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WATER TREATMENT SYSTEMS AND THEIR SUITABILITY FOR GRAVITY FED RURAL WATER SUPPLIES IN MALAWI

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CONTENTS

WATER TREATMENT SYSTEMS AND THEIR SUITABILITY FOR GRAVITY FED RURAL WATER SUPPLIES IN MALAWI

Foreword

Rather than adopting a well known but locally untested technology for the treatment of highly polluted raw water for the rural, gravity fed piped water supplies in Malawi, a research programme was developed which has tested and is still testing a number of known technologies on their suitability for application under rural Malawian conditions.

The outcome of the experiments is so hopeful that far more costly alternatives as described and recommended in literature on treatment systems will not have to be used, but rather a system which is adopted to local conditions making use of locally available materials. In addition the proposed system is a basically well known technique in the rural communities which guarantees easy acceptance and thus increases the chances for successful operation.

The additional benefit of the experiments is the gained experience in the staff with the described technologies which has greatly strengthened the team confidence to overcome pollution problems.

ir. [illegible] van Schaik

15.6.19[illegible]

Lastly, although the available equipment and instruments to do research was minimal, a lot of valuable information was collected which clearly indicates a line of development for the treatment technique to be most suitable, and supports the conclusions of this report quite adequately.
The lack of equipment ~~[illegible]~~ simulates the situation in the rural supplies and thus forced me to develop ways of control which are very simple and can be made locally.

1. INTRODUCTION

Some 5 years ago it was realized that future rural gravity fed piped water supplies would require treatment facilities to clean the raw water from silt and pathogen pollution before it could be served to the users.

Sophisticated treatment systems requiring high recurring inputs - both in technical standards of the operator and operational costs - were not seen to be desirable for the rural water supplies.

It was observed that rural communities have a concept and a technique of cleaning turbid ~~water~~ river water by excavating a hole in the riverbank and scooping out filtered water from the hole, after it has percolated through the separating sandpack. The filtered water is visibly cleaner than the raw water.

Along above outline a pilot scale treatment plant was designed and constructed in [illegible] on the [illegible] training ground.

The treatment plant was built with the following objectives in mind:

1. to find a suitable treatment system for rural water supplies which can remove high silt loads (up to [illegible])
2. remove high pathogen loads efficiently and consistently to acceptable levels (from 50,000 E coli per ... to not more than 50 per 100 ml)
3. which treatment system is easily understood and accepted by the users
4. and which is simple and cheap to operate.

[illegible]

[illegible] pilot scale treatment plant was built for the training [illegible] of the [illegible] Training Centre in [illegible] which [illegible] 19[illegible].

2.1 SITE SELECTION AND RAW WATER QUALITY

The site was chosen because of the nearness of the [illegible] river, which is just behind the fence of the training ground which has its catchment within the [illegible] [illegible] carries high pathogen loads all year round (see table 1) and high silt loads during the rainy season (see graph 1).

The source of the silt load during the rains is the clay soil in the catchment area which is carried into the river with the surface run off during [illegible] showers, [illegible] the colour of the water red-brown, [illegible] the visibility [illegible] to below 1 cm.

During the dry season the visibility* [illegible] 3 [illegible] (for method description see App. 1) [illegible] because of dirt originating from clothes [illegible] washed in the river. However, instead of [illegible] [illegible].

The second important characteristic of the [illegible] River is the high pathogen load all year round which originates from [illegible] surface run-off during the rains and [illegible] or [illegible] bathing practices during the dry season.

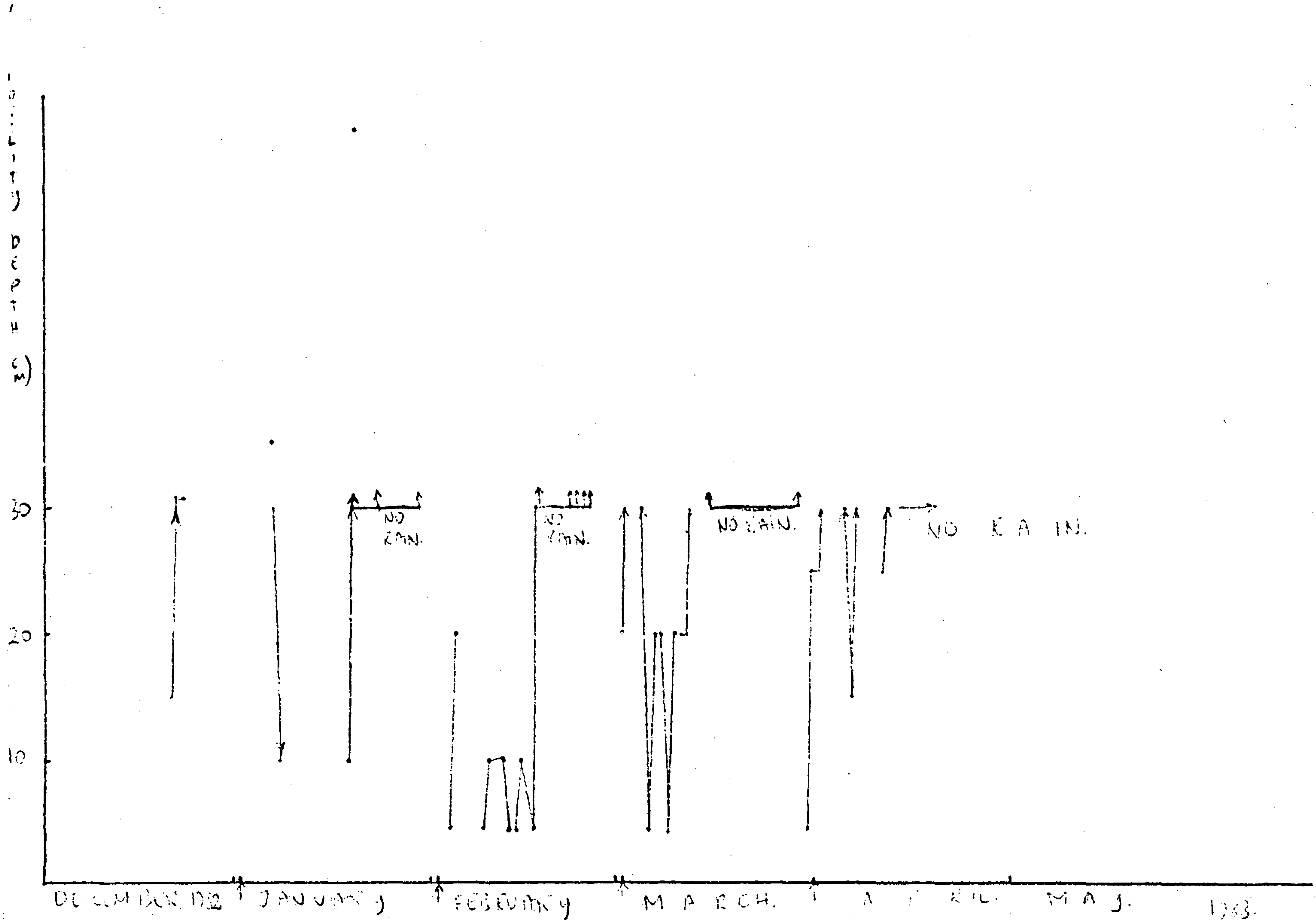
[illegible] characteristics e.g. high silt [illegible] and high pathogen load [illegible] the raw water [illegible] for the [illegible] [illegible].

Table 1: Escherichia coli counts [illegible] River water [illegible] counts were taken with Millipore [illegible].

date	coli/100 ml
[illegible] - 3	100,000
[illegible] - [illegible]	90,000
[illegible] - 4	40,000
[illegible] - [illegible]	[illegible]

[illegible] counts are rough estimates with an accuracy + or - [illegible] but they give a good indication of level of E. coli counts.

