



MUSCLE-POWER DISSOLVED AIR FLOATATION SYSTEM FOR WATER TREATMENT

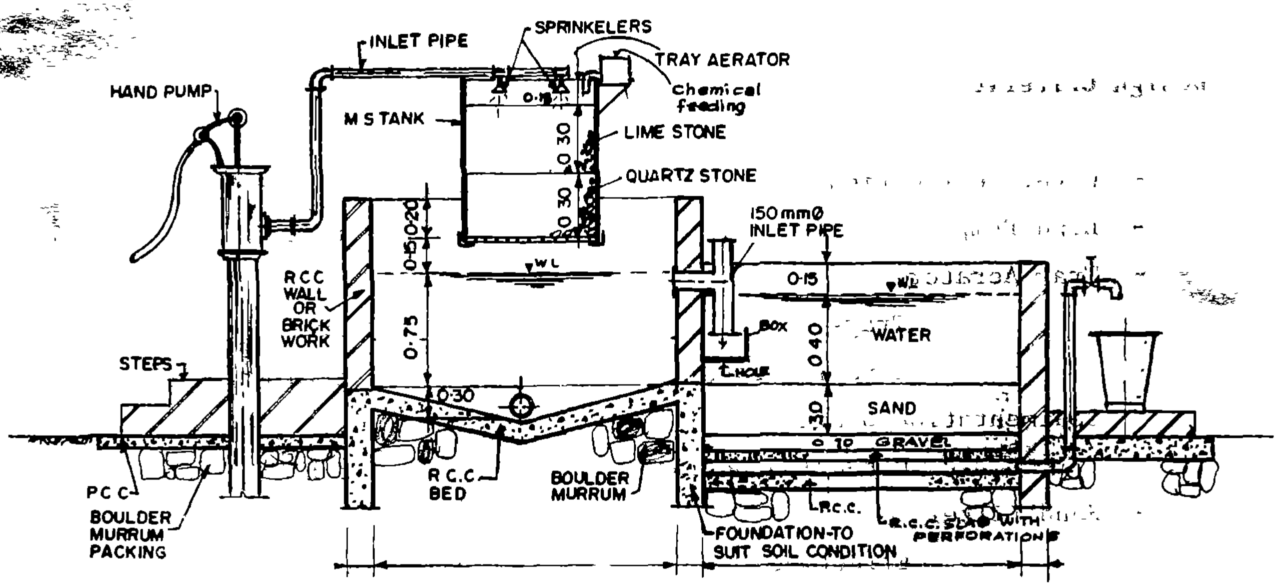
- The floatation tank with filter is filled with iron bearing water and air-water mix is admitted from the saturator. The micro-fine air bubbles quiscently lift the oxidised iron to the surface. The air-water mix discharge continues for nearly 20 minutes by which time the water in the floatation tank becomes clear and rid of iron. The Unit produced water with 0.5 mg of iron from a raw water containing 5 mg/l using 2.5 l of air-water mix.

Rural Water Supply

This is for small communities in rural areas, where the number of people to be serviced is small, and the low density of population makes piped distribution costly. The rural population is often poor and, particularly in subsistance farming communities, little money is available. Frequently, there are hardly sufficient funds to pay for the operation and maintenance of the water supply scheme and the small communities are unlikely to be able to meet the capital costs of their water supply without assistance from the Government. Trained personnel for the operation and maintenance may not be available in the rural areas and are to be provided.

In making the technology choice, unnecessarily complicated designs were avoided, decreasing the cost of construction, and reducing the difficulties of operation and maintenance. An inventory of man-power, chemicals, equipment and spare-parts is made, so that the water supply is regular and reliable. (Figures 7-9).

The rural water supply scheme intends to treat raw water containing free carbondioxide and dissolved iron and includes, hand-pumps, tray-aerators, sedimentation basin and sand filters. The designs for entire water facility are given for 250, 500 and 1000 populations.



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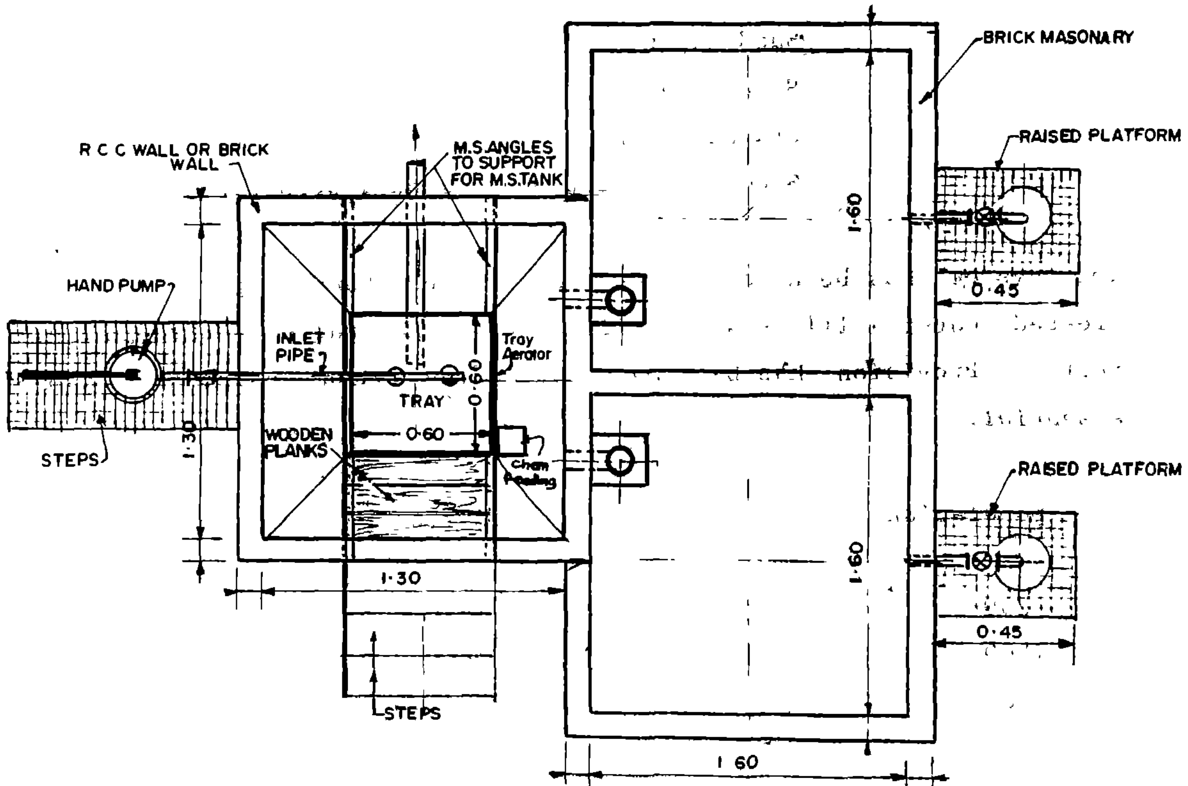


