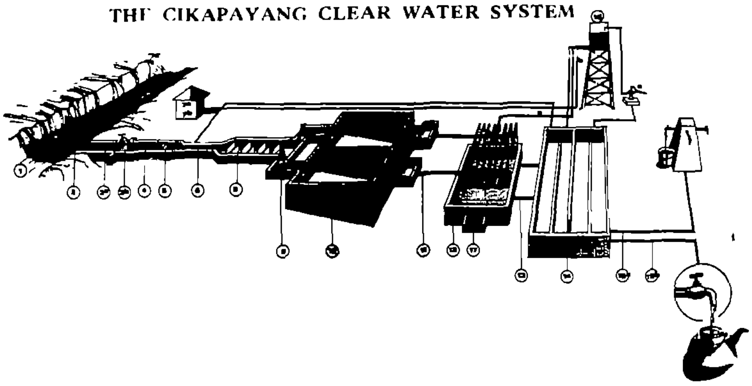
253-387

A SIMPLE WATER PURIFICATION PLANT USING THE CORROSION PROCESS OF IRON IN WATER

PROCESS DIAGRAM FOR
THE CIKAPAYANG CLEAR WATER SYSTEM



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FOREWORD

Directorate General of Cipta Karya has the aim to further the development results that we have already achieved in the national development plans Pelita I and Pelita II, and in the first two years of Pelita III, In fact, it is possible to accelerate development in Cipta Karya's sphere of operation and to raise our capacity for development achievement in the year that follows. Our work to accelerate the fulfillment of our functional aims, requires that policy be defined, particularly with regard to the functional target for the end of 1981/82, in which we will reach at least 60% of the entire Repelita III target.

In Repelita I Cipta Karya was projected to achieve an increase in clear water production capacity (throughout the country) of 15,222 litres/second (this we did). In Repelita II we took in hand the task of providing clear water in a total of 105 large, medium sized and small towns. The production capacity rose to 20,226 litres/second. In this period now we are still below our target of 29,000 litres/second.

By the end of the first year of Repelita III we had already achieved, however, a clear water production capacity of 350 litres/second in 18 cities, whereas 399 towns had already been dealt with, either in completed form or still in the process of development.

Government policy for Cipta Karya in Repelita III stresses equity of development effort (as delineated in GBHN and Repelita II), This equity of development is especially required in the social sector so that people can enjoy basic livelihoods. Included in this is the provision of clear water, environmental health facilities and the physical development of control mechanism, so that standards of living can be raised in our towns and villages.

Cipta Karya will achieve this in its development projects by using a more widespread approach. We are striving for quicker ways to meet the needs of society, and to provide wider services, principally for the low income groups.

We are working to spread development, so that minimum social requirements can be met, and within this aim we are persevering to continue providing a clear water supply for small towns and villages, which can be quickly, simply and cheaply erected and used.

In order to carry out development work in the way described above we have to provide assistance in the aspects of technological research and development, which meets our defined programme and leads to the raising of efficiency and effectiveness.

Just this has been achieved by the Directorate of Building Research in its development of the Cikapayang clear water system. We encourage its application because it appears that there has not before been a system so good, simple and cheap as this.

THE DIRECTOR GENERAL OF "CIPTA KARYA"

Radinal Moochtar

EXPLANATION & RECOMMENDATIONS

In order to fulfill the need to have clear water supplies in village areas, it is our duty to constantly look for, try out and develop technologies which can be simply and cheaply installed and run, which will help to secure health standards and which can meet water production targets.

Finding a technology to meet these requirements is as difficult as finding an advanced technology, because it requires high levels of ability, patience and effort, coupled with extensive bibliographical research and knowledge of the fields involved.

Such a clear water installation has already been pioneered by Ir. Fajar Hadi, Sanitary Engineer and Ir. M. Nasrun Rivai, Chemical Engineer. Their work in laboratory trials has led to (the building of) a pilot-plant on the Cikapayang River in Bandung.

Explanation

Known, for obvious reasons, as the "Cikapayang" system, this installation does not use the usual coagulants for purification process-for instance aluminium sulphate. Instead, the corrosion process of iron in water, with the addition of lime as coagulant aid, is used.

Test carried out to date have given encouraging results. Quality of water produced can already meet World Health Organization and Indonesian Health Department requirements.

Seen from the point of view current development trends, the Cikapayang system has strategic, value for helping to carry out development policies.
This is because :

1 The cost per litre per second of water is relatively low, meaning that when compared with earlier systems, more people can be provided with clear water for the same capital outlay.
2. The Cikapayang system can be located so as to give supplies to villages and districts (as well as to battalion head quaters). It can be used to raise the standard of living within society.
3. Installation of the Cikapayang system does not necessarily require highly skilled labour. It can be managed using local workers which in itself will help to reduce urbanization flows from country to town areas.
4. Iron, in scrap form, and lime, the basic materials used in the system, are easily obtained. Aluminium sulphate is not so easily obtained.
5. Water input is 5 litres/second, a level of input that will not disturb the other rural uses of water, for instance for irrigation. Disturbance to these other functions could cause alarm amongst agricultural workers. In Java, particularly, water is already strictly assigned.
6. The use of the rusting process of iron and the addition of lime constitutes a lesser health risk and to both operations and consumers.
7. The chemical process used does not require precise quantities to work properly The aluminium sulphate process does
8. Scrap iron and lime are much cheaper than aluminium sulphate for production of the same water discharge
9 The construction of the Cikapayang installation and its preparation for use can be completed in less than a year.

Recommendation

The Cikapayang water purification plant can be used to purify surface water from rivers and irrigation channels provided it is not heavily polluted To facilitate its development and deployment we have given below a brief guide to other considerations which must be dealt with before it can be used :

1. Introductory surveys should be carried out to investigate social-economic, cultural and technical aspects, most importantly in regard to the location of proposed installations. It is recommended that water should be fed into the installation and out of it to the consumers by the gravity method. This will avoid the use of pumps.

2. Permission for use of the water, should be obtained from the Provincial Public Works and Water authorities in the regions concerned

3 Raw water samples should be taken and tested in a laboratory to ensure that the in-coming water is suitable for use with the Cikapayang installation

4 Mapping and matching of the design to the local situation must be carried out, particularly with regard to the water intake, position of installation and its area of service

5. Financial planning is needed (when Provincial Public Works help is requested).

6 Proposals should be made to Bappeda, the Department of Health (PPPM) or Directorate General of Cipta Karya (depending on where finance is sought)

7 Preparation and physical execuation planning (when Provincial Public Works help is requested)

DPMB is ready to receive questions and suggestions concerning the Cikapayang project from interested parties.

Hopefully the Cikapayang water purification will accelerate development results by providing clear water supplies for village people.

Bandung, September 1980
Director of Building Research

KARMAN SOMAWIDJAJA

CONTENTS

A simple water purification plant using the corrosion process of iron in water

I. Preliminary

With the expansion of urban and rural communities there is a corresponding increase in the need for clean water. Clean water is used for drinking, cooking, washing and bathing, and it must fulfill the relevant health specifications.
There are five sources from which clean water can be obtained. They are :

a. Shallow wells (ordinary wells)
b Artesian wells
c Springs
d Rain water
e Surface water from rivers, irrigation channels, dams etc

The easiest source to use is surface water, but this is usually dirty and must therefore be purified. There are three major methods of water purification They are ·

a. Slow sand filtering
b. Conventional purification
c. Modern purification

Before the Second World War, surface water purification in Indonesia was done conventionally or by slow sand filtering After our liberation our clean water was obtained by the modern method, and this can be seen in Indonesian cities such as Jakarta, Surabaya and Bandung
River water in Indonesia is usually turbid, especially in the rainy season. This turbidity is caused by very fine colloid material, which is very difficult and time consuming to precipitate. In the conventional and modern methods we use a coagulant to speed up precipitation. Aluminium sulphate is commonly used. As cities grow and thus need more clean water, for both domestic and industrial purposes, water as a raw material becomes more difficult to obtain This, in turn, demands more funds and more skilled manpower. To decrease the demand for funds and manpower, we must, in this age of rising costs, look for technology that will give us water purification plants that are both cheap and simple. One such plant is the Cikapayang water purification plant.