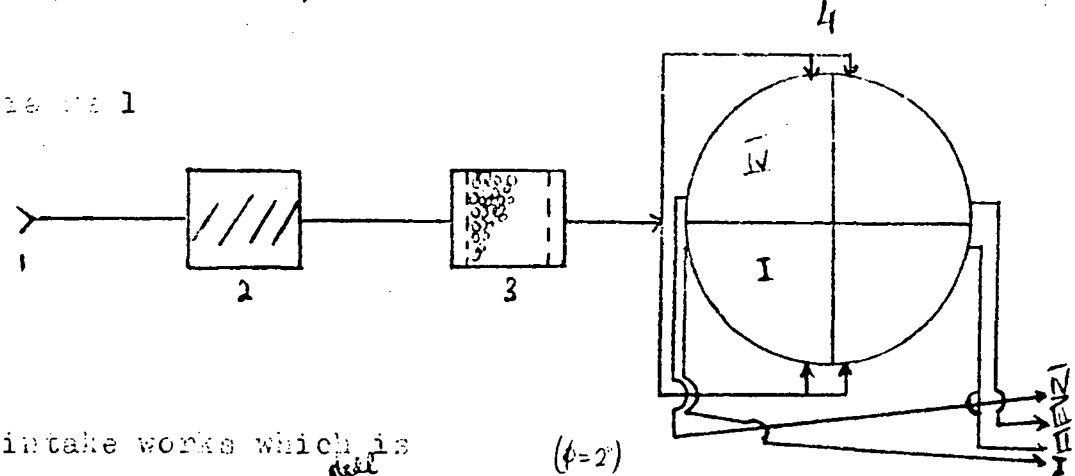
GRAPH 1. VISIBIL… DEPTHS AT ZOMBA PIL… PLANT RAW WATER 1982/1983



2.2. Zomba Pilot Plant lay-out

Diagram Nr 1 shows the lay-out of the Zomba pilot plant (not to scale).

Diagram Nr 1



1 = intake works which is (ϕ=2")

   a. a conventional steel intake pipe with wall perforations facing upstream in the river

   b. an intake gallery underneath the riverbed with riverbed filtration.

2. = tilted plate settling tank

3 = horizontal flow course gravel filter

4 = slow sand filter x 4 parallel tanks. (I, II, III and IV)

3. [illegible]

The above shown stages in the pilot plant will [illegible] be discussed according to the following pattern
- lay-out of design and some salient data
- literature recommendation
- experiments and results
- conclusions and recommendations.

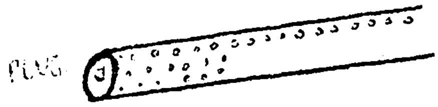
Up to slow sand filtration silt removal efficiency is the only concern.
The efficiency of pathogen removal is only [illegible] and discussed under slow sand filtration.

3.1. Intake works

3.1.1. Conventional intake pipe.

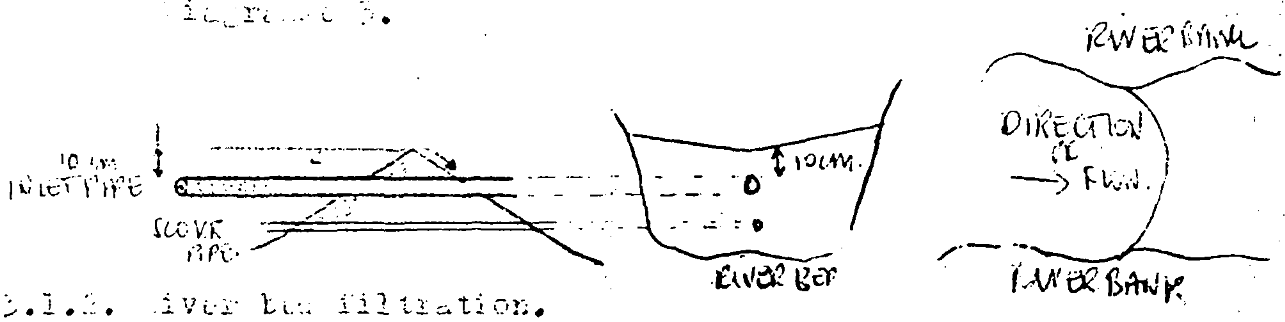
Conventional intakes of the rural water projects [illegible] a small intake pool, with or without a [illegible] weir to [illegible] the water level in the pool constant [illegible] the intake pipe. [illegible] [illegible] is closed with a plug at the [illegible] in the pipe wall of [illegible] diameter [illegible] area of 4 times the cross sectional surface area of the intake pipe. The intention is to prevent leaves and bigger debris from entering the pipe system, but allow sand and silt to enter.

Diagramme 2



Check next condition: this intake system works satisfactorily, although it needs frequent cleaning during the rains when the intake pipe and dam often backfill with sand and thus block the entrance of water.
For rivers which cannot be entered during the rains because of flooding care should be taken to place the intake pipe such and design the openings so that no cleaning or work is required to be done during the rains.
Intake works and dams should be kept to a minimum, disturbing the flow regime of the river as little as possible, thus keeping the risks for a change of course of the river very low.
Rather than a vertical damwall it is recommended to construct V shaped wall with slopes which aim to create the least hydraulic obstruction/resistance to the riverflow.

Diagramme 3.

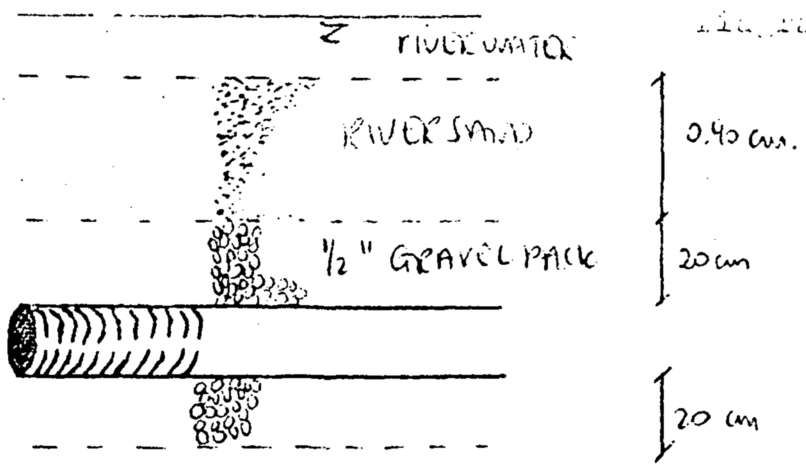


3.1.2. River bed filtration.

- Design and data

A slotted PVC intake pipe (110 mm diameter, 5 m. length, with 4 cm length slots of 0.5 mm wide in three parallel lines around the pipewall at 150 slots per running meter with an open surface area of [illegible] m^2/running meter) was buried in the [illegible] surface [illegible] (1 [illegible]) at approximately 30 cm with riverbed [illegible] refilled on top. (diagramme 4).

Diagramme 4.



The flow into the pipesystem was designed to be 80 l/min which meant a velocity through the slots of

$$v = Q/A$$

v= velocity through slots
Q= flow
A= total surface area of slots

$$= \frac{80\ l/min}{690\ cm^2}$$

$$= 0.02\ m/s$$

The recommended velocity in literature (3) is 0.1 m/s which seems very high for very turbid surface waters when compared with recommended velocities of 0.1 m/hr for slow sand filtration.

Results

The flow dropped within days to below 20 l/min

a. because of the sandpack clogging off with silt which accumulated in the toplayer of the sandpack
b. because of a fairly high percentage of slots getting blocked with sand (up to 30 % within a few weeks)
c, because of developing airlocks in the pipesystem.