LAYOUT PLAN (ALL DIMENSIONS ARE IN METRE)

FIG 7 : HAND PUMP WITH IRON REMOVAL UNIT. CAP: 250 POPULATION

Design Criterion

- Water consumption	40 lpcd
- Hand Pump	India Mark II
- Tray Aerator	
Trays	two
Aeration rate	1.26 $m^3/m^2/h$
- Sedimentation Basin	
Detention period	3 h
- Sand Filter	
Effective size	0.30-0.45 mm
Uniformity coefficient	2-3
Sand depth	0.3 m
Support gravel	3-6 mm
Gravel depth	0.1 m
Sand to be cleaned by manual scrapping.	

The system has been so designed that as the hand-pump is used, the treated water will start flowing out for general use through stand-posts. Provision has been made for adding sodium carbonate wherever essential.

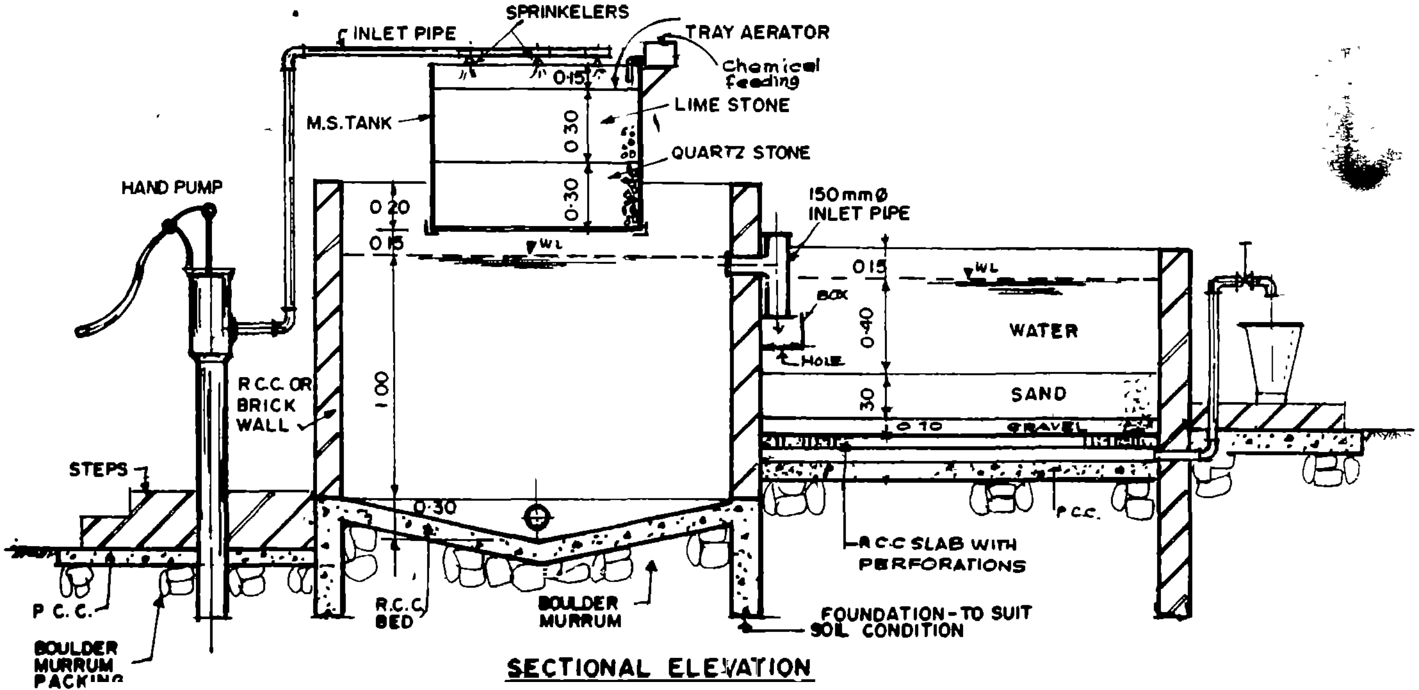
population	design flow
250	10 m^3/day
500	20 m^3/day
1000	40 m^3/day

Inventory of Manpower, Chemicals and Equipment:

This is detailed in Table No.1

Specification of Units

Based on the design considerations enumerated above, the sizes of various units for 250, 500 and 1000 population are given in Table No.2



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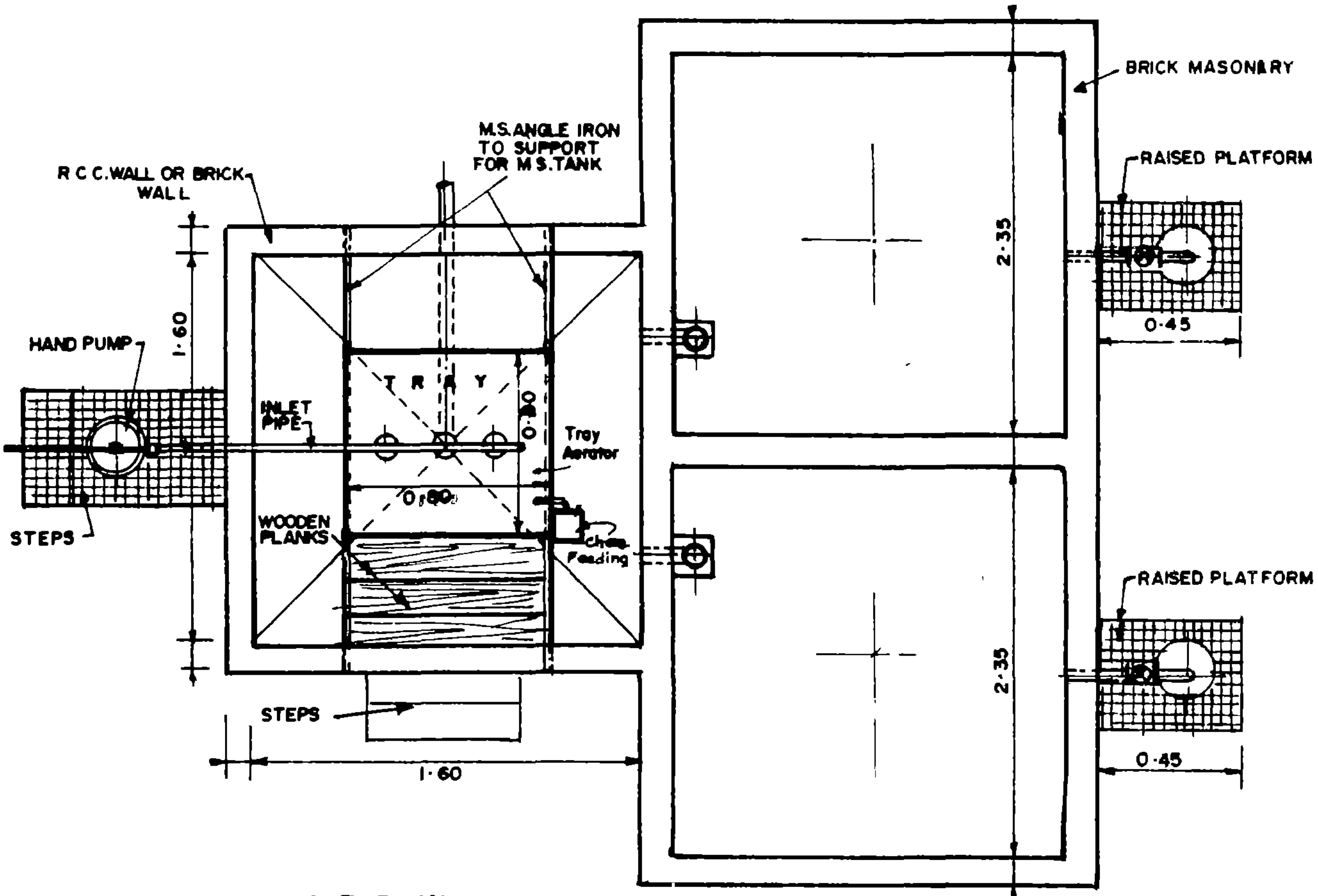