II. The Cikapayang water purification plant

1. The aim

The aim of the Cikapayang water purification plant is to purify river water with the aid of a coagulant This coagulant must be safe, cheap and easily obtained
Special to this plant is its use of the corrosion process of iron in water with the addition of lime as coagulant aid Basically it is similar to the conventional method and it can use local manpower, which can become profficient in its operation after a short course of instruction
The Cikapayang plant can be used not only in villages, but also in transmigration areas, battalion headquarters and other places where the only source of water is a river
There are still many people who use river water for their daily needs, and it is not surprising to find that rivers become polluted, especially by faecal material This can result in outbreaks of typhoid, dysentry, cholera and other stomach illnesses The Cikapayang plant can solve this problem to a certain degree

2. Water source

The Cikapayang water purification plant can be used to purify river water that is not heavily polluted By heavily polluted water we mean water that contains effluent from industry, or water that is highly coloured (for instance humus water), or is brackish The Cikapayang plant cannot be used in these cases.

3. Plant capacity

The maximum capacity of the Cikapayang plant is 5 L/second so it can be used to fulfill the needs of about 5000 people This is based on an average requirement in villages of between 80 and 100 litres per person per day.

4. Distribution of clear water

Clean water is distributed from community supply points, each with two or three taps of ½" diameter. It is also recommended that public bath houses and toilets are built near these supply points so that the general levels of health and hygiene are also improved. Water can also be distributed directly to people's houses, or by a combination of the two methods.

5. The coagulant

To produce flocs of the colloid materials causing turbidity we must use a coagulant. Once coagulated, colloid material can easily be separated and filtered Colloid material is produced from the breakdown of biological agents in the water. The coagulation process induces colloids to form into flocs by reducing their surface action (electric). This is achieved by the formation of a complicated hydroxide binding. The rate of precipitation is increased by stirring, which increases collision between coagulated particles, thus forming flocs which can easily be filtered

The most commonly used coagulant is aluminium sulphate, and it is indeed good for the purpose. But it has drawbacks. Firstly it must be added in just the right concentration, thus requiring a skilled operator. Too much aluminium sulphate in drinking water is dangerous to health. It is also quite expensive and hard to obtain, so its use should be avoided in villages

As has been mentioned above, the Cikapayang plant uses the corrosion process of iron in water Iron will corrode in water very easily, especially when used in small pieces Lime is also added to increase the rate of precipitation. Between 70 and 75 kg of iron in the form of cut-up used water pipes are required to clean 5 L of water every second This means that between 865 and 925 pieces of iron, measuring 7.5 cm in length with a diameter of ¾", are needed This is equivalent to a surface area of iron of between 9 m^2

These iron pieces must be cleaned every two weeks with a steel brush to renew the surface and remove rust.

Between 25 mg/L of lime is needed Thus to clean water at the rate of 5 L/second for 24 hours we need a total of lime as calculated below

Minimum	24 x 60 x 60 x 5 L/sec x 25 mg/L =
	10,800,000 mg =
	10 8 kg of lime per day
Maximum	24 x 60 x 60 x 5 L/sec x 50 mg/L =
	21,600,000 mg =
	21 6 kg of lime per day.

6 The disinfectant

In order to kill bacteria that may escape the sand filter, disinfectants must be added. The agent generally used in Caporiet and between 0.2 and 1 5 mg/L is required.

The daily requirement of Caporiet is thus ·

Minimum	24 x 60 x 60 x 5 L/sec x 0.2 mg/L =
	86,400 mg/day = 0.0864 kg/day.
Maximum	24 x 60 x 60 x 5 L/sec x 1.5 mg/L =
	648,000 mg/day = 0.648 kg/day

Commercially available Caporiet has a concentration of approximately 35%. This means that the actual amount of Caporiet needed every day is :

Minimum	0.0864 x 100/35 kg/day = 0.25 kg/day.
Maximum	0.648 x 100/35 kg/day = 1.85 kg/day

7. Results from the Cikapayang plant

Results obtained from the Cikapayang plant conform to the World Health Organisation and governmental health department standards as can be seen in table 1.

TABLE No. I

ANALYSIS OF CLEAR WATER PRODUCED BY THE "CIKAPAYANG" PLANT FEBRUARY 1977, AND THE CONDITIONS FOR CLEAR WATER AS LAID DOWN BY THE STANDARDS OF THE INDONESIA DEPARTMENT OF HEALTH AND W.H.O

No.	CONSTITUENTS	UNITS	Indonesian Department of Health			W H O	Cikapayang Water	
			A	B	C		Before Process	After Process
	I. PHYSICAL							
1.	Temperature	O_e			air temperature		–	–
2.	Colour	Pt-Co scale	–	5	50	5–50	10	10
3.	Odour	–	–	–	–	not disturb	–	–
4.	Turbidity	SiO_2 scale	–	5	25	5–25	55	12
5.	II. CHEMICAL							
5.	PH	–	6,5	–	9,2	6,5–9,2	7,0	8,5
6.	Total Solids	mg/l	–	500	1500	500–1500	–	–
7.	Organic Subtance	–	–	–	10	–	7,84	5,5
8.	Agresive CO_2	–	–	–	0,0	–	9,1	–
9	Total Hardness	O_j	5	–	10	–	2,38	3,62
10	Calcium Ca	mg/l	–	75	200	200	7,07	17,3
11.	Magnesium Mg	mg/l	–	30	150	150	5,98	5,16
12.	Iron Fe	mg/l	–	0,1	1,0	0,3 – 1,0	0,40	0,20
13	Manganese Mn	mg/l	–	0,05	0,5	0,1 – 0,5	trace	0,0
14	Copper Cu	mg/l	–	0,05	1,5	1,0 – 1,5	none	none
15.	Zinc Zn	mg/l	–	1,00	15	5 –15,0	none	none
16.	Chloride Cl	mg/l	–	200	600	200–600	6,39	8,23
17.	Sulphate SO_4	mg/l	–	200	400	200–400	5,5	5,5
18	Hidrogen Sulphide H_2S	mg/l	–	–	0,0	–	–	–
19	Flouride F	mg/l	1,0	–	2,0	1,0	–	–
20.	Ammonia NH_4	mg/l	–	–	0,0	–	–	–
21*	Nitrite NO_2	mg/l	–	–	0,0	–	–	–
22	Nitrate NO_3	mg/l	–	–	20,0	40	–	–
23.*	Phenolic (as Phenol)	mg/l	–	0,001	0,002	0,001–0,002	–	–
24*	Arsenic As	mg/l	–	–	0,05	0,2	none	none
25.*	Lead Pb	mg/l	–	–	0,10	0,1	none	none
26*	Selenium	mg/l	–	–	0,01	0,05	none	none
27.*	Chromium C_r	mg/l	–	–	0,05	0,05	none	none
28*	Cyanida C_n	mg/l	–	–	0,05	0,01	none	none
29*	Cadmium Cd	mg/l	–	–	0,01	–	none	none
30*	Mercury Hg	mg/l	–	–	0,001	–	none	none
31	III Radioactivity							
31	Alpha rays	μc/ml	–	–	10^{-9}	10^{-9}	–	–
32.	Beta rays	μc/ml	–	–	10^{-8}	10^{-8}	–	–
33	IV Microbiology							
33	Parasitic organism	–	–	–	0,0	–	–	–
34	Pathogenic organism	–	–	–	0,0	–	–	–
35.	Total coliform limit in 100 ml of sample water	–	–	–	0,0	–	–	–

NOTE

A Minimum Allowable Concentration

B Maximum Permissible Concentration

C . Maximum Allowable Concentration

* Chemical Carsinogenic matter.

III. The corrosion process of iron in water

Research concerning the corrosion reaction of iron has been carried out by several researchers and different results have been obtained. The only thing that they agree on is that the speed of the corrosion process is influenced by both the homogenity and purity of the iron.
Furthermore many researchers are of the opinion that the presence of carbon dioxide and a certain level of acid in the water are necessary for the reaction to occur. The following are several opinions about the corrosion process of iron in water.