In addition, the effluent quality of the system was poor after a shower of rain, with a visibility depth hardly better than the raw water quality.

Conclusion and recommendation

This technique is not suitable for rural water supplies.
under this condition in Malawi!

5.2. Tilted Plate Sediment[illegible]

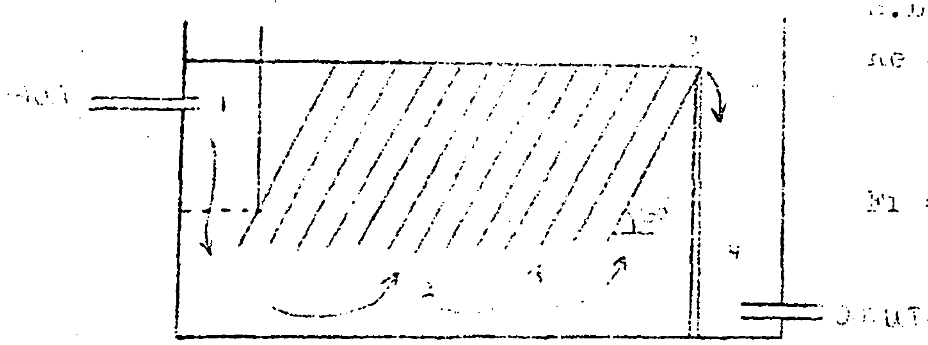
- Design and data see Diagramme 5.

$Q = 2.10^{-3}\ m^3/sec$ (= 3? [illegible])   Re = 53 (Reynolds)

T_{ret} = 12.5 min   Fr = 6.5.10^{-5} (Froude)

S.L. = 0.9 m^3/m^2.hr.

Diagramme 5.



Q = flow

T_{ret} = retention time

S.L. = surface loading

Re = figure of Reynolds which is an indication for turbulence. 50 shows no turbulence.

Fr = figure of Froude which indicates short circuiting. $0.5.10^{-5}$ indicates no short circuiting.

Literature describes a tilted plate sediment tank as having a much better and higher settling efficiency than a conventional sediment tank, and was for this reason tested on its efficiency of silt removal for the Dwaila water.

Results

The effluent of the tilted plate settlement tank were observed over a period of 3 years.

It was noticed that the plates accumulated a lot of silt during the rainy season, but that the effluent quality had not noticeably improved after passing through the settler.

The visibility depth remained unchanged.

This result is supported by a batch settlement experiment in a measuring cylinder of 500 ml which was filled with raw water (visibility depth less than 1 cm) and which was allowed to settle for a period of several weeks.

After 2 weeks (3 months) the silt had settled down to the 400 ml mark (150 ml), with a supernatant which was still reddish brown in colour, although clear. The visibility depth of the 400 ml water was less than 5 cm, which is not acceptable as raw water for slow sand filtration.

Conclusion and recommendation

Conventional sedimentation in a circular tank or rectangular tank without any devise to improve the hydraulic regime has proven to be adequate for the removal of sand and grit.

A tilted plate settler will perform the same function in a smaller volume, and is cheaper to construct.

However the often extra storage capacity which will ... [illegible] of the conventional type either is not available in the tube tilted plate settler.

Both conventional sediment tanks and tilted plate settlers are unsuited to remove silt such as the red silt in the Rufiji River sufficiently to be able to feed the effluent into slow sand filter.

3.3. FILTRATION

Apart from the above discussed sedimentation techniques research was carried out in the suitability of known filtration techniques for the removal of the fine silt in the raw water. Three systems were tested

- 3.3.1. Horizontal flow, coarse gravel filtration
  3.3.2. Slow sand filtration through a course sand bed +
  Slow sand filtration through a fine sand bed. +

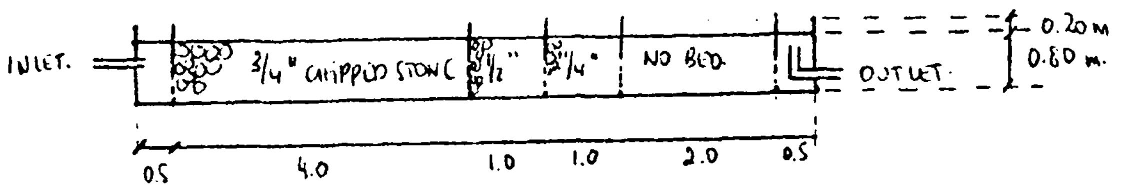
(specifications of the particle size distribution are attached in appendix 2).

3.3.1. Horizontal Flow Coarse Gravel Filtration

- Design and data see Diagramme 6.

SCALE 1 CM = 1 M.

WIDTH OF TANK 1 M.



Q = 70 l/min (= 4.2. m^3/hr) (flow)
S.L. = 5 m/hr (surface loading)
Cross sectional surface area = 0.8 m^2

- Literature recommendation
  The horizontal flow, coarse gravel prefiltration technique is recommended as a technique to reduce the turbidity of surface waters from up above 150 JTU (Jackson Turbidity Units) to below 50 JTU. Yet filterruns are reported to be as long as several years. (   ).

- Results
  Raw water with a visibility depth of less than 5 cm flooded the filter within a day, and produced an effluent with

a visibility depth hardly less than of the raw water.
In addition, the flow dropped considerably after a few hours of rain.
Filtercleaning which was required after every shower took 5 labourers 1.5 days which included cleaning out the tank, washing the filterbed material and refilling the tank.
The silt penetrated right through the filter, into the final compartment, which made the cleaning exercise so enormous.

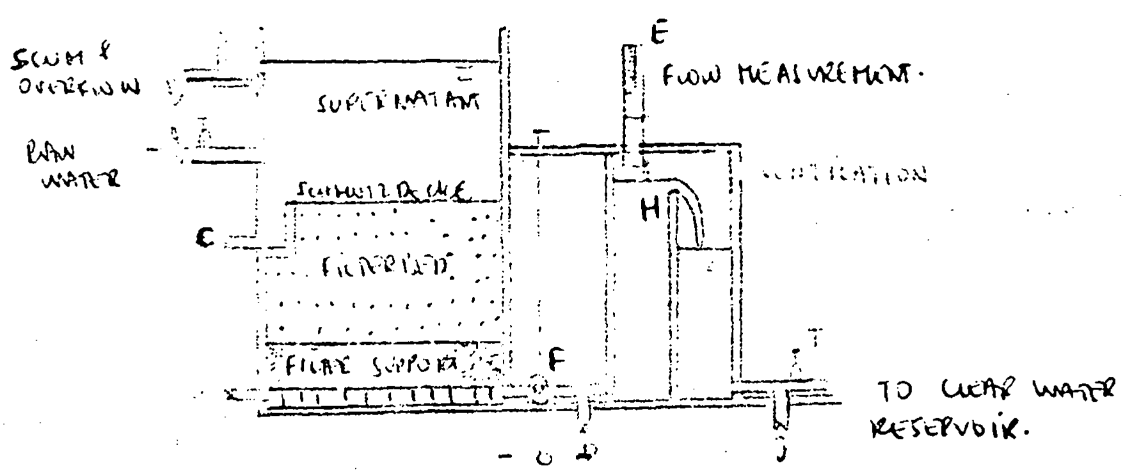
Conclusion and recommendation

This method of "filtration" which operates with very big pore volumes and mesh openings removes silt basically through adsorption of the siltparticles onto the chipped stone surfaces and through sedimentation.
To increase the efficiency of this system a vastly lowered loading should be practised (say in the order of 0.5m/hr). However, this would increase the required volume with a factor 10.
Although the removal efficiency will than likely increase, it is still very doubtful if the effluent quality will be good enough for feeding it into a slow sand filter.
In addition, the labour required to clean the filter when it does block, although likely after several weeks only, will be enormous (5 men for a plant supplying water to 5000 users for 1.5 days). Lastly the investment cost for this filter is enormous.
For above reasons it is not recommended to use horizontal flow, coarse gravel filters for rural piped water supplies.

