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SUPPLY OF DRINKING WATER TO RURAL POPULATION

BY

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(1) Sources for the supply of drinking water

While there is nothing wrong with the use of groundwater as the source for drinking water provided it can be established that this source is going to be adequate, both in quality and quantity, on long term basis and that there are definite indications of its being constantly replenished from the surface, there appears to be rather an over simplified general tendency among some of our Engineers to go for the groundwater in any case even in areas not so well known for the adequacy of supply of water for drinking purposes from the existing wells or boreholes because of the sub-surface strata. In some instances heavy investment is made on the groundwater investigation only to find that the supply from the ground is going to be too meagre to meet the present and future demand of water and that the same investment could have been adequate enough to develop the surface water source as far as the source is concerned. This happens because the water Engineers quite often assume that the alternate surface water source would be very expensive from water treatment point of view presumably taking into account the heavy capital investments in foreign exchange on the importation of Water Treatment Plant employed for purification of surface water.

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The purpose of this paper is to consider the surface water as the alternate source as majority of the areas in Pakistan have adequate availability of surface water whereas in some of these areas groundwater is either inadequate in quality as well as quantity or is difficult and uneconomical from "extraction" point of view. The paper discusses the economy of the treatment of surface water along with its universal availability in practically all the areas of the country and proposes some cheap and indigenous methods of surface water treatment, already tried in countries of the third world with similar socio-economic factors involving equipment which could be locally manufactured. Contrary to what has been the general belief so far about the surface water treatment, some extremely economical methods have been employed in certain developing countries in Africa where the surface water had to be preferred over the groundwater mainly for the reason of its adequacy in the long run allowing thereby rapid developments in both urban and semi urban areas of these countries.

(2) Area - Categories

The whole country can be divided into the following area-categories for the purpose of water resources for drinking water and water supply problems need to be tackled in these areas in the order of the priority as indicated herebelow :-

(i) Areas where no perennial streams or rivers are available and dependence is solely on rain-water which falls for only a few days in a year. Rain water in these areas can be conserved in natural depressions or ponds and artificial lakes created by constructing small dams over hill torrents. The water thus impounded could be used throughout the year after necessary purification.

(ii) Areas where groundwater is saline but the surface water is available from perennial streams or rivers including irrigation canals distributaries and water courses.

In this case all that is required is to purify water and supply it to the rural areas.

(iii) Areas where abundant quantity of groundwater is available and only extraction and distribution needs to be done.

The only other category of the area would be with no groundwater and no rainfall at all and also where no perennial stream or irrigation system exists. It is assumed that habitation at such places would almost be negligible as nothing else would exist for the sustenance of life and hence can be excluded from this discussion.

The problems of rural water supply in particular and municipal water supply in general, can be effectively tackled only if scientific methods are employed to determine the suitability and adequacy of any of the two sources of water. The outright rejection of surface water from the treatment and purification points of view without evaluating the potentialities of the groundwater and economics of its extraction and distribution in a particular area would not be much justified as can be seen from this paper. Surface waters on the other hand, are abundantly available from impounded and perennial sources and in case of areas where the replenishment of groundwater from surface cannot be established, any attempt to exploit the ground water source would prove to be extremely futile, as heavy investment made for the extraction and distribution of water from a source which would deplete in a matter of few years, would be a wastage of national financial resources. In case of ground water equally important factor is also that of the "transmissibility" of the acquifer from where the water is to be extracted, as in many cases the water is there in the acquifer but it cannot be extracted at any economical rate without drilling a number of boreholes.

In view of the fact that surface water as a source is annually replenished by either the direct rainfall or the rainfall occurring somewhere in the watershed and flowing down as surface run-off to the point of extraction and utilization. The dependability of surface water as a source can be established relatively with more precision as compared with the ground water for the same amount of money invested on investigation etc.

The ground water is often found to have picked up all sorts of dissolved salts from the strata, it passes through during its percolation journey from surface to acquifer and cannot be used without prior treatment to attain the International Public Health Standard. Also the ground water acquifers under heavily populated locations are often found to be heavily polluted. PH correction and disinfection has, therefore, to be

applied to a number of ground waters in any case and as such the surface waters, as compared with ground waters, would need only the clarification in addition to these two processes namely the pH correction and disinfection.

(3) Surface Water

The surface waters are quite prone to pick up the foreign matter in dissolved or suspended form, the quantity of which vary in accordance with the erosion taking place in the catchment areas supplying the surface water. In all tropical and semi-arid climate the rainfall usually occurs after a period of dry-spell when the vegetation cover in the catchment is all decayed and first rain can cause heavy erosion and pick up the decayed vegetable matter as trash which creates heavy colour because of the dissolved organic matter. Heavy erosion on the other hand causes excessive turbidity with the solid suspension reaching 2000 to 3000 P.P.M. mark quite often. The first rain can thus always erode the catchment and produce excessive colour and turbidity in water in addition to the contamination caused by washing down of the land surface in the catchments due to heavy down-pour.

While the rainfall causes these physical changes in the surface water after every rain, it also creates changes in the chemical quality and pH of raw water varies considerably throughout the year. Figure-I indicates the variation in pH of raw water for a complete typical year in such a climate.

(4) Treatment of Surface Water

4.1 Clarification

For converting the surface raw water into potable water the first and foremost vital step is the "clarification" of raw water which actually means solid/liquid separation by a chemical process known also as coagulation and flocculation and then removing the solids in the form of "sludge" and decanting off the clear water also known as "settled water". The solid liquid separation takes place by the addition of a coagulant like "alum" which causes a chemical reaction with the natural alkalinity present in the raw water and the resultant flocs are removed by an engineering process hitherto known as "sedimentation". For proper coagulation it has been established in the context of surface water obtained in an area such as Pakistan, that

pH of flocculated water must be in the range of 6.0 to 6.5 for an efficient solid/liquid separation which means the flocs formed at this pH should be heavy and tough.