1. **G. Galvert and C. Brown** have the opinion that the chemical reaction of iron corroding in water is as follows :

$$Fe + H_2O + CO_2 \longrightarrow FeCO_3 + H_2$$

$$4\,FeCO_3 + 6H_2O + O_2 \longrightarrow 4\,Fe\,(OH)_3\downarrow + 4CO_2$$

2. **G.T. Moody** came to the conclusion that pieces of iron, kept for months in water free from carbon dioxide, do not corrode These pieces of iron will become corroded after CO_2 gas has been added This dissolves the iron as Fe $(HCO_3)_2$, which with the further addition of oxygen from the water becomes the precipitate Fe $(OH)_3$

3. Thenard used several pieces of iron as poles in Volta cells From these experiments we see that the corrosion process of iron is as follows .

$$Fe + 2H^+ + 2OH^- \longrightarrow Fe^{++} + 2OH^- + H_2$$

$$4\,Fe\,(OH)_2 + O_2 + 2H_2O \longrightarrow 4\,Fe\,(OH)_3\downarrow$$

We see from the above equations that the corrosion process first forms iron hydroxide as ferri before it forms the precipitate

The forming of this iron oxide salt as ferri can be used for the coagulation process in turbid water The coagulating effect of ferri hydroxide on the colloidal materials in the water is not a simple reaction from ferric iron (Fe^{+++}), but a reaction forming a ferri hydroxo salt compund From research we also know that the concentration of this compound is relatively small. However it can promote a very effective coagulation process
The formation of this compound in water follows the acid-base balance reaction of ferri ion, by exchanging one proton with one water molecule The water molecule will in turn change into the hydroxide H_3O.

$$\left[Fe\,(H_2O)_6\right]^{+++} + H_2O \rightleftharpoons \left[Fe\,(H_2O)_5OH\right]^{++} + H_3O^+ \quad (1)$$

The conjugated base in equation (1) can still exchange one proton

$$\left[Fe(H_2O)_5(OH)\right]^{++} + H_2O \rightleftharpoons \left[Fe(H_2O)_4(OH)_2\right]^{+} + H_3O^+ \;\cdots\cdots\; (2)$$

This exchange can go on and will force the ferri salt to dissolve into the water following the above equation This hydrolisation process will be followed by a decrease of pH factor and alcalinity.
The ferri hydroxo compound so formed has the tendency to polymerise and a simple di-mer form is :

$$2\left[Fe(H_2O)_5(OH)\right]^{++} \rightleftharpoons \left[Fe_2(H_2O)_8(OH)_2\right]^{++++} + 2H_2O \;\cdots\cdots\; (3)$$

The polymerisation hydroxo reaction can go on forming hydroxo-polymer and ferri oxide hydrate salts which are insoluble in water and thus precipitate.
Auxilliary materials are also required for the water purification process to speed up coagulation. Lime, besides being used as a coagulant (although a weak one), is used in many purification processes as an auxiliary material.

IV. Equipment used in the Cikapayang plant

Building and equipment needed for the plant are as follows . (see picture 1.)

1. The water source

As source water, river water conforming to the specifications of II.2 is used. It must not be heavily polluted.

2. Dam

To heighten the water level a dam is sometimes needed. This enables the water to enter the installation with greater force.

3. Water intake construction

The water intake construction consists of :

a. Bar screen
This is made from harmonica wire or something similar which can be pulled up. (see diagrams 1 and 2).

b. The sluice
To control the amount of water to be purified we move the sluice up and down by turning a bar to the left or to the right. (See diagram 2).

4. Preliminary channel

This is used to calm the water. The water must be calm before its intake rate can be measured. The length of this channel must be at least 10 m. It is recommended that wooden partitions be placed in this channel so that it can be shortened to just a few metres. (See diagram 2).

5. Thompson flow gauge

This is used to measure the inflow of the water to be purified. (See diagram 3). A ruler is placed at the upper end of the partition so that the zero point of the ruler is on the underside and its height is the same as the top (upside down) of the right-angled triangle of the v–notch. If we wish to purify 5 L/second of water and the height of the water at the upper end of the partition is h = 10.56 m for example, then we would read-off the figures 10.56 on the ruler.
Measruments based on Thompson's flow gauge are calculated using the following formula :

$Q = 1.39\ h^{5/2}$, where Q is the rate of water flow and h is the height of water as read above. In practice we simply make a table to measure the water flow, so that only the factor h need be read. Table 2 is an example.

Table 2
Measuring the water debit

h (in cm)	Q (in L/sec.)	Q (in L/sec)	h (in cm)
1	0,014	1	5,55
2	0,078	2	7,32
3	0,215	3	8,61
4	0,442	4	9,66
5	0,772	5	10,56
6	1,217	6	11,35
7	1,790	7	12,08
8	2,499	8	12,74
9	3,331	9	13,36
10	4,370	10	13,93

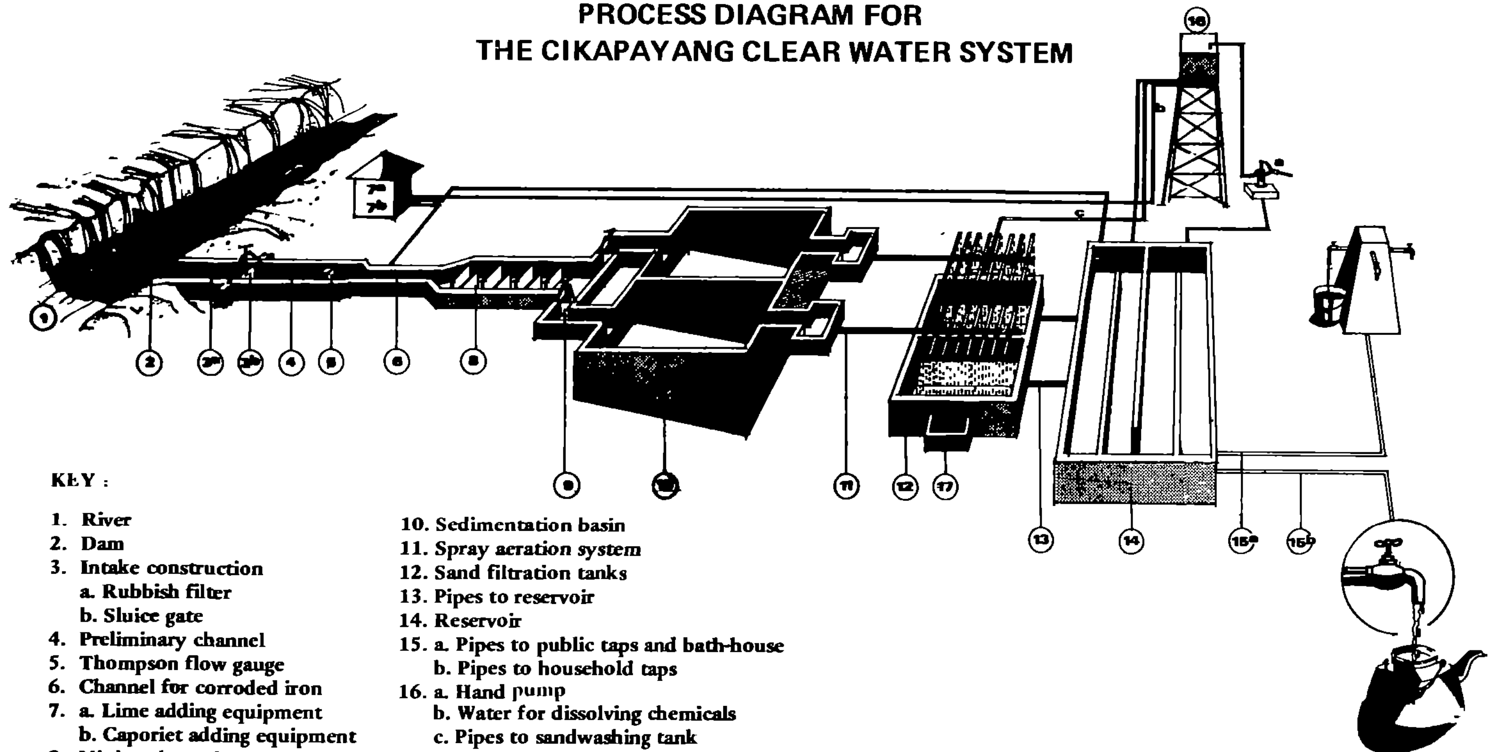
If the water to be purified is 4 L/sec. then the height is h = 9,66 cm.