5.5.2. Slow Sand Filtration

- design and data

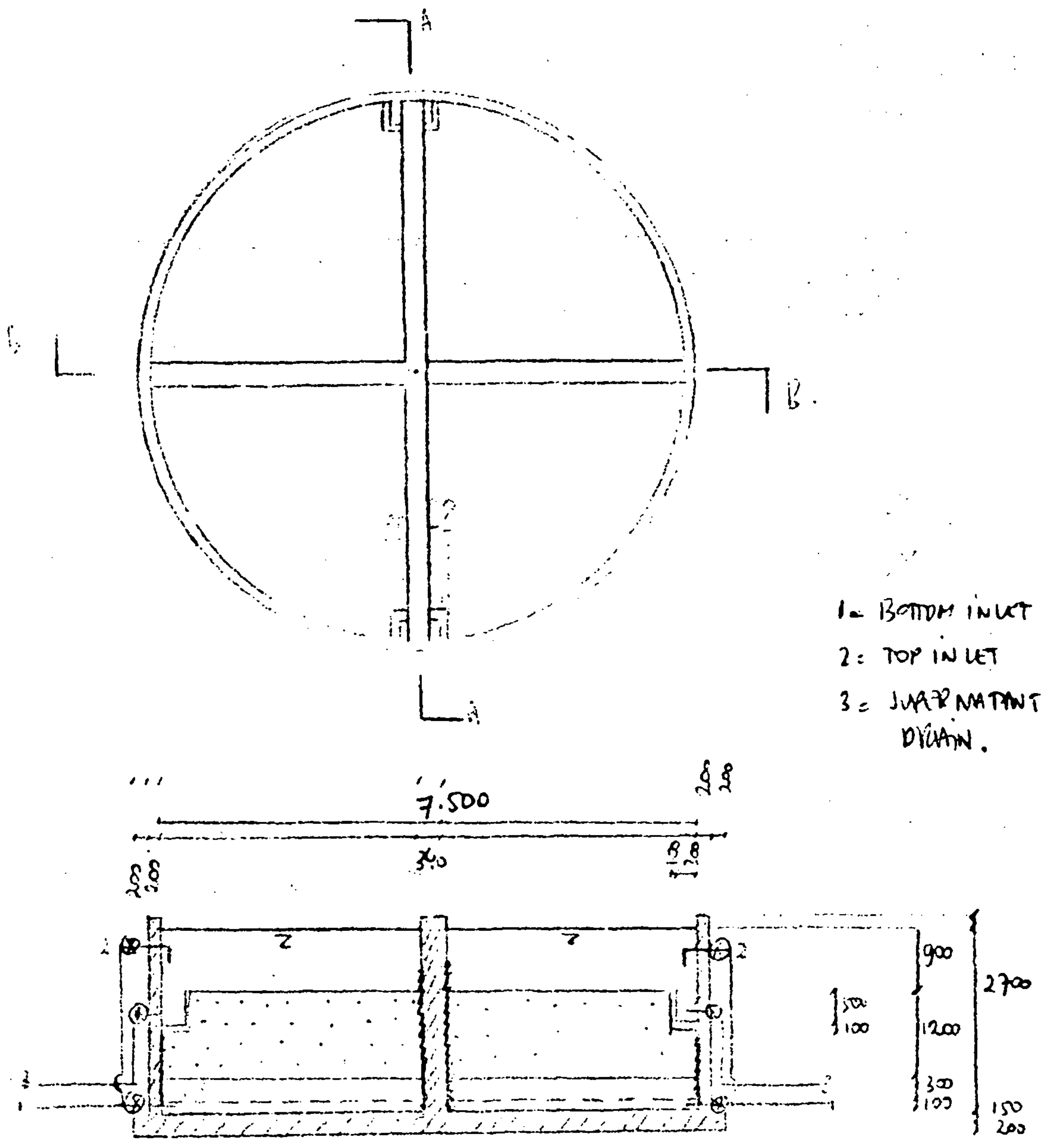
DIAGRAMME 7



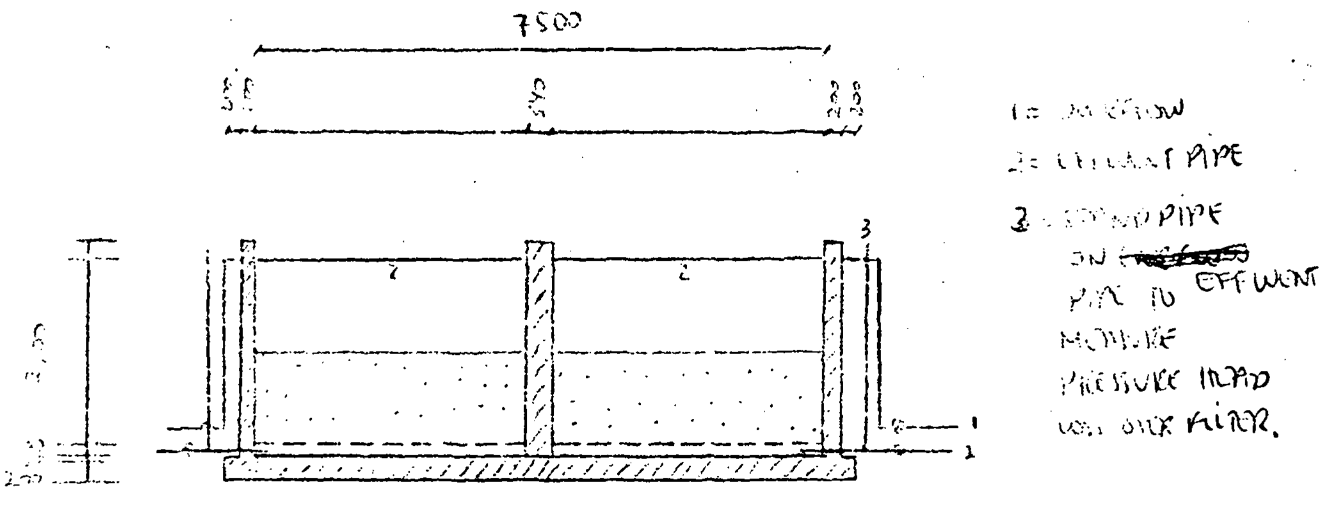
A = raw water inlet
B = overflow
C = supernatant drain
D = drain of effluent
E = flow measurement device
F = butterfly flow control
G = bottom inlet
H = prevention negative pres
I = effluent to sump
J = effluent to waste.

The Zomba pilot plant filters were 4 in number parallel tanks accomodated within a circular tank (diameter 7.5 m), divided into 4 compartments with dividing walls, with surface areas of 10 m^2/filter.
The actual design of the Zomba Pilot Plant was slightly different from the geberal design as in Diagramme 7, and is shown in Diagramme 8.

Diagramme 8 Zomba Pilot Plant lay-out. Slow Sand Filters



SECTION A-A



Section B - B.

Literature recommendation

Slow sand filtration is the process by which water is purified by passing it through a porous material at rates of 0.1 - 0.3 m/hr.

Due to the fine grain size the pores of the filter bed are small. The suspended matter present in the raw water are largely retained in the upper few cm's of the filterbed. This allows the filter to be cleaned by scraping away the top layer of sand. As low rates of filtration are used the intervals between two succesive cleanings will be fairly long.

The main purpose of slow sand filtration is the removal of pathogenic organisms from the raw water, in particular the bacteria and viruses responsible for the spreading of water related diseases ( ).

Slow sand filtration is an excellent method of water treatment for rural water supplies ( ).

Slow sand filtration provides a single step treatment for raw water not exceeding a turbidity of 50 NTU ( ).