The coagulated water needs to be passed on to a structure which should be so shaped that it allows the "aging of flocs" in water to make these flocs very tough so that they do'nt break due to any turbulent action of water during the period that chemically coagulated water flows to the clarifier. The basic design criteria of a clarifier is therefore, to provide smooth inflow and outflow of the flocculated and settled water respectively in order to eliminate the chances of turbulence during the removal of the accumulated sludge from the clarifier - a process also known as "desluding". The flocculated water should on the other hand have enough time to pass through the clarifier prior to its conversion as supernetant, settled or clarified water. It is actually this time factor which determines the size, cost and ease in operation for handling a particular volume of flow through the clarifier. Places, where land cost is very high, this time factor also known as "detention time" is minimised by providing the complete and efficient coagulation with the shape of the clarifier structure so designed that it takes minimum space. On the other hand places where land cost is not a big problem higher magnitude of this "time factor" can be tolerated which results in the reduction of the quantity of chemical used for efficient clarification. The clarifier structure may also be constructed cheaply in this case but true hydraulic shape for proper settling may be maintained. Figure-2 indicates a typically cheap type of clarifier which has been found to be working extremely efficiently in tropical countries both for settlement of flocs as well as "desludging". Detention time would determine the size of such clarifier.

Figure-I also shows the coagulant dose and the resultant pH of the flocculated water throughout a typical year. Since the pH for proper flocculation is already described as 6.0 to 6.5, lime or any other alkali has to be added in addition to alum during the height of the Rainy Season to get the pH of flocculated water in the proper range as is the case with Fig.I which is applicable to areas where the rainy season extends from April to September. The pH of the floc water otherwise tends to be depressed to the values less than 5.0 because of the excessive use of alum to create the chemical reaction with the amount of suspension present in raw water during rainy season.

In view of the foregoing, this vital treatment step in the treatment of surface water would boil down to the following facts :-

(i) Proper coagulants must be applied to create the efficient flocs for settlement so that these flocs don't break during the process of clarification.

(ii) Depending upon the availability of space, the quantities of chemicals used can be so adjusted along with the annual capital value of the clarifier structure itself so that cheapest alternative for clarification of water can be determined.

4.2 Filtration

Many of the surface waters are expected to be clarified by the process already described and no colour or suspension in any form, whatsoever, shall be present in the settled water, and such clarified water can straightaway be disinfected with chloride of lime or chlorine before supplying to the people. This application can most econimically be made to a number of rural areas where the people at the moment have to rely on the contaminated streams, rivers and ponds for the supply of their drinking water.

In large urban towns or semi urban areas where the quality of water has to be of much higher standard, filtration would be necessary to remove the residual solids or colour if any, in the settled water. In this case also the cost of land counts a lot as, if there are no restrictions of space, the slow sand filtration with indigenous type of under-drainage system, can be applied very effectively. The under-drainage system over which the filter media are placed is shown in Fig. 3 and filter shells plus main collecting channel can be constructed in bricks or concrete whichsoever could be cheaper. However, where cost of land is high then rapid gravity filtration is applied in which the filter "modules" and "slow start arrangements" can all be fabricated locally along with the wash water arrangements. The rapid gravity filtration shall thus apply only to large towns where the cost of land is excessive.

4.3 pH Correction

If the settled water is found to be having pH value below 7 in case of rural areas, and 7.6 in case of urban areas, the pH needs to be corrected with lime or soda-ash.

4.4 Dis-infection

Dis-infection can be carried out either by means of chloride of lime which gives only one third chlorine by its weight or by liquid chlorine. While the arrangements for mixing and dosing of the former can be fabricated locally the latter may have to be specifically imported until such time that this could be manufactured by the local industry.

4.5 Chemical Dosers

For chemical dosing, displacement dosers, as shown in Fig. 4, which work on the venturi high and low pressure principles can be fabricated locally and dosing applied in places where the flow is under pressure. Otherwise the chemical drip-dosers of the float type as shown in Fig.5 can be fabricated. The principle being that the rate of dosing should not be affected by the level of the solution in the stock solution tank. The usual problem with the Displacement Dosers, as shown in Figure-4, is that over a period when water from the high pressure side of venturi flows through the solution to the low pressure point of venturi, the strength of solution drops and a constant checking is necessary on the effect of the chemical dosing. In order to eliminate this difficulty Displacement Doser of the type as shown in Figure-6 can be employed in which the solution is kept in-side a polythene sack which is squeezed by the high surrounding pressure to allow the solution to flow to the Low Pressure point on venturi. The solution does not mix with the high pressure water and the arrangements have been found to be working very satisfactory.

For the correction of pH alkaline solution such as Soda Ash if found expensive can be replaced with lime but the problem of dosing of lime is more complex because of the insolubility of lime in water and as such lime saturater as shown in Fig.7 can be fabricated to dose the lime water to the water under free or pressure flow.

The foregoing chemical dosing arrangement can all be manufactured in Pakistan as these have already been fabricated and used in countries where similar socio-economic conditions have been prevailing and aim has been to provide the water to rural masses in the cheapest and simplest form.

For a more sophisticated plant, the usual metri-pumps which work on variable stroke reciprocating principle, can be used and until

such time that these can be manufactured locally, they will have to be imported.