Thus we can see that if we need to purify 4 L/second then the height will be 9.66 cm.

6. Channel for the iron pieces

This channel is used to put the easily corroded iron pieces into the plant. (see diagrams 1 and 2). The iron pieces must be fully immersed in the water.

PROCESS DIAGRAM FOR THE CIKAPAYANG CLEAR WATER SYSTEM



KEY :

1. River
2. Dam
3. Intake construction
   a. Rubbish filter
   b. Sluice gate
4. Preliminary channel
5. Thompson flow gauge
6. Channel for corroded iron
7. a. Lime adding equipment
   b. Caporiet adding equipment
8. Mixing channel
9. Sluice gates
10. Sedimentation basin
11. Spray aeration system
12. Sand filtration tanks
13. Pipes to reservoir
14. Reservoir
15. a. Pipes to public taps and bath-house
    b. Pipes to household taps
16. a. Hand pump
    b. Water for dissolving chemicals
    c. Pipes to sandwashing tank
17. Sand washing tank

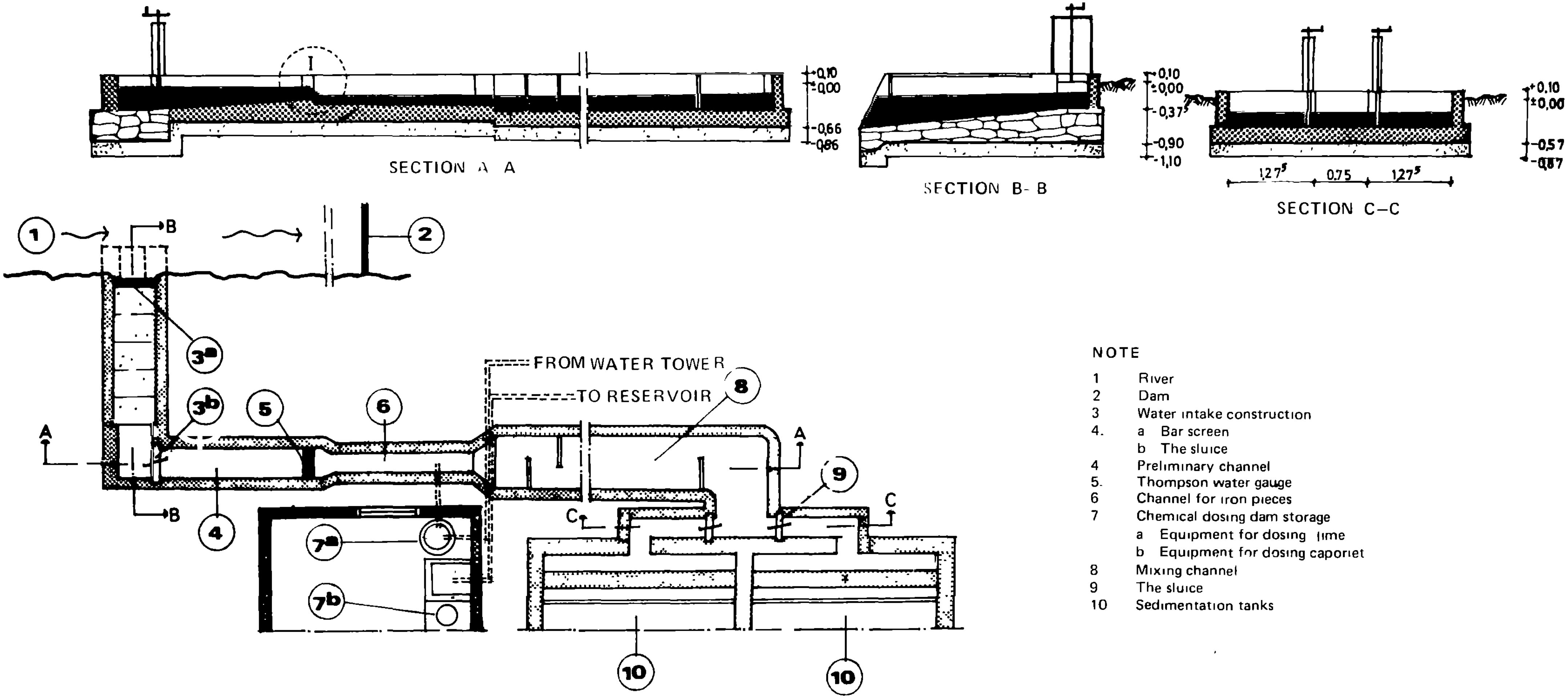


DIAGRAM 2
- PRELIMINARY CHANNEL
- CHANNEL FOR IRON PIECES
- THE SLUICE

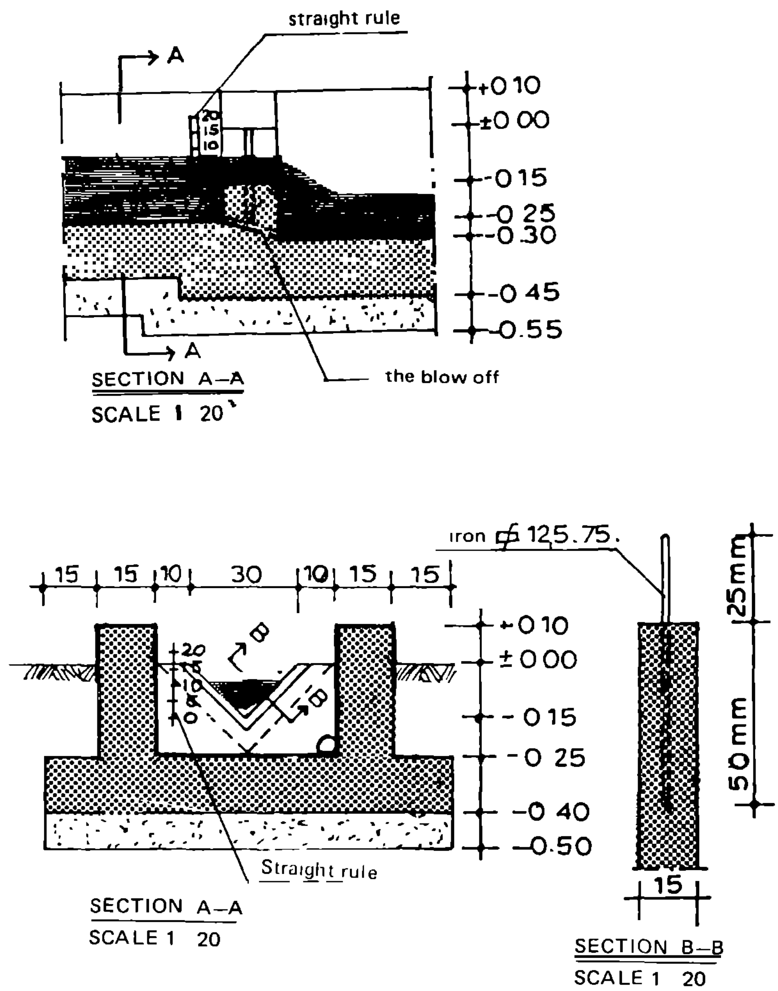


Diagram 3 : **THOMPSON FLOW GAUGE**

7. Chemical dosing and storage.

a. Equipment for dosing lime

As calculated in II.5, as much as 10.8 kg of lime has to be put into the lime adding cylinder Before putting it into the equipment it is recommended that the lime be dissolved into water in a pail It should then be stirred and sieved It is also better if only half of the lime is added in the first twelve hours. Whilst adding the lime the cylinder is slowly filled with water from the water tower In this item of equipment, the lime will precipitate and the water above it will contain dissolved lime In this lime solution there will be a concentration of 1000 mg of lime in 1 L of solution, or 1 mg/cm^3 From II 5 we know that the minimum lime solution requirement is 25 mg of lime solution per litre of water to be purified 25 cm^3 of lime solution will thus contain 25 mg of lime So to purify 5 L/second of water we must add the following amount of lime solution. 25 cm^3/L x 5 L/second = 125 cm^3/second So every second we must add 125 cm^3 of lime solution