Experiments

After testing and improving the slow sand filterplant during 1981 the real tests were done since 1982.

A comparison was made between unsieved dambo sand and unsieved riversand as locally found.

Daily recordings were taken of

- effluent flow as measured from the effluent pipes in l/min.
- influent and effluent visibility depth in cm.
- pressure head losses over the filters

Some escherichia coli counts were taken of both the raw water and the effluents.

Results

Table 1 LENGTH OF FILTERRUN IN DAYS

A Tank filled with coarse river sand

Run 1 During rains and with low flow velocity

Days	Visib. depth (cm)		Flow	Press. head loss
	raw water	effluent	(m/hr)	(cm)
1	< 5	> 30	0.14	80
2	< 5	> 30	0.13	92
3				
4	20	> 30	0.11	105

After day 4 filterrun was stopped.

Run 2 During rains with high flow velocity

Day	Visibility depth		Flow (m/hr)	Pressure head loss (cm)
	raw (cm)	effluent		
1	< 5	> 30	0.48	137
2	10	> 30	0.40	162
3	25	> 30	0.23	235
4	30	> 30	0.15	245

After day 4 filterrun was stopped, and filter cleane

Run 3 After rains and with low flow velocity

Day	Visibility depth		Flow	Pressure head loss
	raw (cm)	effluent	(cm)	(cm)
1	30	> 30	0.11	35
52	15	> 30	0.10	190

Soon after the filter was cleaned.

Tank filled with fine sand from dambo

Run 1 during rains with low flow velocity

Day	Visibility depth		Flow	Pressure Head Loss
	raw (cm)	effluent	(m/hr)	(cm)
1	< 5	> 30	0.1	156
2	20	> 30	0.06	183

After day 2 operation was stopped and filter cleaned.

Run 2 After rain with low flow velocity.

Day	Visibility depth		Flow	Pressure Head Loss
	raw (cm)	effluent	(m/hr)	(cm)
1	30	> 30	0.08	120
20	15	> 30	0.06	250

After day 20 filterrun was stopped and filter cleaned.

Run 3 after rain with low flow velocity

Day	Visibility depth		Flow	Pressure Head Loss
	raw (cm)	effluent	(m/hr)	(cm)
1	15	> 30	0.12	155
17	15	> 30	0.04	255

After day 17 filterrun was stopped and filter cleaned.

Run 4 After rain with low flow velocity

Day	Visibility depth		Flow	Pressure Head Loss
	raw (cm)	effluent	(m/hr)	(cm)
1	15	> 30	0.13	155
17	15	> 30	0.06	180

After day 17 filterrun was stopped and filter cleaned.

Conclusion

1. The filters filled with dambo sand had short filterruns, both during the rains and during the dry season, and the tanks filled with river sand had filterruns of several days even during the rains with visibility depth of less than 5 cm! and a flowrate of around 0.3 m/hr.
2. The effluent quality of both the river sand filter and the dambo sand filter was very good
3. During the dry season with raw water visibility depth of 15 cm the dambo sand filter lasted only around 20 days, whereas the riversand filter could operate more than 50 days.

Table 2 PRESSURE HEAD LOSS AFTER CLEANING OF FILTER

River sand filter			Dambo sand filter		
Date	Flow (m/hr)	Head loss (cm)	Date	Flow (m/hr)	Head loss (cm)
1/5	0.18	20	1/11	0.11	130
9/2	0.42	30	15/11	0.10	118
25/3	0.55	45	22/ 2	0.15	[illegible]
8/ 4	0.31	45	8/ 3	0.11	147
12/4	0.11	15	14/4	0.08	12[illegible]
9/6	0.08	20	1/6	0.11	135

Conclusions

1. Cleaning off the top 5 cm of the river sand filled filter after it has clocked rejuvenates the filter and restores the Head loss to its original value. This indicates that no resistance builds up underneath the top 5 cm of the filterbed, and that thus the silt does not penetrate beyond the top 5 cm.
2. Cleaning off the top few cms of the dambo sand filled filter also restores the original pressure head loss, although the figures are slightly more erratic. This may be due to the practise that only a very thin layer (approximately 1 cm or less) is removed, and that this may at times leave some silt pockets on the filtertop.

EFFLUENT QUALITY.

The visibility depths of both the river sand and the dambo sand filters are recorded in Table 1 and indicate that the quality is very good for both failter effluents.
However, a visible slight turbidity was observed in the river sand filter effluent, which was absent in the effluent of the dambo sand filters, although it was not enough to reduce the visibility depth below 30 cm.
In addition a slight brown color was noticed in the effluent of the river sand filter, which was not seen in the dambo sand filter.

[illegible]

An estimate of the volume of silt carried in the [illegible] during a heavy shower of rain was made by allowing the [illegible] water to settle in a measuring cylinder for a few months.

The volume of silt found at the bottom of a 500 ml measuring cylinder was less than .5 ml which indicates a siltvolume of less than 0.1 % in the raw water at a visibility depth of less than 5 cm.
The porevolume of the riversand was measured at 30 %.
At a penetration depth of the silt of 5 cm into the filterbed, and a flowrate of 0.3 m/hr the porevolume will be filled with silt after a [illegible] day run, assuming a visibility depth of less than 5 cm continuously.
This outcome supports the data in Table 1.

COLI COUNTS

Table 3 ESCHERICHIA COLI REMOVAL EFFICIENCY

Date	Raw water	River sand filter			Dambo sand filter		
	counts/100 ml	No days	counts/100 ml	eff (%)	No of days	counts/100 ml	eff (%)
30/3	100,000	5	10,000	90			
19/4	50,000	10	1,700	95	5	700	-
31/5	50,000	50	200	99			
23/6	100,000	16	-	100	16	-	100

All counts are the average of 2 samples.
Deviation from average was not more than 20 %.
No of days stand for the number of days of operation.

Conclusions
The E coli removal efficiency is 90 % or over for both river sand and dambo sand filters, and regardless the length of the filterrun.
The sandfilter filled with riversand reached an efficiency of 99 % after about 2 months running.
Generally the dambo sand filter had higher removal efficiencies than the riversand filter.

5.3.3. OVERALL EVALUATION

A slow sand filter filled with course sand of a local river can remove high silt loads very efficiently at a flow rate of 0.3 m/hr, and will even remove approximately 90 % of the pathogenload.
During times when the raw water visibility depth has gone down to below 5 cm the filterrun will be reduced to only a few days before cleaning out of the top 5 cm of the filtersand is required.

The cleaning of the sand and the refilling will require 1 labourer per 10 m^2 for 1 day, as was found in Zomba on the pilot plant.
For silty rivers it is recommended to have a Phase 1 which removes the turbidity as well as 90 % of the pathogen load, and which phase is followed by Phase 2 which should operate at a flowrate of 0.15 m/hr and which is mainly concerned with the removal of pathogens.
A removal rate of 99 % should be obtainable in Phase 2 assuming that filterruns will reach up to 2 months and more, because of the virtual absence of turbidity.
An overall removal efficiency of 99.9 % for the above 2 phased treatment system should be possible.

4. DISCUSSION AND RECOMMENDATION FOR DOMBOLE AND KWANZA RURAL PIPED WATER SUPPLIES

Two projects will be discussed which are both under construction and need both a treatment process before the water can be served to the consumers.
Both examples are typical examples. Dombole project will use the Dombole river as its watersource as from April onwards up to the next rains. During this time the river is clear but has a considerable pathogenload of approximately 100 Faecal coli/100 ml (as measured by the senior water chemist on 4.3.'85).
The Kwanza river which is the single source for the Kwanza Valley project carries very high silt loads during the rains and no silt during the dry season (see Graph). All year around it has very high pathogen loads as was measured by Blantyre Water Board and the author of up to 20,000 E. coli/100 ml.