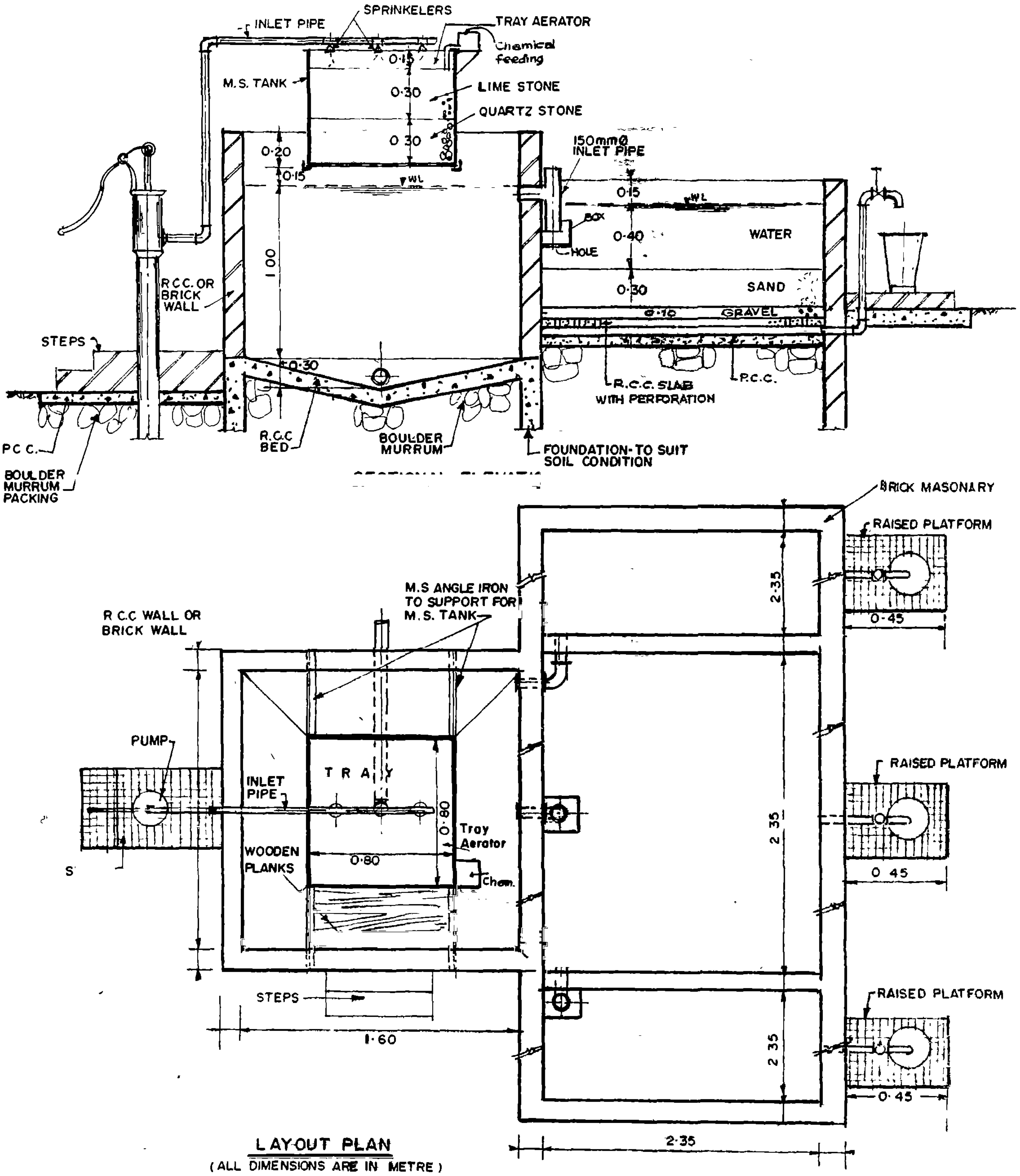
LAY OUT PLAN

(ALL DIMENSIONS ARE IN METRE)

FIG. 8: HAND PUMP WITH IRON REMOVAL UNIT CAP: 500 POPULATION

TABLE 1 : Hand Pump with Iron Removal Plant - Inventory of Manpower, Chemicals, and Equipment

Population	Manpower	Chemicals	Equipment	Remarks
250 Design Flow : 10 m^3/d	Supervisor : 1 @ Rs.800/= p.m. Helper : 1 @ Rs.600/= p.m.	Sodium Carbonate Rs.4,000/= per MT.	**Pipe Size(dia.in mm.)** Sludge Pipeline: 75 Inlet pipe to tray aerator: 100 Distribution 25 Valves: 25, 75, 100mm **4 Nos. each.**	Length as per actual site condition.
500 Design Flow : 20m^3/d	Supervisor : 1 @ Rs.800/-p.m. Helpers : 2 @ Rs.600/= p.m. per head.	Same as above.	**Pipe Size(dia.in mm.)** Sludge Pipeline : 75 Inlet pipe to tray aerator : 100 Distribution : 25 Valves: 25, 75, 100mm **6 Nos. each.**	Same as above.
1000 Design Flow : 40m^3/d	SUPERVISOR : 1 @ Rs.800/= p.m. Helpers : 3 @ Rs.600/= p.m. per head.	Same as above	**Pipe Size(dia. in mm.)** Sludge Pipeline : 150 Inlet pipe to tray aerator : 100 Distribution : 37.5 Valves : 100 & 150 mm. **6 Nos. each.**	Same as above.



LAYOUT PLAN

(ALL DIMENSIONS ARE IN METRE)

FIG.9: HAND PUMP WITH IRON REMOVAL UNIT. CAP: 1000 POPULATION

TABLE 2 : Specifications of Iron Removal Plant (Using Hand Pump)

	Population		
	250	500	1000
Design flow, I/d	10,000	20,000	40,000
1. Tray Aerator			
Number and size	2 Nos. of 600 mm x 600mm	2 Nos. of 800 mm x 800 mm	2 Nos. of 800 mm x 800 mm
Height	0.30 m	0.30 m	0.30 m
Media	Calcite/ Marble/Coke	Calcite/ Marble/Coke	Calcite/ Marble/Coke
Size of media	25-40 mm	25-40 mm	25-40 mm .
2. Sedimentation Tank			
Size	1.3m x 1.3m x 0.75 m.	1.6m x 1.6m x 1.0 m.	2 Nos. 1.6m x 1.6m x 1.0 m.
Detention time	2.5 h	2.5 h	2.5 h
3. Sand Filter			
size	1.6m x 1.6m	2.35m x 2.35m	2.35m x 2.35m
numbers	2 Nos.	2 Nos.	3 Nos.

Estimated Cost for Rural Water Supply Schemes:

The capital cost and O & M cost (Rs/m^3) for the various populations is given in Table No.3

TABLE 3 : Hand Pump with Iron Removal Unit
Cost Estimates for Iron Removal Unit

Population	Design flow m^3/d	Capital Cost		O & M (Running Cost)	
		Total cost, Rs/m^3	Total cost, Rs/m^3	Total cost, Rs/d	Total cost Rs/m^3
250	10	17000	1700	61.60	6.[illegible]
500	20	19700	9850	81.60	4.10
1000	40	22000	5500	112.00	2.30

Note : Capital Cost does not include Land Cost.