By adjusting the tap we can regulate the addition of the lime solution to 125 cm^3/second This adjustment process is slow, so patience is required when setting up the equipment After 24 hours the precipitated lime will be capable of no further dissolving and it becomes a sediment consisting of gravel, stones, limestone etc This sediment is flushed out by opening a tap under the equipment The flushed out sediment is put into a filtering tank (see diagram 4) The water will filter out into the earth below whilst the sediment will be left on top of the filtering sand When the tank is full the sediment can be thrown away It must be noted that the equipment used for adding lime must be cleaned every week to avoid the accumulation of lime on it

b. Equipment for dosing Caporiet

Two of the equipments that can be used for the addition of Caporiet to the purification process can be seen in diagram 5 These can be made of glass or plastics but not of metal As calculated in II 6 as much as 1 85 kg of Caporiet is required It is recommended that the Caporiet be first dissolved and stirred in a plastic pail before adding it to the Mariotte bottle There will be a sediment left in the pail and this must be mixed with water several times and stirred to make sure that what is left in the pail at the end is really sediment and not undissolved Caporiet

The Caporiet is then put into a Mariotte bottle and if this bottle has a volume of 50 L then 50 L of water is required to dissolve the Caporiet. The Caporiet in solution is then put into the reservoir (see sketch in diagram 1), and it must all be used up within 24 hours

The exact amount of Caporiet solution needed is calculated as follows

$$\frac{50 \times 1000 \text{ cm}^3}{24 \times 60 \times 60 \text{ sec}} = 0\ 58 \text{ cm}^3\text{/second}$$

By adjusting the tap (see diagram 4) a droplet rate of 0 58 cm^3/second can be obtained This adjustment must be done patiently and is aided by the use of a measuring glass filled with drops of the Caporiet solution from the Mariotte bottle

It is actually better to make the Caporiet solution twice a day and feed it in at twice the above rate, i e 1 16 cm^3/sec To find the exact amount of Caporiet required, resulting purified water should be tested in a technical hygeine laboratory or other suitable chamical laboratory This is because Caporiet gives off toxic fumes that can damage the respiratory system This also means that Caporiet mixing should be carried out out of doors If however this is impossible, all windows and doors should be opened The worker doing the operation should also wear a mask, or if none is available, cover his nose with a wet piece of cloth

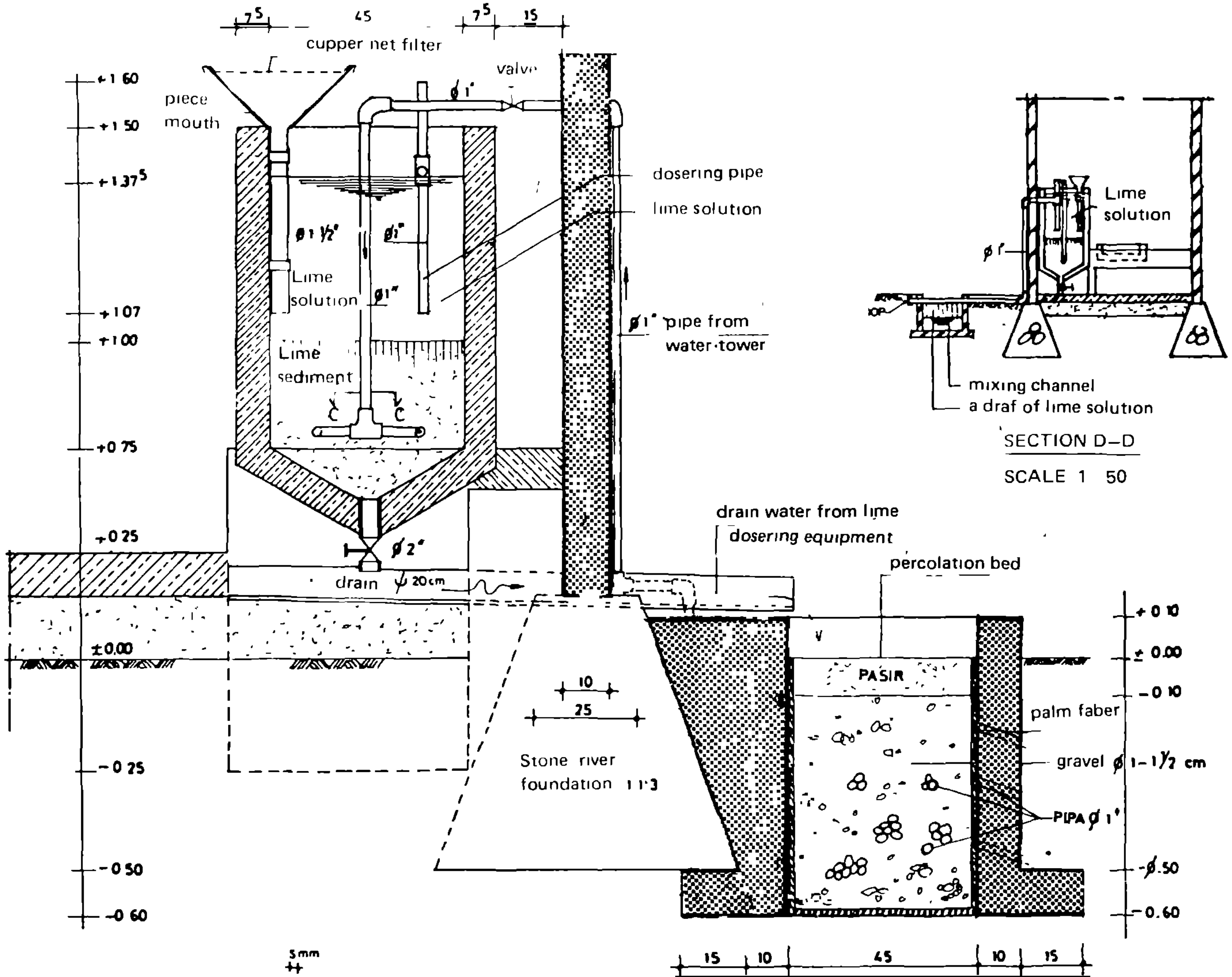
It should be noted that all the tools and equipment required for the mixing and adding of Caporiet and lime must be wetted first and must be washed directly after the operations are completed

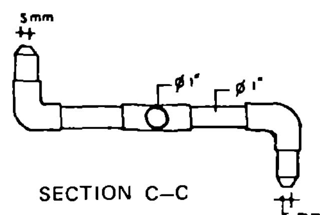
c. Storage for lime and Caporiet

Lime can be stored in closed drums It should not be contaminated by dust or water Caporiet must be stored in either glass or plastic containers and these must be tightly closed Caporiet may not be stored for longer than 3 months, as it is not fit for use after this period

8 Mixing channel

The mixing channel is designed to allow the coagulant to mix with the colloids in in the water to be purified, so that flocs can be formed The Cikapayang water purification plant has a mixing channel of 15 to 20 m in length and it has many turns If required wooden bottles can be added The basic design con-