4.1. DOMBOLE TREATMENT WORKS PROPOSAL

The only function of the Dombole river treatment works is to reduce the pathogen load.
A slow sand filter operating at a rate of 0.1 m/hr and filled with an unsieved riversand (which should be clean) with a filterbed depth of 1.2 m should be sufficient.

At a design flow of 120 gpm a total filtersurface area should be required of 360 m². With 1 extra filter available whenever a filter needs to be cleaned, 3 tanks of 180 m² each will be required. At an estimated cost of K 100.- per meter square a total of K 54,000 will be required to construct the filters (transport cost excluded).
At a transport cost estimate of 50 % of the construction cost the total comes to

construction cost	K 54,000
transport cost	27,000
contingencies etc.	10,000
TOTAL	K 91,000.-

Filteroperation

Since slow sand filtration is new in the rural piped water projects and therefore operational practises and routines have to be developed and trained to staff it is very important to design a monitoring routine system for this first plant for at least 1 year.
The responsibility for the monitoring programme should be under the direct responsibility of a qualified engineer, and the data should be condensed into a report at the end of the first year. A "Monitoring programme for slow sand filters" is attached in Appendix .

Consequent to the monitoring year a manual should be drawn up for the Plant Operators and a training course developed for operators

4.2. KWANZA VALLEY TREATMENT [illegible]

To make Kwanza river water fit for human consumption is a real challenge. Kwanza river is namely carrying high silt loads during the rains (below 5 cm visibility depth) as is illustrated by Graph , and has high pathogen loads during the whole year.(see Table 4).

GRAPH 2

[illegible]ISIBILITY DEPTH IN [illegible]RANZA RIVER
AT JASICHINDOKO (cm)

1982/1983 SEASON

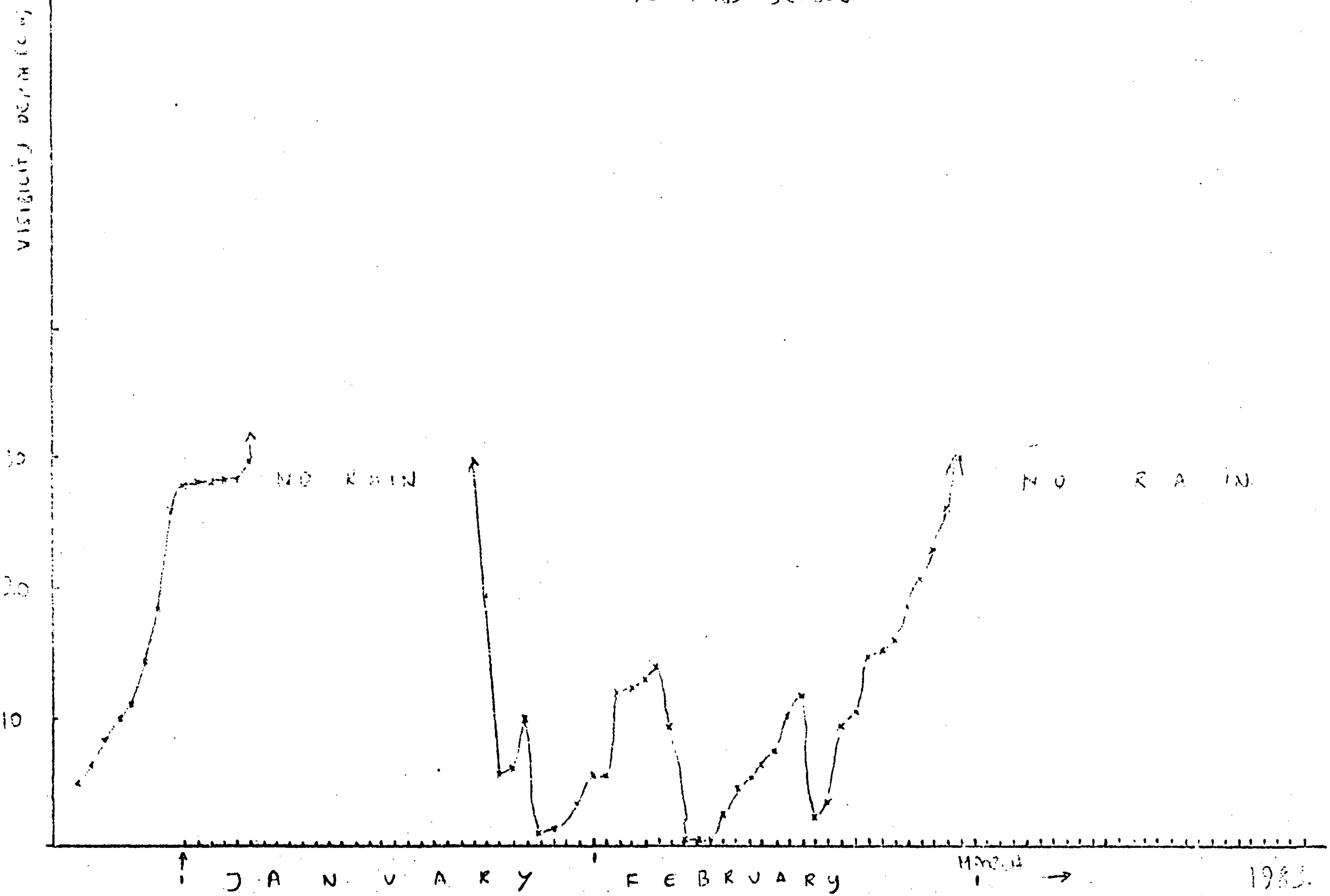


Table 4 [illegible] RIVER [illegible]

date	E.coli count / 100 ml
[illegible]	18 - 2000 (Blantyre Water Board)
[illegible] 1.82	15,[illegible]-18,000 (Blantyre Water Board)
[illegible] 1.92	13,000-18,000 (Blantyre Water Board)
[illegible]	approx. 20,[illegible] (Millipore on site)

During the 1982-1983 season the turbidity did not go beyond a visibility depth of less than 5 cm for more than a few days between the end of January and mid February. In addition does the river clear fairly quickly after rain, although it may take a couple of days to reach a visibility depth of 15 cm. Taking into account that 1982-1983 was a very dry year, it is assumed that a normal year will be a year with high turbidity for a period of 3 months, although there will be spells in between with lower turbidities.

A test in a measuring cylinder to establish the settlement characteristics of the silt showed that the silt has very much the same settling velocity as the raw water of the Bwalla river, namely several weeks to settle even a few cms.

A 2 phased treatment plant is suggested as described under "Recommendation" on pages 14 and 15.
The Phase 1 will consist of 2 parallel tanks, with 1 tank operating at the time. During the rains each tank will likely operate for periods of a few days, however, this should enable the operators to clean the top 5 cm. of sand and refill it, before the parallel tank cuts itself out.
The Phase two will consist of 3 tanks, 2 of which operating at the time, and a 3'rd one as a stand-by, to take over whenever 1 tank needs cleaning.

An overall removal efficiency of 99,9 % of the pathogen load should be obtained which should reduce the count from 20,000 to 20 or below. This is quite acceptable.