O & M Cost includes

i) Manpower
ii) Chemicals-sodium carbonate, bleaching powder
iii) Depreciation @ 5% p.a.
iv) Annual Interest on Capital Investment @ 12% p.a.

Community Water Supply:

When the question of iron removal is under consideration for community water supply, it is important to decide and cover what other treatment of the water, if any, is necessary or desirable. It is, for example, inadvisable to remove the iron yet leave sufficient free carbondioxide to cause corrosion of mains and pipes, and the presence of considerable free carbondioxide and toxic substances is usual in ferruginous waters.

The means by which iron, free carbondioxide and other toxic substances are removed from water in community systems consists substantially of their oxidation and removal of free carbondioxide, followed by precipitation and its separation by sedimentation and/or filtration. Aeration may suffice for the preliminary precipitation but may not be adequate when concentrations are high.

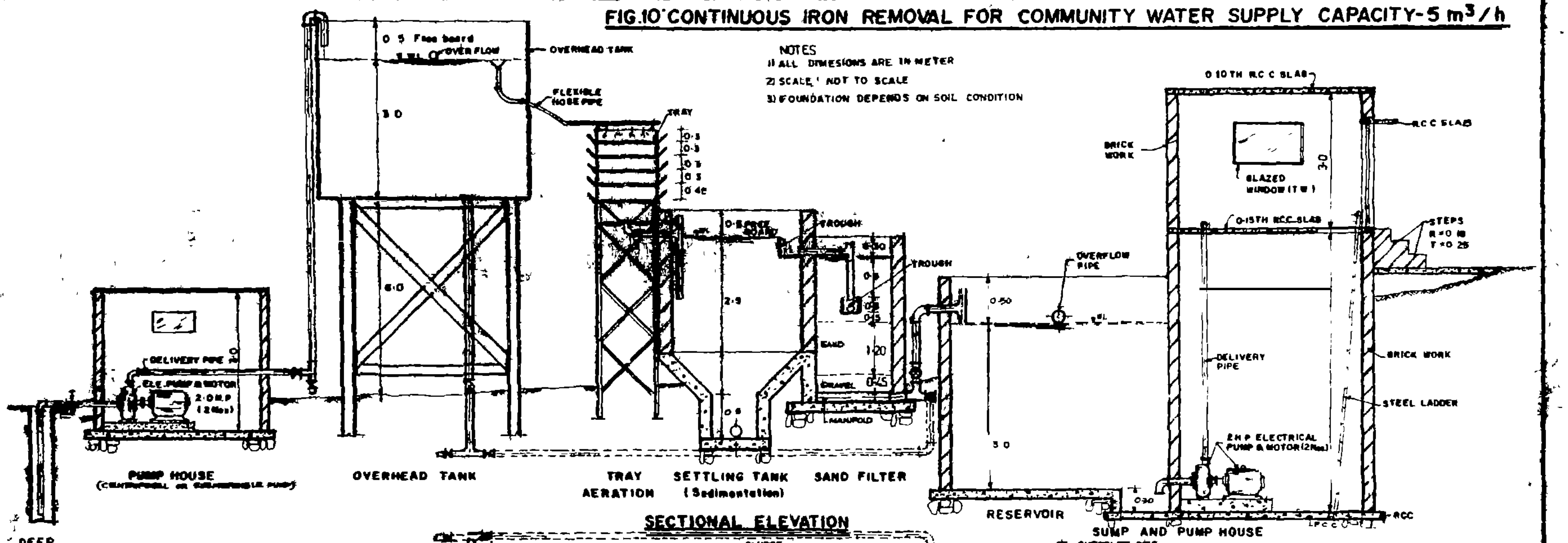
The community water supply scheme makes provision to meet these requirements and comprises of raw water storage tank, cascade tray aerators, chemical dosers, sedimentation basin, filtration and disinfection. The source of raw water is bore wells since shallow dug wells may not contain soluble iron.

Basis of Design:

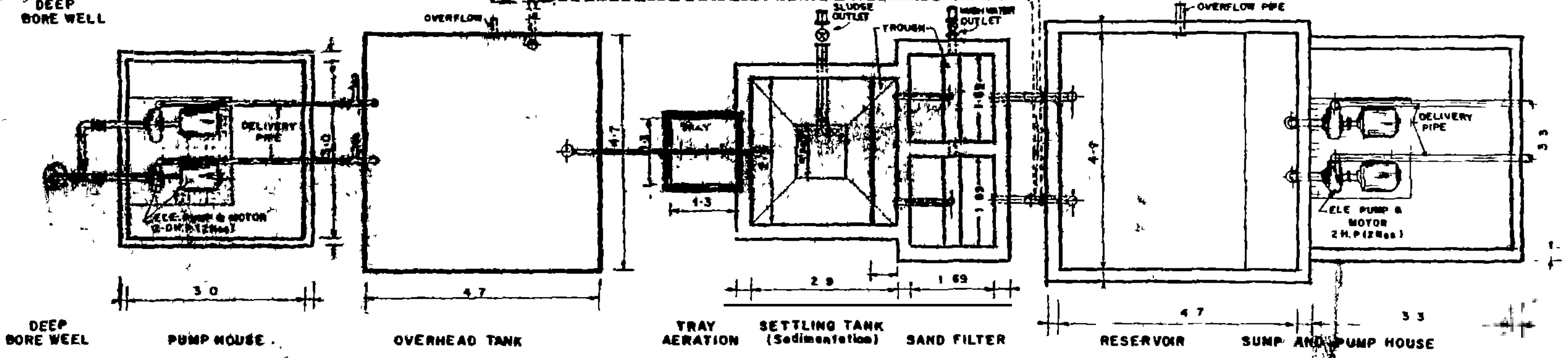
The design of the various units for community have been covered for 5, 10, and 20 m^3/h continuous supply for 16 hours (Figure 10-12).