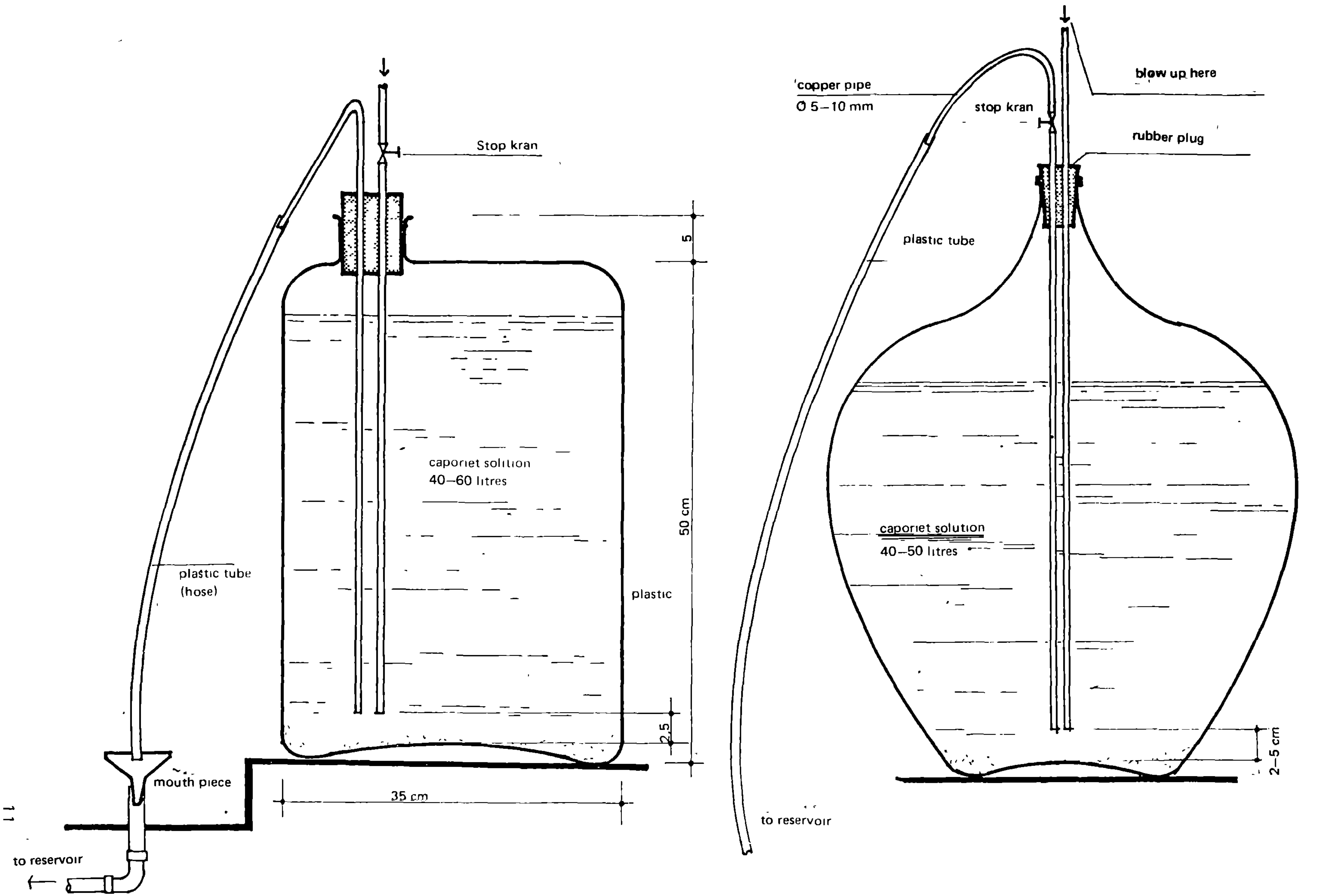




SECTION C–C
Rotering pipe

Diagram 4 : LIME DOSERING DETAIL

Diagram 5 : EQUIPMENT FOR DOSING CAPORIET



straints are as follows

> inflow of water to be cleaned - 5 L/second
> rate of flow of water = 0 1 m/second
> from these facts the dimensions are worked out to be
> width = 0 32 m
> depth = 0 16 m

9 The sluice

The sluice is located at the end of the mixing channel (see diagrams 1 and 2) Sluices are needed to control the flow of water into the depositing tanks If one of the depositing tanks is being cleaned then the sluice concerned must be closed

10. Sedimentation tanks

The sedimentation tanks are used to precipitate the lumps Two are provided so that if one is being cleaned the process need not stop The sediment deposited on the bottom of the tank is removed by cleaning the tank once a week with the help of a drain

The basic dimensions of the tanks are calculated as follows

> Inflow of water to be purified is 5 L/second
> Detention time is 2 hours

This leads to a sedimentation tank with a volume of 18 m^3 and with measurements as follows

> Length = 5 4 m
> Width - 2 7 m
> Average depth = 1 25 m
> Slope = 1 10

11 Aeration pipe network

The aim of aeration is to let the water have as much contact with air as possible This is achieved with a network of pipes, which remove iron and manganese from the water The aeration pipe network consists of a main pipe with 3" diameter and capped side-pipes with 1" diameter (See diagram 6) The undersides of the side-pipes are provided with holes The height between the main aeration pipe and the iron plate in the sandfilter tank, known as the aeration height, is between 1 and 3 metres

12 The sand filtration tank (see diagram 7)

After aeration the water falls into a tank containing layers of gravel and sand which act as filtering agents The sand filtration tank in the Cikapayung plant has a filtering capacity of 5 m^3/m^2 of filtering area/hour Given our 5 L/second or 18 m^3/hour requirement this leads to a filtering area of .

$$\frac{18\ m^3/hour}{5\ m^3/m^2/hour} = 3\ 6\ m^2$$

This leads to a length of the filter of 2 7 m and a width of 1 35 m

Two filtering tanks are required so that if one is being cleaned the other can carry on operating.

The filtering layers from top to bottom are

a. A gravel layer from Ø 2 50 to 5 00 cm The thickness of this layer is 5 cm This layer is used to split the falling water into finer drops and thus to increase aeration

b An iron plate drilled with holes to hold the gravel in layer a and thus prevent it sinking into the sand The thickness of this plate is 3 mm and hole diameters are 10 mm The distance between holes is 50-100 mm To avoid corrosion the plate must be painted Asphalt paint would suffice

c A sand layer consisting of silica sand particles An example of this type of sand is Bangka sand, Sand grains are of diameter between 0 5 and 1 mm and the thickness of the layer is between 0.7 and 1 0 m

d Three layers of gravel, each layer having a minimum thickness of 0.10 m. Layer I has particle diameters of about 1 0 cm, layer II of 2 5 cm and layer III of 5 0 cm Gravel used for these layers should be from hard material