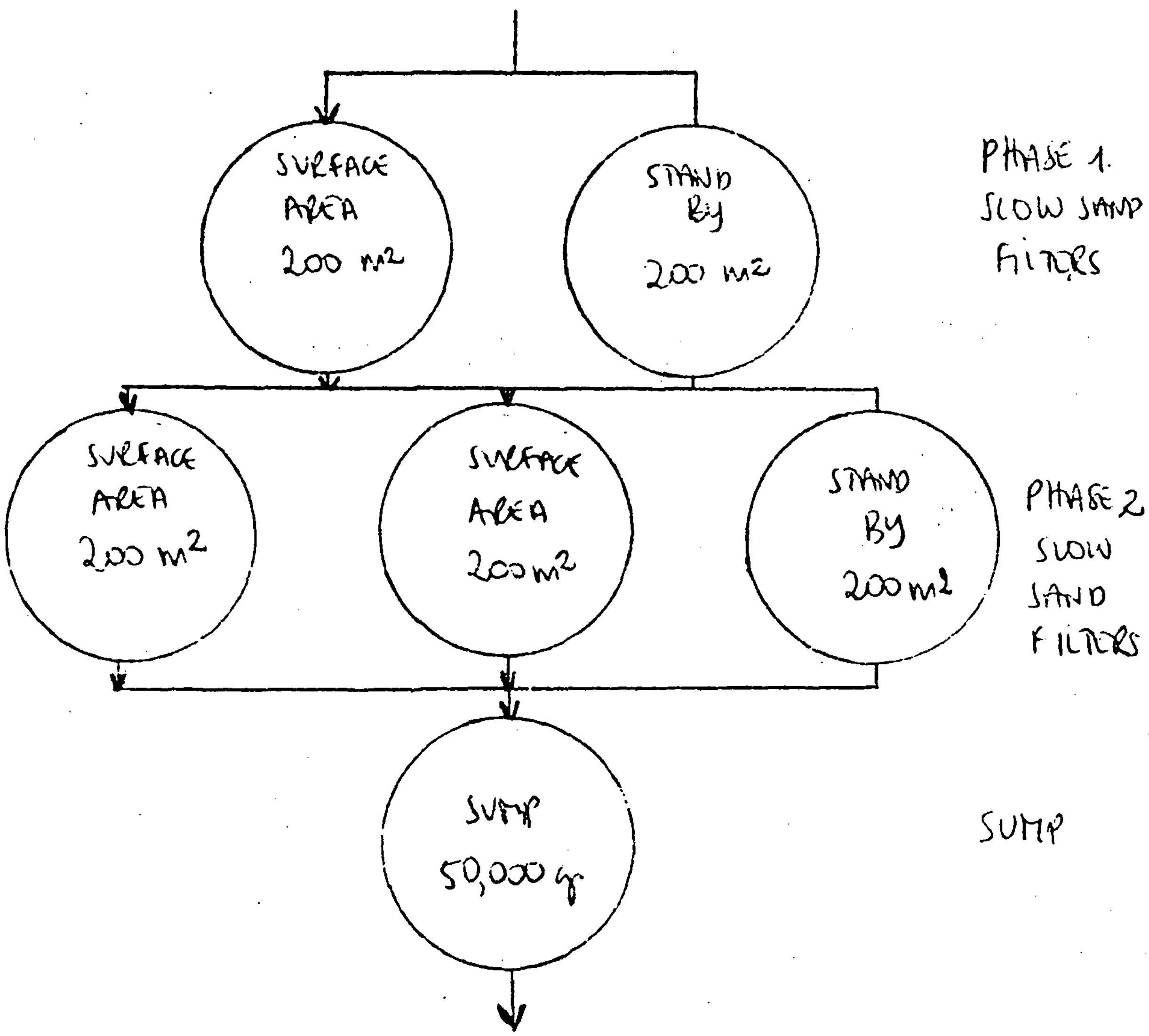
In order to experiment with the above layout it is suggested to have a treatment works build at Kubalalika which will serve a population of 5000 users. The plant is sited and ready for construction now, during 1983. The feasibility and effluent quality of the system will be shown by this plant, during the 1983-1984 rainy season.

Before the raw water reaches the treatment plant it has already passed through a grit trap which removes all bigger sand particles and grit.

After the treatment plant at Lubalahina has been made to work properly, will the construction of the Makina Kaboliti tanksstart, which site has been found already.

A layout for the Makina Kaboliti plant is shown in Diagramme 9.

DIAGRAMME 9 <u>MAKINA KABOLITI LAYOUT</u>



Sand for the filterbeds was found within a distance of 15 miles from the site. Appendix gives the particle size distribution.

Cost Estimate

Mulalalika plant

2 tanks a 64 m^2 a K 100/m^2	K 12,800
sump of 10,000 g	6,000
transport	9,000
contingencies which includes a house and a fence	5,000
TOTAL	K 32,800

Makina Kaboliti plant

5 tanks a 200 m^2 a K 100/m^2	K 100,000
sump of 50,000 g	10,000
transport	55,000
contingencies including a house and a fence	35,000
TOTAL	K 200,000

Grandtotal for the Mwanza Valley Treatment Plant
K 232,800.-

Monitoring programme

It is very important to establish a monitoring programme for the Mwanza Valley treatment works right from the start. The objectives should be

- to assess the feasibility of the proposed layout for the Mwanza water
- to determine the filterrun lengths of Phase 1 and Phase 2 over one full year
- to monitor the effluent quality of Phase 1 and Phase 2 (both turbidity and pathogen load) over 1 full year
- to record the operational costs
- to develop the operational routines and supervision requirements for this treatment plant in the staff and to write up a manual and training programme.

A checklist and data record sheet for the above programme is attached in Appendix .

5. FINAL CONCLUSION

The objective of the experiments carried out with the Zomba Pilot Plant was to find a suitable method of treatment for polluted raw water in rural areas of Malawi, which treatment process was to be cheap and simple in operation, easily understood by the user and hardly trained operators, and which process can not deteriorate the quality of water even under very poor operation.

The results of the experiments indicate that a possible solution to remove both turbidity and high pathogen loads from raw water is a 2 phased slow sand filtration process with Phase 1 mainly removing the siltload and Phase 2 removing the pathogen load further.
However, during the rainy season this treatment process will be fairly labour intensive because of the regular cleaning off of the accumulated silt from the filtersurface. But under a proper supervisory system this should be possible and quite a lot more attractive than costly alternatives, both in terms of transport and chemical inputs.

Proposals for two projects, Dombole and Mwanza, complete the report, which plants should however be carefully monitored during the first year of operation to collect the information and operational experience required to train operators and write an operational Manual.

Appendix 1

[illegible]

A ruler with a red painted bottom up to the 0 mark is inserted into the water drawn from the source in a bucket. The depth up to which the ruler can be inserted with the red mark on the ruler still seen is the visibility depth and is recorded on a record sheet as a daily reading.
Taken over a full season this gives an accurate idea about the turbidity of the water.

The test can be done by unskilled personel.

Appendix 2

SPECIFICATIONS OF PARTICLE SIZES AND PARTICLE DISTRIBUTION FOR RIVER AND DAMBO SAND AS USED IN THE SLOW SAND FILTER AT THE ZOMBA PILOT PLANT

particle size (mm)	river sand (g)	river sand (%)	dambo sand (g)	dambo sand (%)
4.8-2.4	12	1		
2.4-1.2	57	7	10	1
1.2-0.6	320	41	[illegible]	7
0.6-0.3	305	39	[illegible]	23
0.3-0.15	46	6	[illegible]	36
0.15-0.07	20	3	[illegible]	25
< 0.07	15	2	60	8
TOTAL	787	99	786	100
d_{10}		0.3		0.075
d_{60}		0.6		0.3
U		2		4

Thus riversand fairly uniform and dambo sand less unfiorm.

Appendix 3

CHECKLIST [illegible]

[illegible]

1. Daily recordings

   - visibility depth
     influent (= raw water)
     effluent (if applicable) of Phase 1
     Phase 2

   - flows into Phase 1
     Phase 2
     sump

   - Pressure head loss over Phase 1
     Phase 2

2. Weekly recordings (but not less than monthly recordings).

   - E coli count raw water
     effluent Phase 1
     effluent Phase 2

3. Recordings when cleaning off Schmutzdecke

   - labour time to clean the filter sand off
   - time to empty tank, clean off sand, backfill sand and start operation again (phase 1)
   - amount of sand cleaned off (in wheelbarrows or m^3)
   - time required to clean the filtersand in the cleaning tank.