(5) Cost Analysis

Figure-8 is a typical layout of a Water Treatment Plant for rural communities, in which any particular process could be by-passed depending upon the quality of water required for potable purpose. An attempt has been made to analyse the cost of providing treated water through such a plant for rural and semi urban communities of capacity varying from 100,000 gallons per day to 2 million gallons per day for population varying from 5000 to 60,000, in Table "A". Table "A" indicates the cost of constructing and running a complete water supply scheme comprising of raw water extraction, raw water pumping, treatment plant, chemicals, highlift pumping, transmission and distribution system. The table also incorporates the elements of amortised value of the plant, equipment and structure @ 8% interest charged over the useful life of 35 years.

The analysis indicates that cost per thousand gallons of fully treated water goes down, with the increase in the capacity of a plant and the figures shown in this table are extremely cheap when compared with the cost of production of water in places other than Pakistan indicating thereby that this concept of rural water supply scheme is extremely economical. Even the cost per capita (initial investment) and the cost per capita per annum is not unusual when compared with WHO figures given for many other countries. The treatment cost alone for 1,000 gallons of water as given in column 9 of this table is also extremely cheap.

In working out these costs following parameters have been used:-

(i)	Cost of raw water extraction	Rs.50,000 to 100,000.
(ii)	Raw water pumping head	60 ft.
(iii)	Length of raw water mains	Half a mile.
(iv)	Structure of clarifier	Constructed in Class A concrete
(v)	Filter shells	Constructed in Class A concrete with top class filter media.
(vi)	Treated water balancing tank to have 2.5 hours pumping capacity as the waterworks storage.	

(vii)	Head of Highlift pumps	110 ft.
(viii)	Length of transmission line	one mile
(ix)	Cost of distribution system	Rs.50.00 per capita for rural areas and Rs.80.00 per capita for semi-urban areas.
(x)	Rate of interest	8%

(xi) Useful life of the scheme as a whole 35 years.

(xii) Transmission and distribution lines of AC and pipes within the water works to be in cast iron.

(xiii) Alum dose 10 P.P.M. for rural and 40 P.P.M. for semi urban areas.

(xiv) Lime 5 P.P.M. for rural and 10 P.P.M. for semi urban areas.

(xv) Chloride of lime 3 P.P.M.

Under these circumstances, it is obvious that reduction in any of these parameters would correspondingly reduce the cost of the scheme. Extreme cases have been considered for the purpose of pricing a scheme for incorporation in Table "A" hence chances are, that cost per capita would further come down.

(6) Conclusions

(i) In order to supply water to the maximum number of rural citizens in Pakistan, it is absolutely necessary to reduce the cost of treatment of water and save at the same time the hard-earned foreign exchange, as this would facilitate providing amenity to more people.

(ii) The concept shown here is already functioning very effectively in West Africa having similar socio-economic conditions and it would have characteristics of being indigenous in Pakistan because of the local fabrication of chemical dosers etc.

(iii) In order to reduce the capital cost it may be necessary to group various rural communities and build one central waterworks which would be a cheaper proposition within the distance as included in the cost element in the scheme. The table indicates that the investment cost does not vary prorata with the population for rural areas and larger scheme cost relatively less.

Figure 9 shows the variation in cost per capita per annum versus the increase in population. For rural areas this cost per capita per annum goes down for larger sizes of plant whereas for semi-urban or urban areas it behaves differently and cost per capita per annum goes up with the increase in the size of plant. The border line is a population of 20,000 upto which the scheme shall be considered rural and above this it would be urban or semi urban.

(iv) In order to provide a basic necessity of life to the people in rural areas Federal Government will have to come to the aid of the Provincial Governments by way of providing men and materials through a Federal Ministry which should take care of all activities pertaining to the establishment of rural water supply systems for subsequent handing over to the Provincial Governments for the purpose of operation and maintenance either directly or through agencies involved in the coordination of community self help efforts.