FIG.10 CONTINUOUS IRON REMOVAL FOR COMMUNITY WATER SUPPLY CAPACITY-5 m^3/h

NOTES
1) ALL DIMESIONS ARE IN METER
2) SCALE : NOT TO SCALE
3) FOUNDATION DEPENDS ON SOIL CONDITION



SECTIONAL ELEVATION



LAYOUT PLAN

Design Criterion:

- Water consumption	40 lpcd
- Tray Aerator	
Spacing of Trays	0.010 $m^3/m/s$
Aeration Rate	1.26 $m^3/m^2/h$
- Sedimentation Basin	
Detention Period	2.5 h
- Sand Filter	
Effective Size	0.6 - 0.8 mm
Uniformity Coefficient	1.3
Sand Depth	1.2 m
Total Head above Sand	1.35 m
Rate of Filtration	4.88 $m^3/m^2/h$
Minimum Backwash Rate	72 $m^3/m^2/h$
Total Head for Filter Wash	12 m
Gravel Depth	0.39 - 0.62 m
Gravel Size	

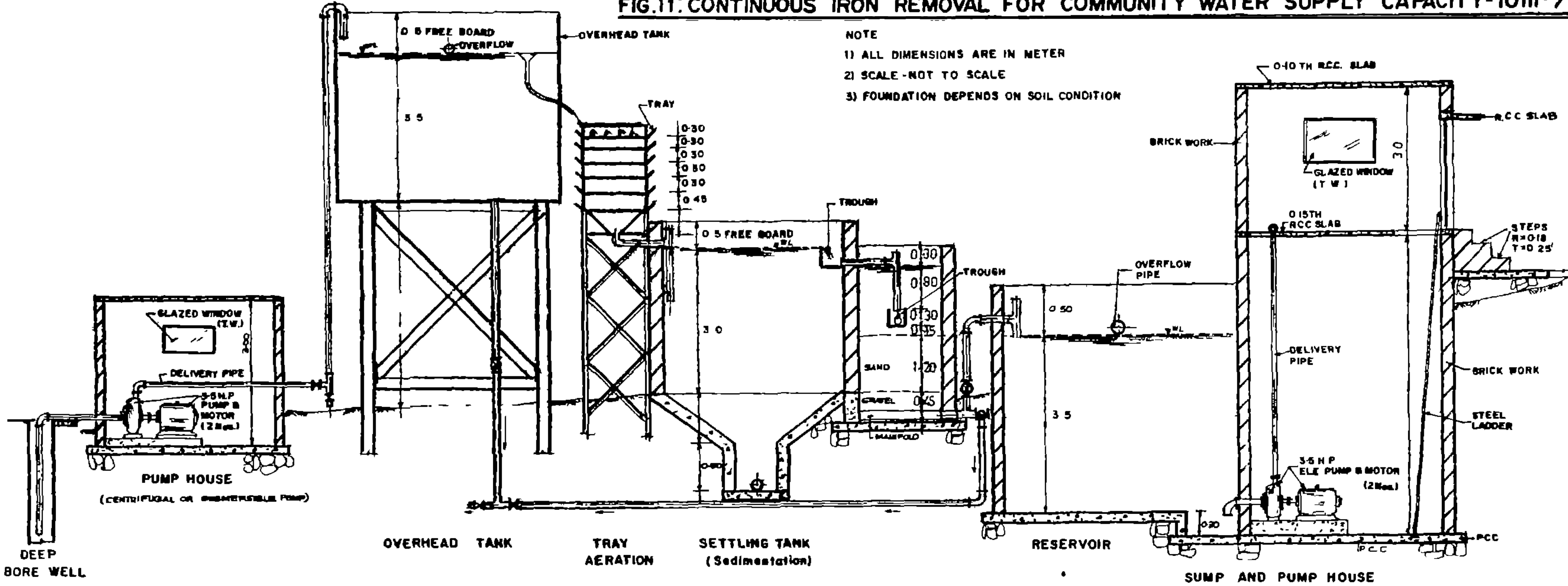
65-38 mm	13-20 cm
38-20 mm	8-13 cm
20-12 mm	8-13 cm
12-5 mm	5-8 cm
5-2 mm	5-8 cm

Basic Considerations:

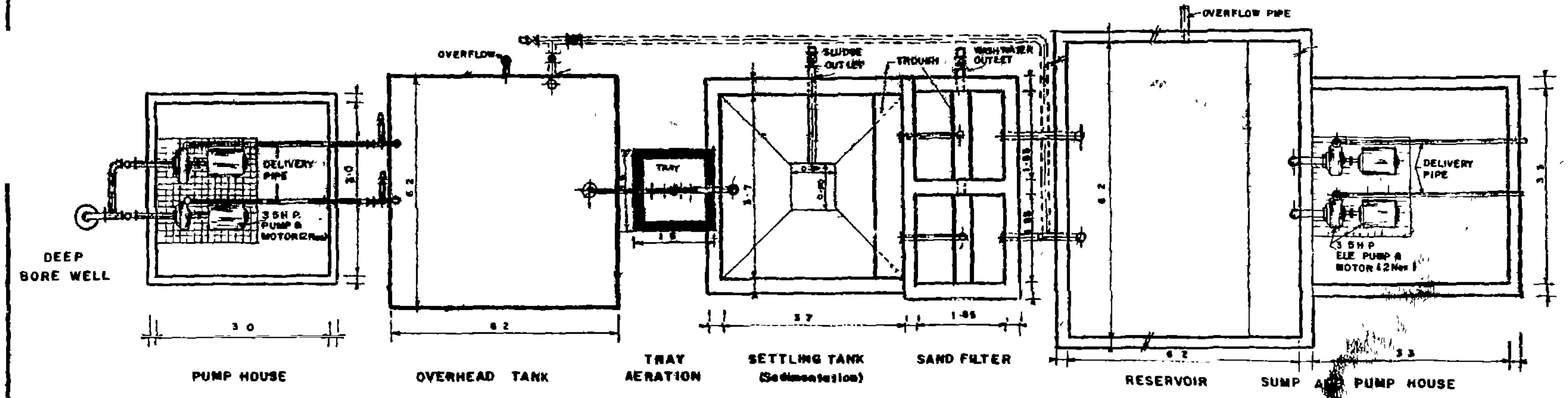
- Schemes have been designed for 5, 10 and 20 m^3/h flow and 10% extra water quantity to cover sedimentation bleed losses and filter back-wash requirements.
- Power shut-downs are frequent and rarely more than two hours supply is available in the morning and evening. Accordingly, raw water pumping hours are assumed to be 2 hours in the morning

FIG.11: CONTINUOUS IRON REMOVAL FOR COMMUNITY WATER SUPPLY CAPACITY-10m^3/h

NOTE
1) ALL DIMENSIONS ARE IN METER
2) SCALE-NOT TO SCALE
3) FOUNDATION DEPENDS ON SOIL CONDITION



SECTIONAL ELEVATION



LAYOUT PLAN

and 2 hours in the evening. During these total 4 hours pumping period, total daily requirements of water are to be pumped to raw water elevated storage tank. The treatment plant has been designed to operate under gravity from the raw water storage tank.

- To avoid extra cost for additional over-head tank for filtered water, it is assumed that the filtered water from the sump-well will be directly pumped for the distribution. The distribution of treated water would follow the same time schedule as is being contemplated for pumping raw water.

- Backwashing of the sand filter would be carried by using raw water from the overhead tank.

Inventory of Manpower, Chemicals and Equipment:

This is detailed in Table No.4

Specifications of Units:

Based on the design considerations indicated above, specifications of various units are detailed in Table No.5

Estimated Cost for Community Water Supply:

For the design flows of 5, 10 and 20 m^3/h, the capital cost and O & M costs are given in Table No.6.