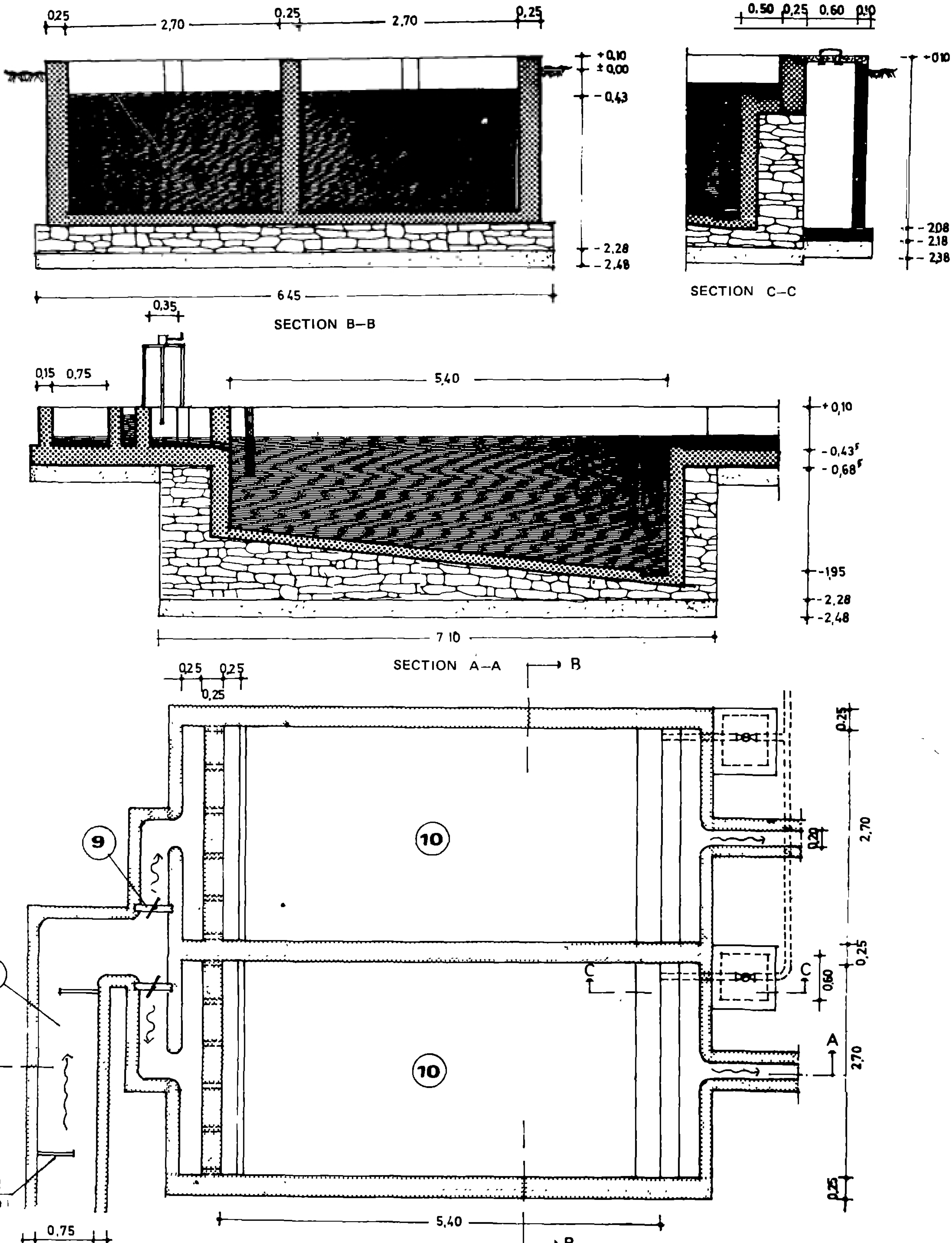


Diagram 6 : SEDIMENTATION TANKS

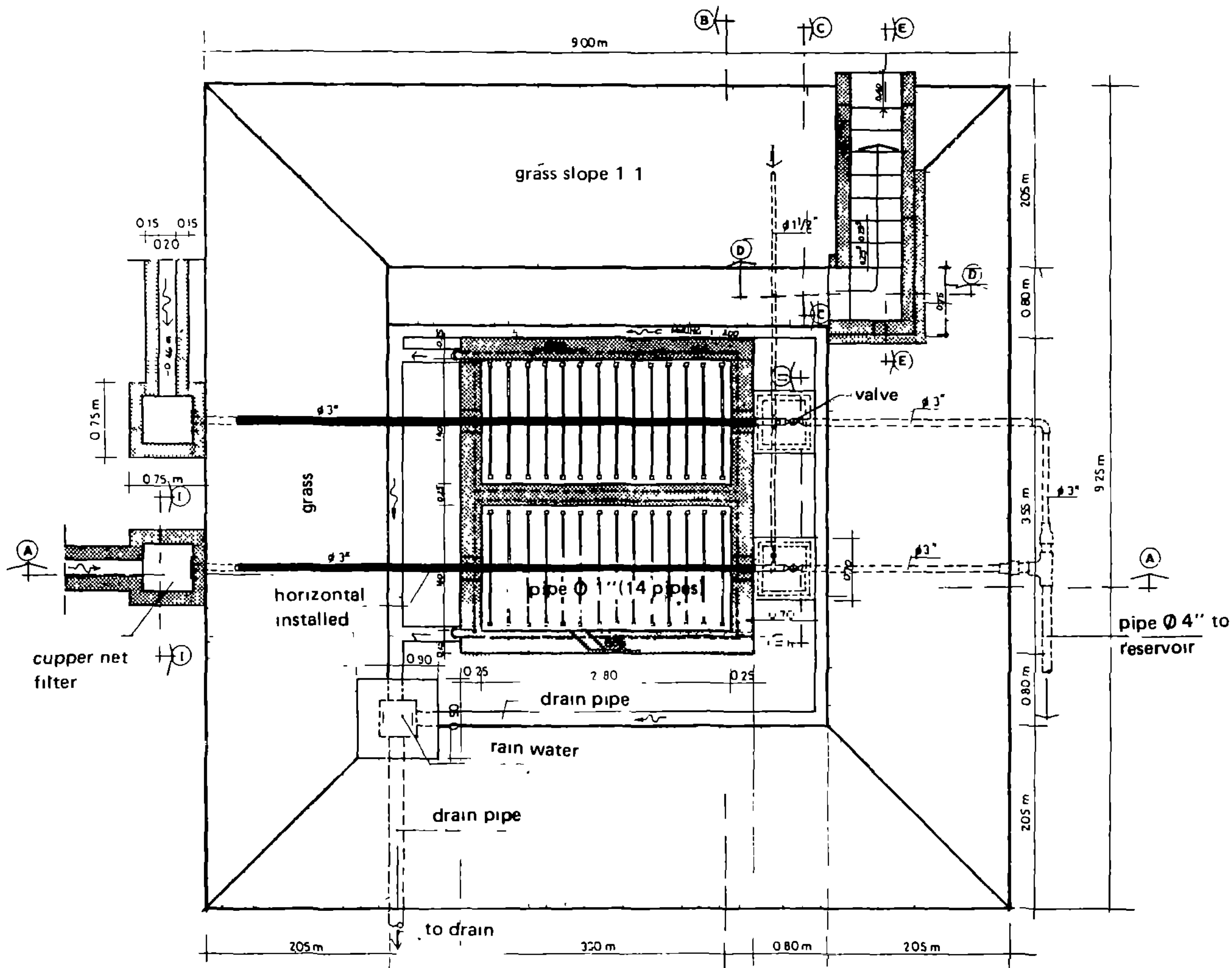


Diagram 7 · AERATION SPRAYER PIPE
(The rapid sand filter bed)

e. A drainage pipe of 4" diameter, through which the water coming from the sand and gravel layers flows. The beginning of the pipe is capped and the end is connected to a smaller pipe of 3" diameter by means of a reducer. This drainage pipe has holes. (See diagram 6).

The sand layer in the filtering tank becomes clogged if used to filter the water for too long. It should therefore be cleaned every 24 to 48 hours to prevent clogging. If the sand layer in the first tank needs cleaning, filtering in that tank is stopped by closing one of the sluices. The sand is washed in the same manner as rice is washed; in parts in a sand washing tank (See diagram 1, number 17).

13. Reservoir for storing clean water (See diagram 1).

This reservoir has an air pipe of 2-3" in diameter, an inspection hole, partitions in brick and a control tank In the control tank are located a water distribution tap and a drain tap

The use of this reservoir is to enable water to be stored when demand is low and later distributed when demand is high. It is also used to store water for washing the sand in the filtering tank and water used to dissolve lime and Caporiet as well as for washing other parts of the plant.

The volume of the reservoir is calculated as follows

We know that the amount of clear water produced per hour is constant whilst the demand is not After 16 hours of purification we get a volume of clear water produced of 65 cubic metres

14. Distribution main pipe

From the reservoir, distribution is carried out to the various consumer points If these places lie lower than the reservoir then pumping is not required This saves in costs

15. Water tower

This is used to store clean water for

1 Washing the filter
2 Dissolving the lime
3 Dissolving the Caporiet
4 The needs of the workers.

The water tower capacity is calculated as follows

1. Washing the filter

   This part of the total capacity required is calculated by equating the volume of water required to the volume of sand to be washed The volume of sand to be washed = area of filtration x depth of sand layer = 2 7 x 1 35 x 0 7 m^3 = 2 55 m^3

2 Dissolving the lime

   The lime added is approximately 25 mg/L

   In 1 L of water 1 gram of lime is dissolved. In 1 cm^3 of water 1 mg of lime is dissolved. If the rate of purification is 5 L/second, then the amount of water needed for 24 hours of operation is :

   (5 x 24 x 60 x 60 x 25) mg = 10,800,000 mg $\leftrightarrow$ 10,800,000 cm^3 = 10 8 m^3

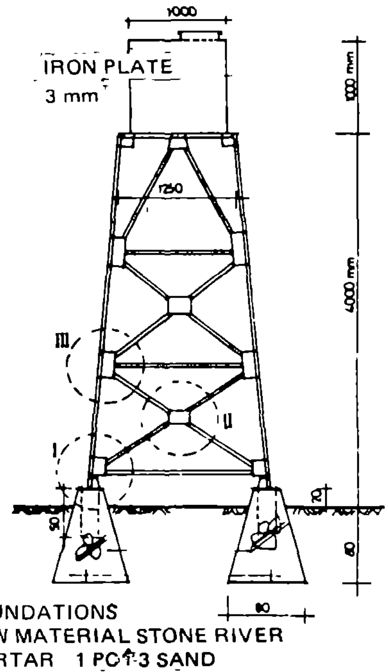
3 Dissolving the Caporiet

   The water needed to dissolve the Caporiet is 50 L every 12 hours. This is the volume of the Mariotte bottle Therefore the water needed per day is 2 x 50 L = 0 1 m^3

4 The needs of the workers Based on an average requirement of 20 L/person/day and on a staff of two workers, this volume is 40 L or approximately 0 05 m^3.