R E F E R E N C E S

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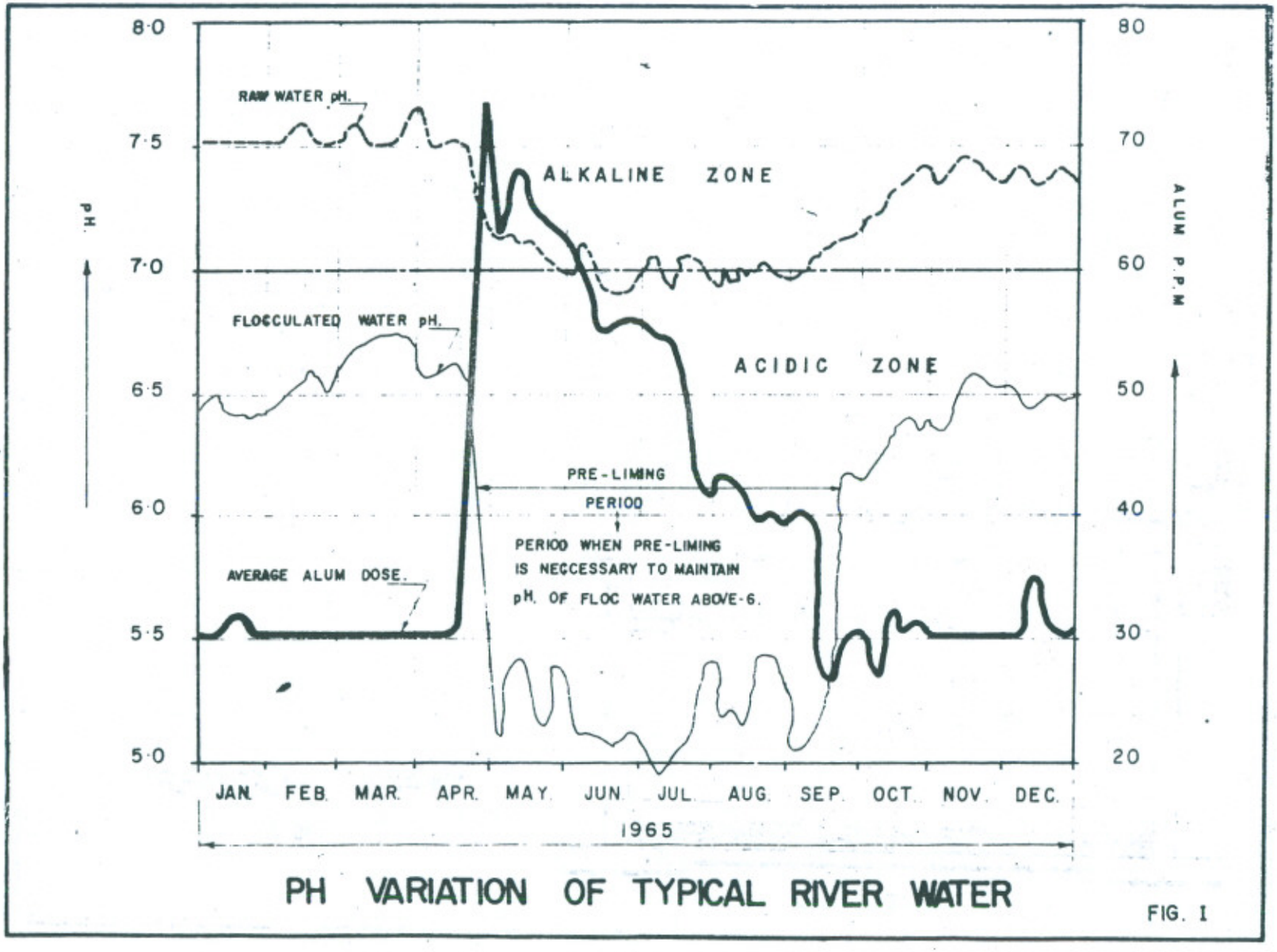
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TABLE "A"

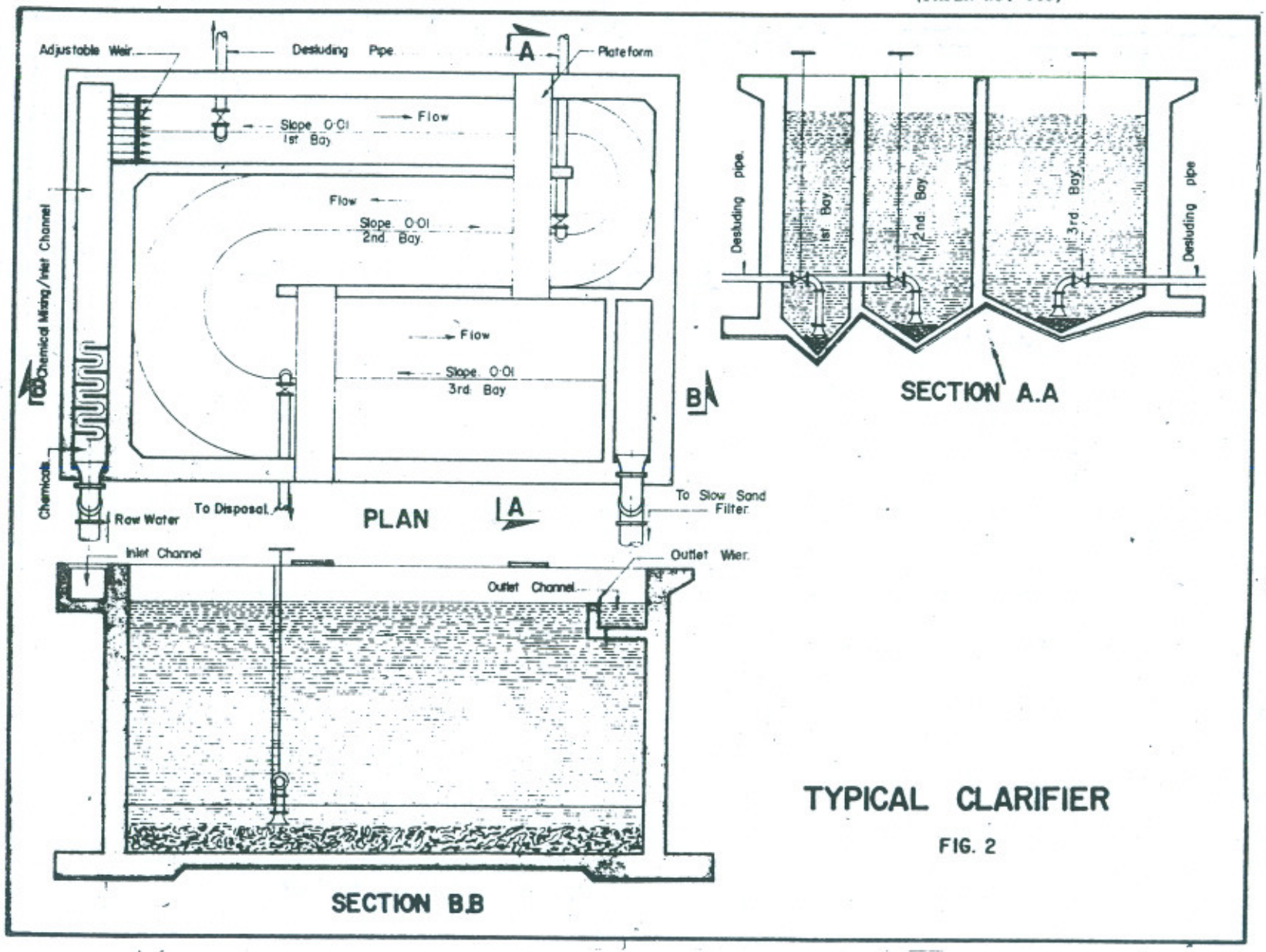
COST ANALYSIS OF WATER SUPPLY SCHEMES:

Community	Capacity of Scheme	Population	Demand per capita	Estimated capital cost (initial investment). Rs.	Amortised cost	Annual operation & maintenance cost	Cost/ 1000 gallons	Treatment cost per 1000 gallons	Cost per capita (initial investment	Cost per capita per annum	Remarks
1	2	3	4	5*	6	7**	8	9	10	11	12
	100,000	5,000	20	7,77,840	66,739	48,741	3.16	0.93	155.6	23.0	*This cost includes Raw Water Extraction, Pumping, Treatment High lift Pumping, Transmission and distribution for the community. **This cost includes Electricity, Chemicals and manpower.
	200,000 gpd	10,000	20	13,64,110	1,17,045	83,615	2.74	0.87	136.4	20.06	
	300,000	15,000	20	20,12,575	1,72,680	116,230	2.60	0.83	134	19.26	
	400,000	20,000	20	25,55,000	2,19,219	150,260	2.53	0.82	127.75	18.47	
	1 MGD	33,300	30	51,44,384	4,41,388	449,041	2.44	1.07	153.6	26.70	
	1.5 MGD	50,000	30	81,62,448	7,00,388	647,068	2.46	1.06	163.2	26.91	
	2 MGD	66,600	30	107,63,947	9,23,525	916,184	2.52	1.12	161.6	27.60	