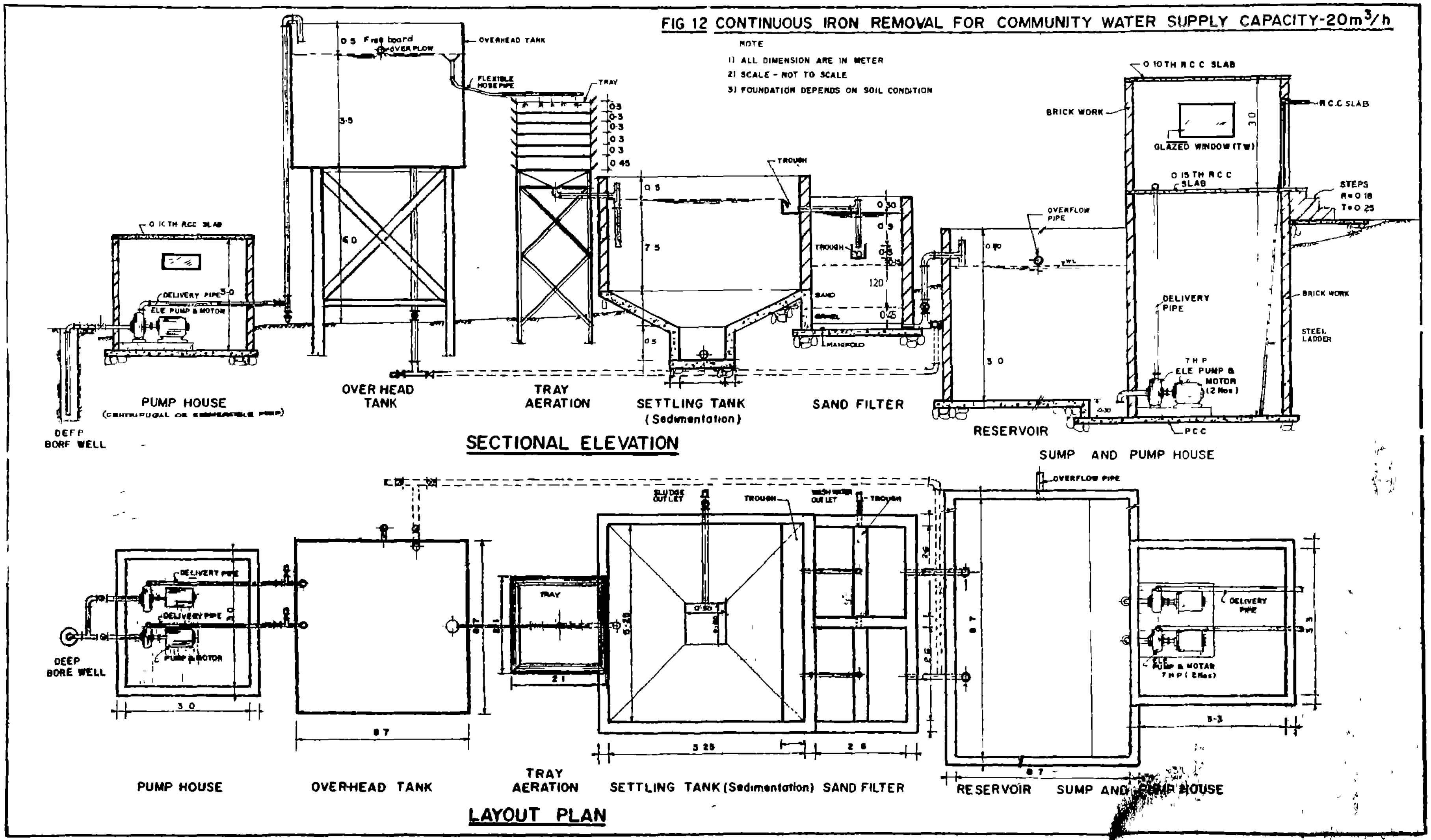


FIG 12 CONTINUOUS IRON REMOVAL FOR COMMUNITY WATER SUPPLY CAPACITY-20m^3/h

NOTE

1) ALL DIMENSION ARE IN METER
2) SCALE - NOT TO SCALE
3) FOUNDATION DEPENDS ON SOIL CONDITION

SECTIONAL ELEVATION

LAYOUT PLAN

TABLE 4 : Continuous Iron Removal System for Community Water Supply - Inventory of Manpower, Chemicals and Equipment

Design Flow	Manpower	Chemicals	Equipment	Remarks
5 m^3/h	Supervisor: 1 @ Rs.1000/= p.m Chemist: 1 @ Rs.800/= p.m Helpers: 4 @ Rs.600/= p.m per head.	**Cost of -** Sodium Carbonate:Rs.4000/= per MT. Power:Re.0.35 per Unit Bleaching Powder:Rs.1000/= Per MT.	**Pumps:** 2 HP - 2 Nos. for raw water. 2 HP - 2 Nos. for treated water. **Valves:** 50mm dia., 150mm dia. **Pipe Size:**(diameter) Sludge Pipeline:150mm Overflow Pipe: 150mm Distribution: 150mm	Against minimum head of 10m raw water pumping. Length of pipes will be as per actual site conditions
10 m^3/h	Jr. Engr. : 1 @ Rs.2000/= p.m Supervisor: 1 @ Rs.1000/= p.m Chemist: 1 @ Rs.800/= p.m Helpers: 6 @ Rs.600/= p.m per head.	**Cost of -** Sodium Carbonate:Rs.4000/= per MT. Power:Re.0.35 per Unit Bleaching Power:Rs.1000/= Per MT.	**Pumps :** 3.5 HP - 2 Nos. for raw water. 3.5 HP - 2 Nos. for treated water. **Valves:** 75mm dia., 150mm dia. **Pipe Size:**(diameter) Sludge Pipeline:150mm Overflow Pipe: 150mm Distribution: 75mm	Same as above. Same as above.
20 m^3/h	Sr. Engr. : 1 @ Rs.3000/= p.m Jr. Engr. 1 @ Rs.2000/= p.m Supervisor : 1 @ Rs.1000/= p.m Chemist: 1 @ Rs.800/= p.m Helpers: 6 @ Rs.600/= p.m per head.	Same as above.	**Pumps :** 7 HP - 2 Nos. for raw water. 7 HP - 2 Nos. for treated water. **Valves:** 75mm dia., 100mm dia. and 150 mm dia. **Pipe Size:**(diameter) Sludge Pipeline:150mm Overflow Pipe: 150mm Distribution: 100mm	Same as above. Same as above.

TABLE 5 : Design Specifications for Continuous Iron Removal Unit for Community Water Supply

Design capacity, m^3/h	5	10	20
Raw water Pump, hp	2.0, 2 Nos	3.4, 2 Nos	7,2 Nos
Overhead Reservoir			
capacity m^3	66	132	264
size	4.7m x 4.7m x 3 m	6.2m x 6.2m x 3.5m	8.7m x 8.7m x 3.5m
Tray Aerators,			
No.of Trays	4	5	6
collecting trough	1	1	1
Tray size	1.3m x 1.3m	1.6m x 1.6m	2,1m x 2.1m
Height of each tray	0.3 m	0.3 m	0.3 m
Sedimentation Tank			
size	2.9m x 2.9m x 2.5m	3.7 x 3.7m x 3.0m	5.25m x 5.25m x 3.0m
Sand filter			
size	1.69m x1.69m	1.85m x 1.85m, 2 Nos	2.6m x 2.6, 2 Nos
Clear Water storage Tank	4.7m x 4.7m x 3m	6.2 m x 6.2m x 3.5m	8.7m x 8.7m x 3.5m

TABLE 6: Continuous Iron Removal System for Community Water Supply

Cost Estimates for Iron Removal Unit

Design flow	Capital Cost		O and M Running Cost	
	Total Cost Rs./day	Total Cost Rs./m^3	Total Cost Rs./day	Total Cost Rs./m
5 m^3/h	95000	792	235.60	2.35
10 m^3/h	133000	554	397.00	1.65
20 m^3/h	215000	448	608.00	1.26

O and M Cost includes :

1) Manpower
2) Power - 0.35 kwh
3) Chemicals - Sodium carbonate dose 50 mg/1 and bleaching powder - 1-2 mg/1
4) Depreciation at 5% p.a.
5) Annual interest on capital investment - @ 12% p.a.

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