The total requirement is thus 2 55 + 10.8 + 0 1 + 0.05 = 13 5 m^3

A water tower of this capacity would be expensive It is therefore suggested that a smaller one be constructed A 4 5 m^3 capacity tower would require filling three times a day.



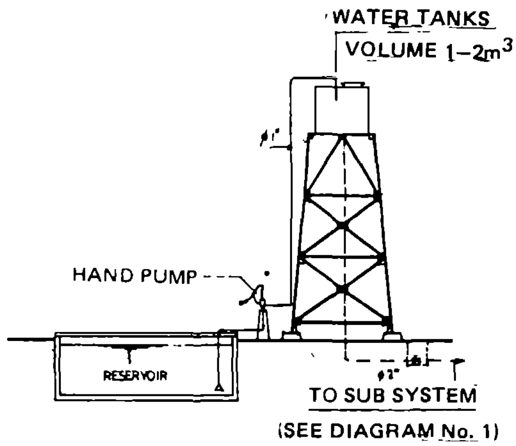


DIAGRAM 8 : WATER TOWER

V. Estimated costs of the "Cikapayang" water purification plant

In planning the budget to install this "Cikapayang" water purification plant we use the prices valid in Bandung as of October 1981.

Specification of the total cost is as follows :

A. Intake and mixing channel	Rp.	833.750,-
B. Sedimentation tank	Rp	3.208.700,-
C Filtering tank and aeration sprayer pipes	Rp	2.673 670,-
D. Reservoir	Rp	11.783 450,-
E Building for adding and storing chemicals	Rp	634.415,-
F. Watertower and effluent lime treatment plant	Rp.	612 203,-
TOTAL	Rp	19 756 188,-

These cost do not include the purchase of land for the plant, ± 1000 sq metres and the provision of distribution pipes

VI. Operation and maintenance cost

The operation cost consists of :

1. Need of lime/year	= 330 X 12 X Rp. 20,-	= Rp.	79.200,–
2. Need of caporiet/year	= 56 X 12 X Rp. 1300,-	= Rp.	873 600,–
3. Salary of 2 operators/year	= 12 X 2 X Rp. 40.000,-	= Rp.	960.000,–

Maintenance cost .

1. Annual maintenance 12 X Rp. 20.000,- = Rp 240 000,–

Total operation and maintenance cost/year = Rp 2 152.800,–

Operation & maintenance cost/month = Rp 179 400,–

VII. Price of the water

$$\text{Price of the water} = \frac{\text{TAC}}{\text{water production}}$$

Average cost of the water

The TAC above does not include profit

If we assume that in the first year we get a profit of 10% then

The average cost of the water

$$\frac{1{,}1\ \text{TAC}}{\text{water production}}$$

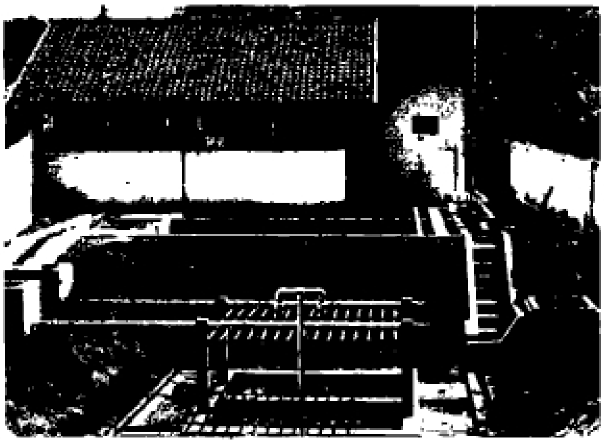
Rp 33,50/m^3 or Rp 0,03/l

VIII. Cost comparation between "Cikapayang" and Aluminium Sulphate System (Bandung as of October 1981).

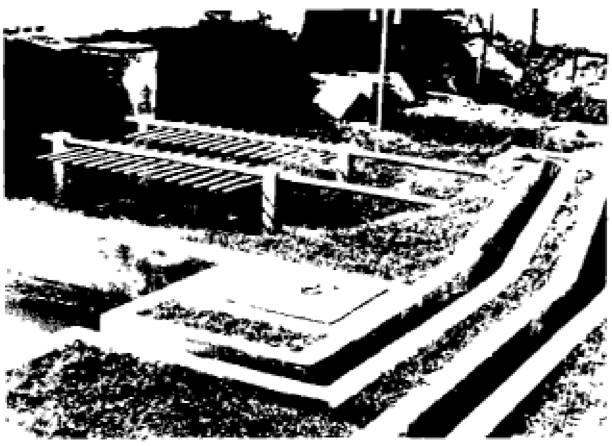
NO.		Iron and lime	Aluminium Sulphate
1	Dose	25 mg/l	40 mg/l
2.	Capacity	5 l/second	5 l/second
3	Daily dosing chemical	10,8 kg	17,8 kg
4	Cost per kilogram	Rp 20,-	Rp. 300,-
5	Daily chemical costs	Rp 216,-	Rp. 5184
6	Monthly chemical costs	Rp 6480,-	Rp 155 520,-
7	Yearly chemical costs	Rp 77 760,-	Rp 1 866.240,-
	Cost quantity ratio	1	24

Terminology

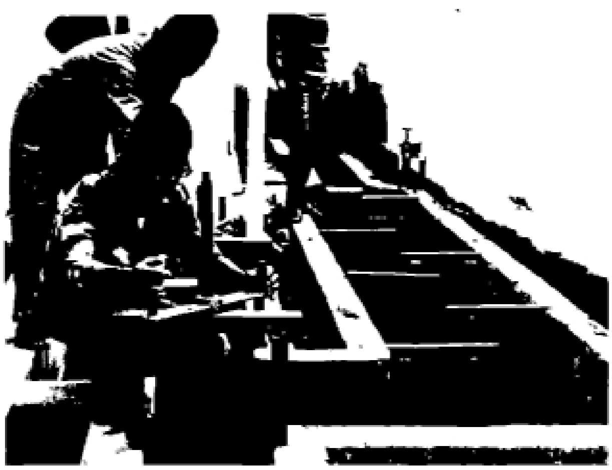
1. *Raw water* is water which will be purified into clean water, and can be decisive of the type of purification process
2. *Clean water* is water justified to be drunk, cooked and used for ordinary house needs and has the specified quality.
3. *Waste water* is water contaminated by faecal material from people, animals or plants and includes also industrial waste water and chemical waste
4. *Water as a solvent* is water used to dissolve solid material.
5. *Surface water* is water from the surface of the earth and waterbodies such as rivers and less lakes
6. *Control tanks* are tanks to control the smooth operation of a process
7. *A disinfectant* is a chemical used to kill bacteria
8. *Diameters* stated are nominal diameters as used in trade unless otherwise stated.
9. *Distribution* is a system of distributing water to the consumer
10. *A coagulant* is a chemical used to bind the colloidal matter into lumps
11. *Colloids* are materials that are so fine that they are difficult to precipitate
12. *The drain tap* is the tap used to drain the tank
13. *A mask* is an appliance to protect a person's respiratory system
14. *Distribution pipes* less are the pipes which are going to be used to distribute clean water



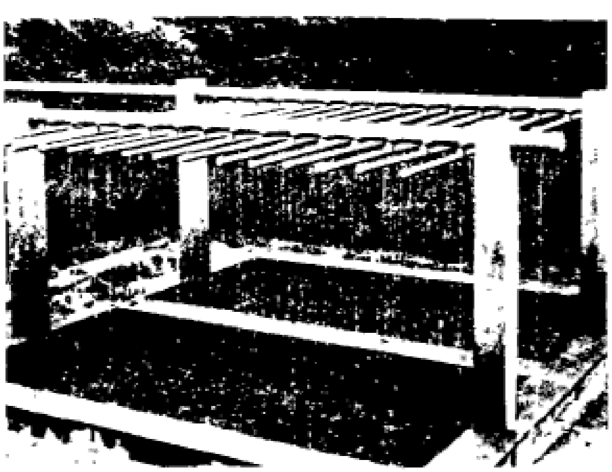
The situation of Cikapeyang mini treatment plant.



Direction from sedimentation basin to aeration pipe, draft to filter bed.



The operator arrange the sluice from mixing channel to sedementation basin



Aeration pipe, water dropped on the filter bed.