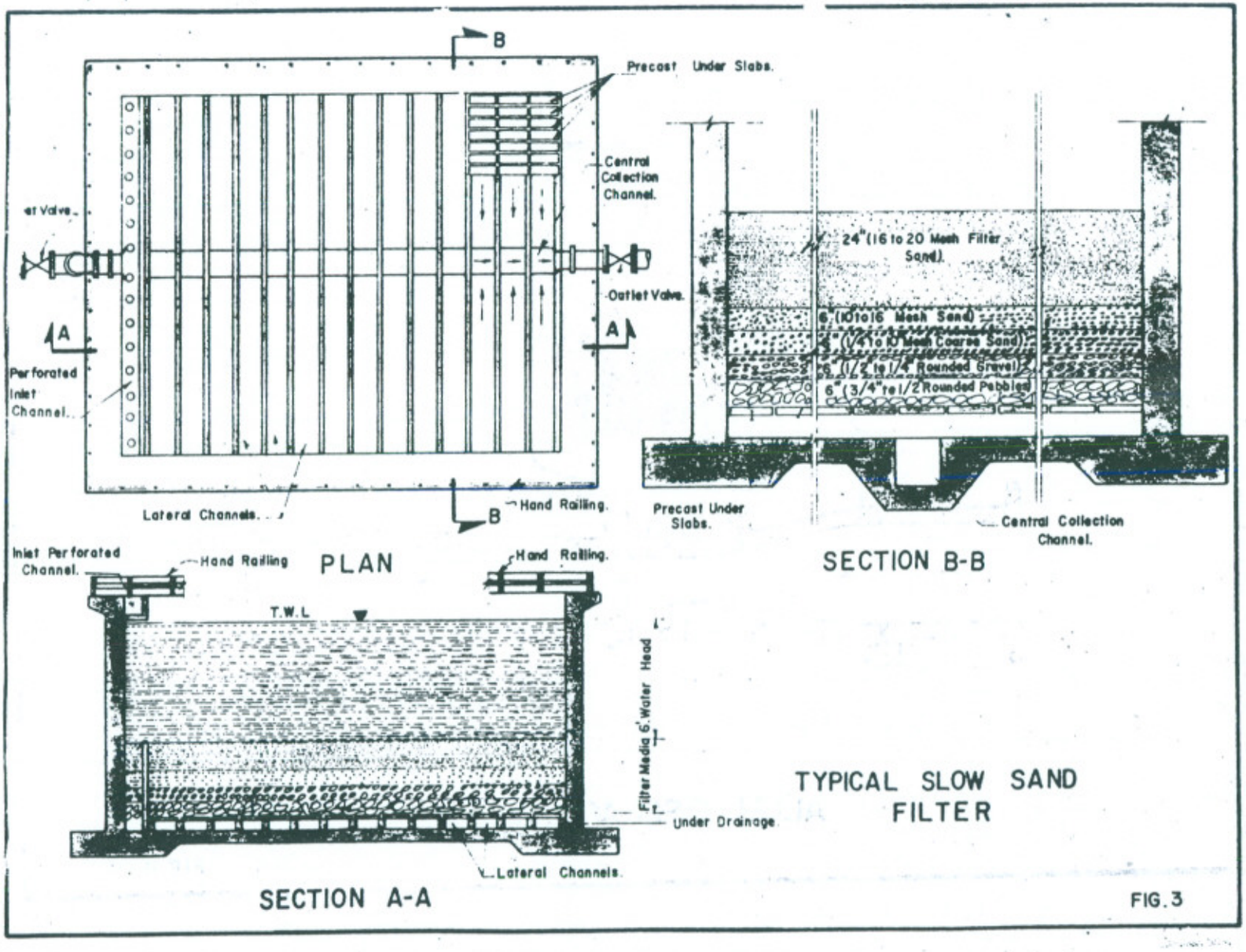
PH VARIATION OF TYPICAL RIVER WATER

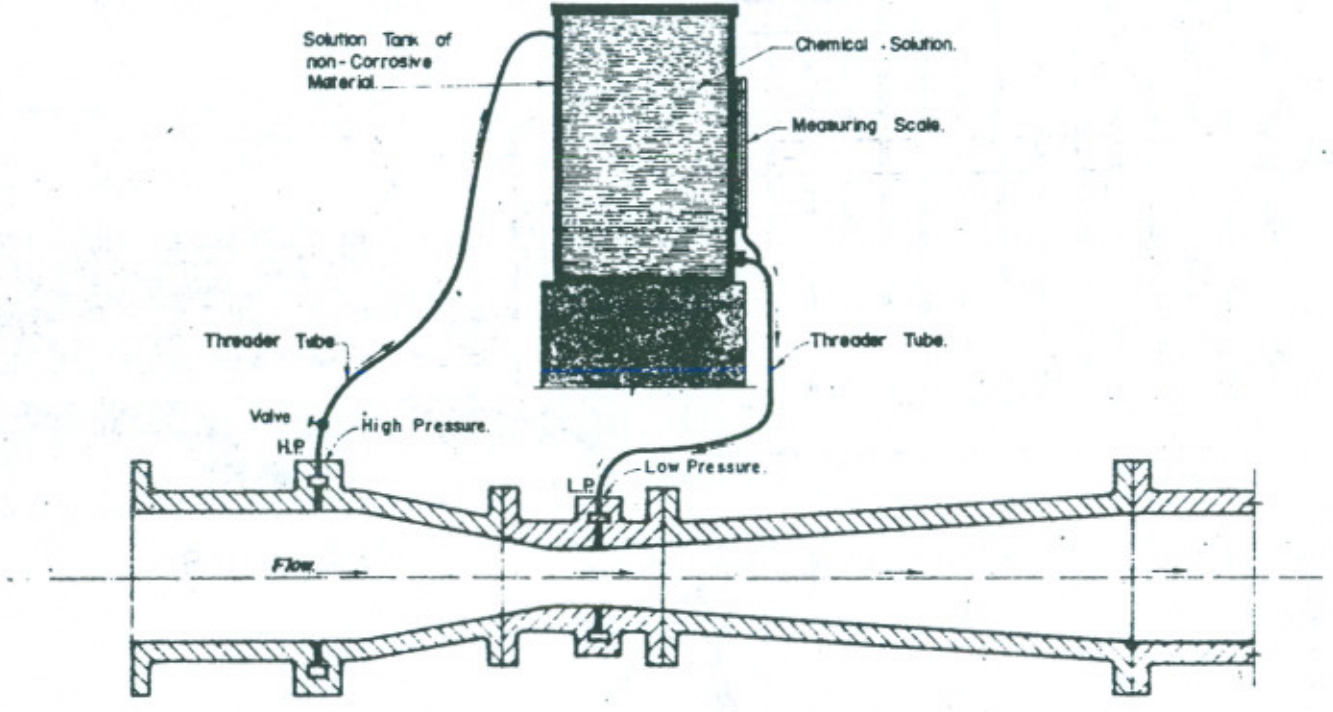
FIG. I



TYPICAL CLARIFIER

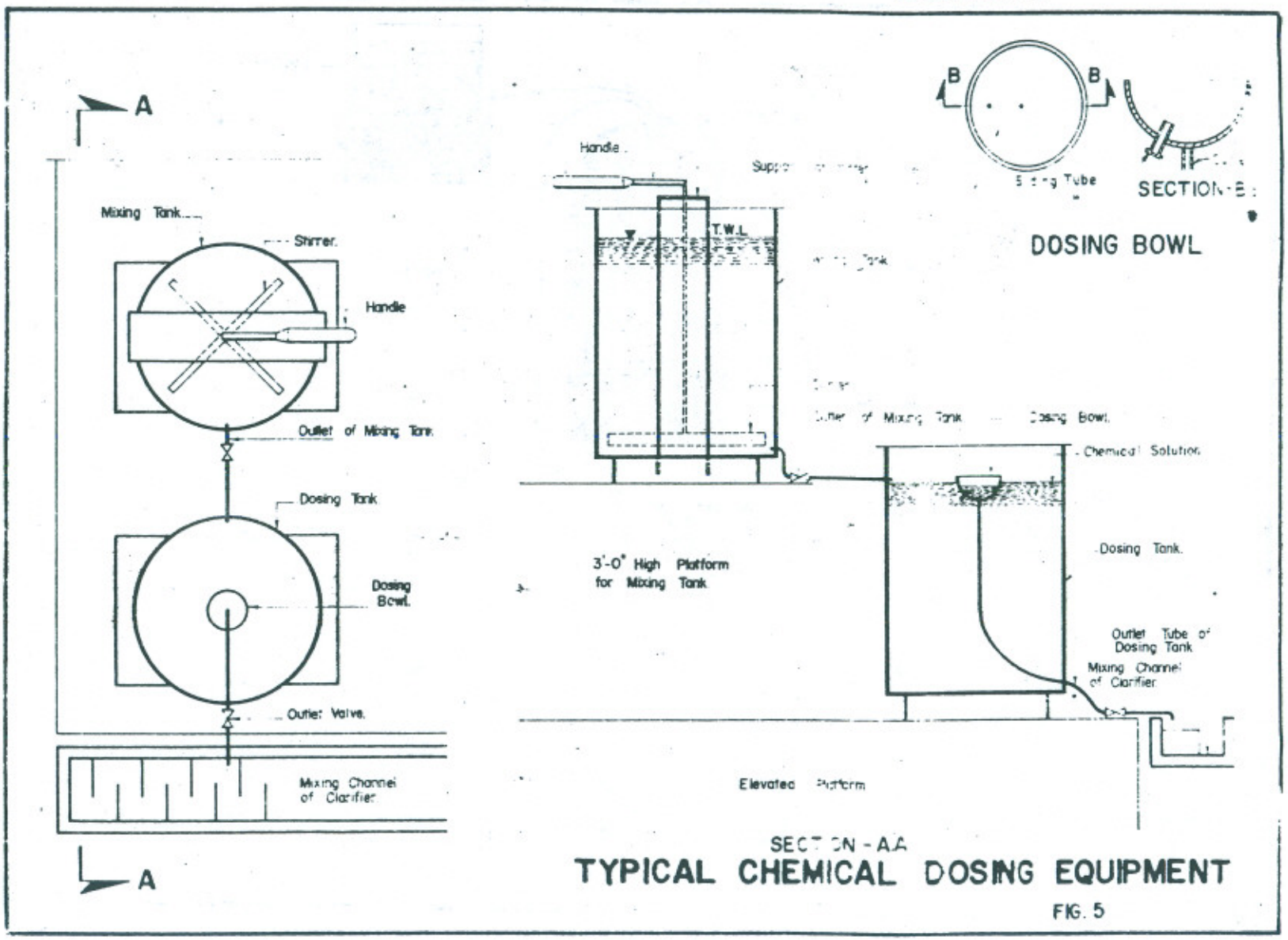
FIG. 2


B
Precast Under Slabs.
Central Collection Channel.
et Valve.
Outlet Valve.
A
A
Perforated Inlet Channel.
Lateral Channels.
B
Hand Railing.
PLAN
24" (16 to 20 Mesh Filter Sand).
6" (10 to 16 Mesh Sand)
4" (1/4 to 10 Mesh Coarse Sand)
6" (1/2 to 1/4 Rounded Gravel)
6" (3/4" to 1/2 Rounded Pebbles)
Precast Under Slabs.
Central Collection Channel.
SECTION B-B
Inlet Perforated Channel.
Hand Railing
Hand Railing.
T.W.L
Filter Media 6' Water Head
Under Drainage
Lateral Channels.
SECTION A-A
TYPICAL SLOW SAND FILTER
FIG. 3



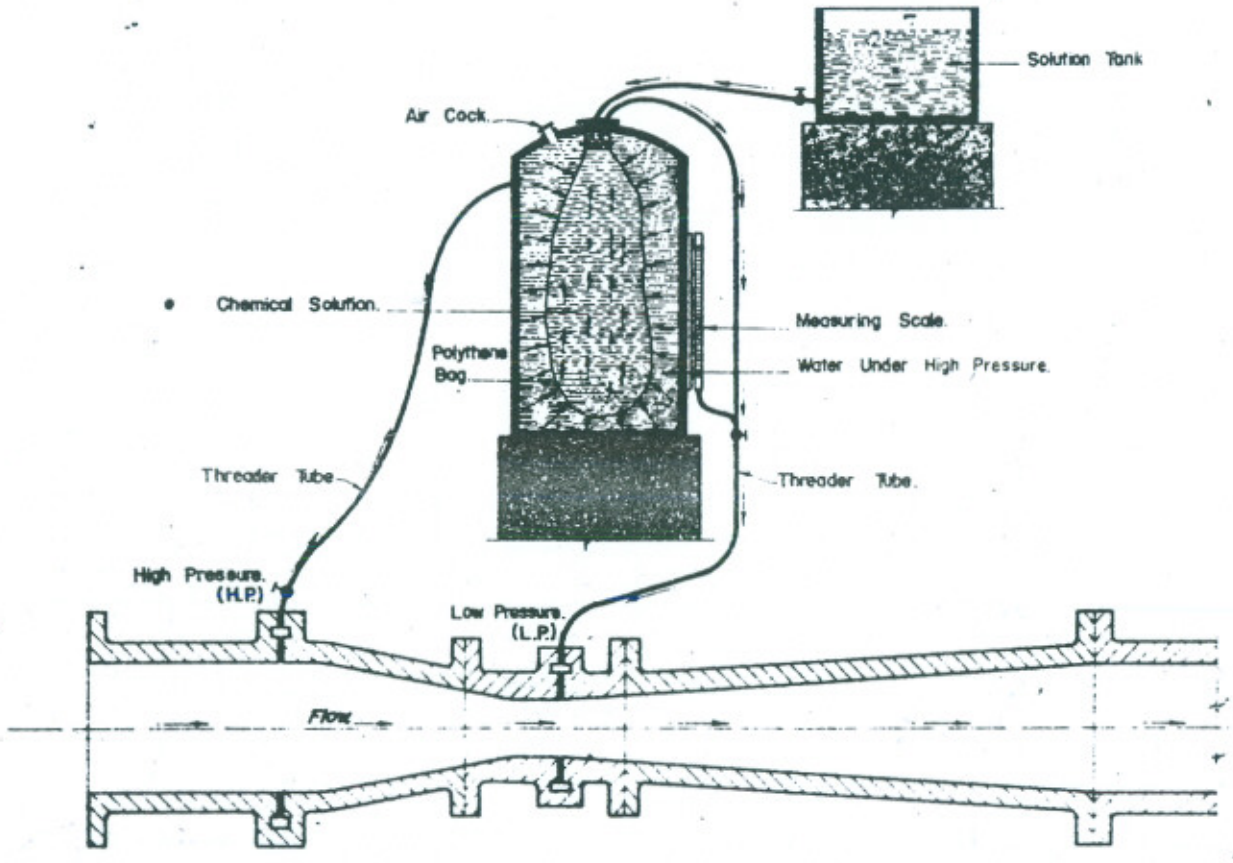
ALUM DISPLACEMENT DOSER

FIG. 4



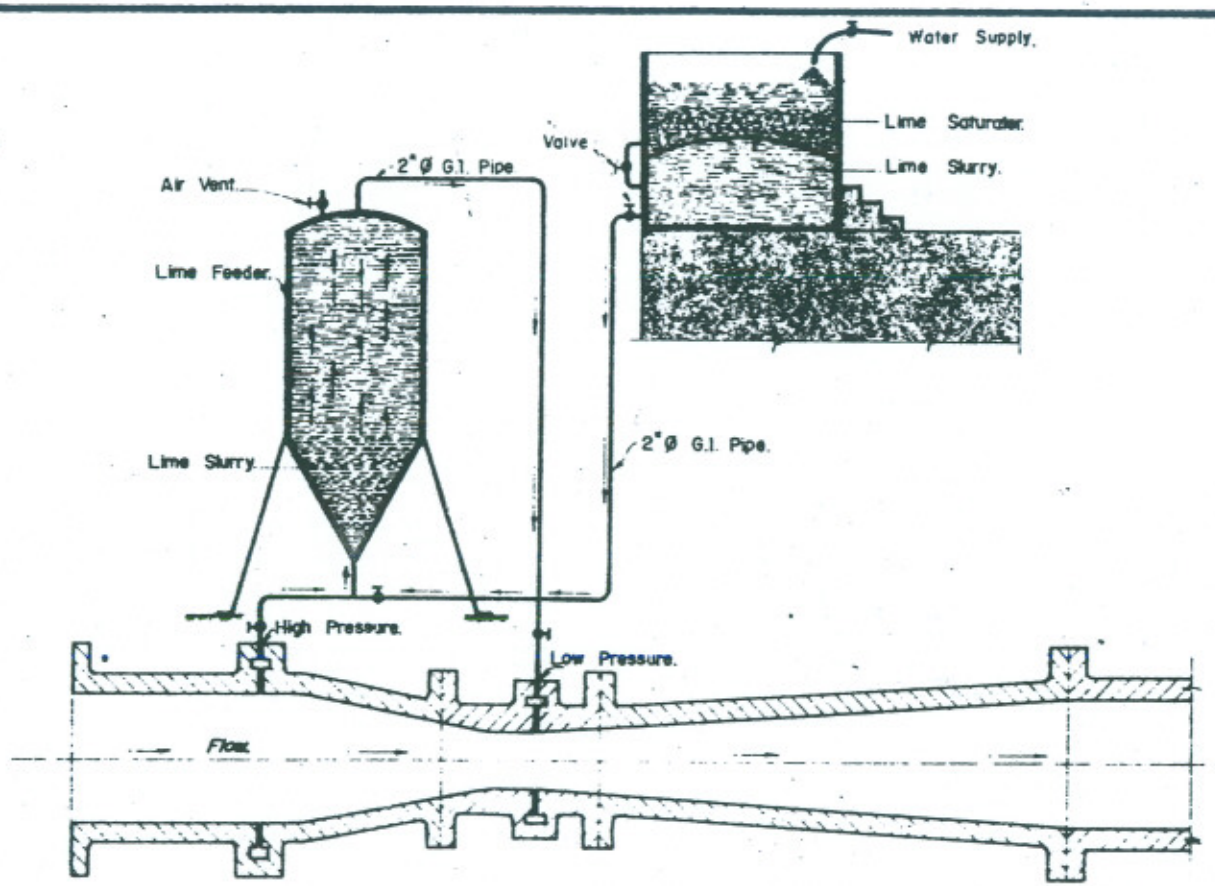
TYPICAL CHEMICAL DOSING EQUIPMENT

FIG. 5



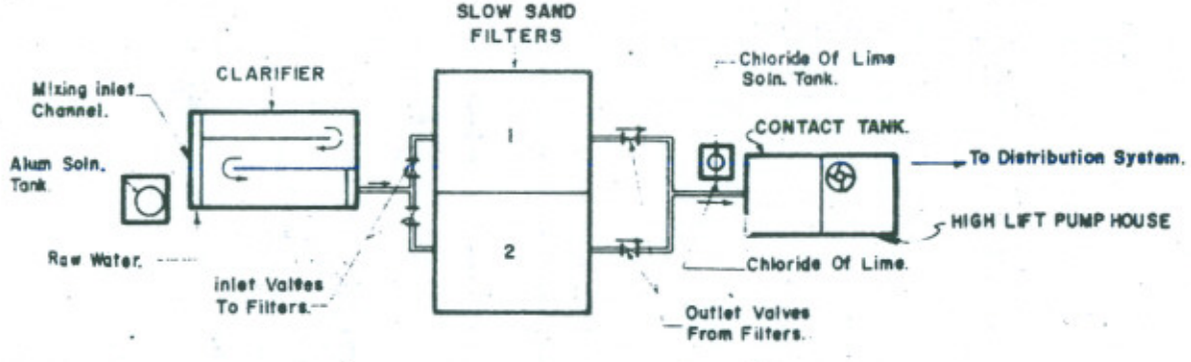
ALUM DISPLACEMENT DOSER

FIG. 6



VENTURI DISPLACEMENT LIME DOSER

FIG. 7



TYPICAL WATER TREATMENT PLANT FOR RURAL COMMUNITY.

FIG. 8

(Drawn By Mohd Saleem Akhtar)

FIG: 9
POPULATION
15,000
30000
45000
60000
75,000
0
5
10
15
20
25
30
35
COST PER CAPITA PEP ANNUM IN RUPEES
Slow Sand
Filtration
Rural
Rapid Gravity Filtration
Semi-urban/Urban
Rural
Semi-urban / Urban