4. Recordings of any observation made which is not normal.

SHEET ACCORDING TO SLOW SAND FILTER

FORM 1. SSF

DATE	VISIBILITY DEPTH (cm)						FLOW (m/hr)					PRESSURE HEAD LOSS (cm)				
	RAIN WATER	PHASE I		PHASE II			PHASE I		PHASE II			PHASE I		PHASE II		
		T_1	T_2	T_1	T_2	T_3	T_1	T_2	T_1	T_2	T_3	T_1	T_2	T_1	T_2	T_3

FORM 5.12.

E. COLI REMOVAL EFFICIENCY.

DATE	RAW WATER			PHASE I								PHASE II											
				TANK 1				TANK 2				TANK 1				TANK 2				TANK 3			
	V_{SAM}	COUNTS E.COLI	E.COLI / 100ML	V_{SAM}	COUNTS E.COLI	E.COLI / 100ML	N_{EFF} %	V_{SAM}	COUNTS E.COLI	E.COLI / 100ML	N_{EFF} %	V_{SAM}	E.COLI COUNTS	E.COLI / 100ML	N_{EFF} %	V_{SAM}	E.COLI COUNTS	E.COLI / 100ML	N_{EFF} %	V_{SAM}	E.COLI COUNTS	E.COLI / 100ML	N_{EFF} %

FORM JSF 2

TANK CLEANING RECORDS

DATE	INSPECT TANK No.	EMPTYING, CLEANING AND BACKFILLING					WASHING SAND					AMOUNT OF SAND CLEANED
		STARTED		FINISHED		NO OF LABOURERS	STARTED		FINISHED		NO OF LABOURERS	m3.
		DATE	TIME	DATE	TIME		DATE	TIME	DATE	TIME		15 WHEEL BARROWS = 1 m3

Appendix 4

PARTICLE SIZE DISTRIBUTION FOR MWANZA AND KAKOMA RIVERS

Size (mm)	MWANZA RIVER (g)	(%)	KAKOMA RIVER BAND top sand (g)	(%)	bottom sand (g)	(%)
above 4.7	3	1			4	1
4.7-2.4	9	3			10	2
2.4-1.2	35	12	15	5	68	17
1.2-0.6	120	40	28	9	178	45
0.6-0.3	115	38	140	44	102	26
0.3-0.15	22	7	120	38	27	7
0.15-0.07	negl		10	3	4	1
TOTALS	304	101	315	99	393	99
d_{10}		0.20		0.1		0.15
d_{60}		0.45		0.25		0.50
U (uniformity)		2.3		2.5		3.3.

The Mwanza river sand as excavated at Jasichindoko is acceptable for the filterbed material.
The Kakoma river sand is not uniform enough, in particular when top and bottom sand are mixed up.

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NOTES ON FLOW CONTROL ARRANGEMENTS FOR SLOW SAND FILTRATION

. INTRODUCTION

The two write-ups which were done cover:

- the treatment lay-out and principles by H. van Schaik
- the design for the Kubalalika and Makina Kabeliti tanks by R. Neakes.

The first write-up by H. van Schaik covers the treatment arrangements for the very turbid and highly polluted Mwanza river water. The recommendations are based upon the outcome of experiments conducted in Zomba at the pilot treatment plant over a period of 3 years. However, definite research with the Mwanza water itself was not done. For this reason it is important that the Kubalalika treatment plant is built ahead of the Makina Kabeliti plant, the main works. The Kubalalika plant should be operational for 1 year to test the appropriateness of the suggested and proposed treatment system for the Mwanza water.

The design by R. Neakes can be duild without too many problems since it is basically very similar to the designs of the storage tanks which are built in the rural water supplies. However, the flow control devices regulating the supply and demand as well as the controls over washing and backfilling have not been designed and thought out carefully.

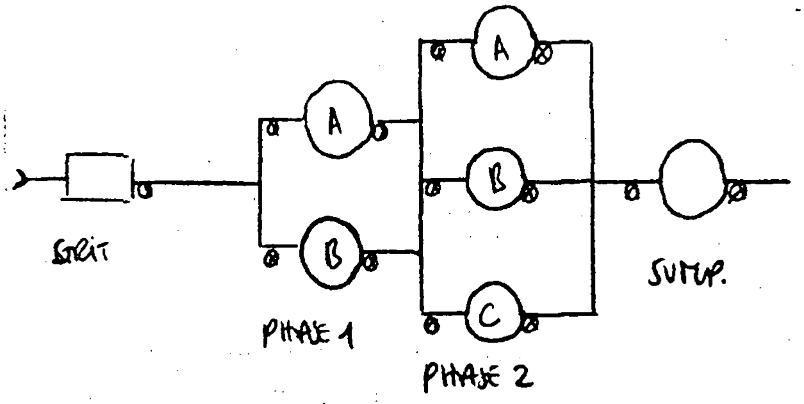
The intention of these notes is to give a few suggestions for the flow control system. In addition I will try to find some advise in Netherlands in return for you on this particular point.

2. TREATMENT PLANT AND CONTROL POINTS

The proposed treatment plant at Mwanza consists of:

- grit trap
- Phase 1 filter
- Phase 2 filter
- Sump.

A lay out of the plant is drawn in Fig. 1.



The devices to control the flows will address two main issues:

1. the actual distribution of the water over the individual tanks;
2. the matching of supply and demand.

2.1. DISTRIBUTION OVER THE PLANT

To enable proper control over the distribution over water over the operational tanks and filters it is important to have control valves installed at all branches of both inlet and outlet lines, of all the tanks which are part of the system.

The flow control valves should be installed such that they are easily operational and clearly positioned to prevent confusion.

2.2. <u>THE MATCHING OF SUPPLY AND DEMAND</u>

The matching of supply and demand is required at each stage of the plant and will therefore be discussed per each stage:

- GRIT TRAP

The amount of water passing through the grit trap is equal to the design flow of the inlet pipes and is not meant to change at any time.

During the dry season, during times of low silt loads, the grit trap can function with closed scour plug, but during the rains the grit trap can be made self scouring by having the scour plug open.

- PHASE 1 TANKS

The flow entering the Pahse 1 tank in operation is the design flow of the top section. However, the flow processed through the Phase 1 filter should be the demand of the users and not more, since any extra will shorten the lifespan of the operation.

For this reason it is suggested to have a ball valve controlling the outflow of the Phase 1 tank, which valve is located on the point of inflow into the Phase 2 tank, and which closes off when the water level of the Phase 2 tank filter reaches its maximum height.

PHASE 2 TANKS

The inflow into the Phase 2 tanks is equal to the total outflow of the Phase 1 tanks, which outflow is regulatee by the flow float valve on the inlet pipe into the tanks.

Phase 1 consists of 2 tanks, wit only 1 being in operation at any one time wit and wit the second tank either being cleaned or at stand by.

The distribution of the outflow of Phase 1 tanks over the 3 operational tanks of Phase 2 is controlled by water flow meters which should be installed on the outlet side of the operational Phase 2 filters, and which should be read daily and flows should be calculated, in order to find the evenness in the distribution over the operational filters of the required flow, and production.

The total production of the operational filters is regulated by a float valve in the sump

If the flows of the operational tanks were not as required, the flow adjustment can be made by opening or clsing the control valves on the outlet side of the tanks a little thus increasing or decreasing the out-flow of a particluar filter aiming to balance the flows as per designed operation.

It is suggested to have the opening of the float valve controlled inlet above the ~~xxxxxxxxx xxxxx xx~~ maximum water table thus allowing for sprinkling of water into the tank at the entry moment which will allow for reaeration.

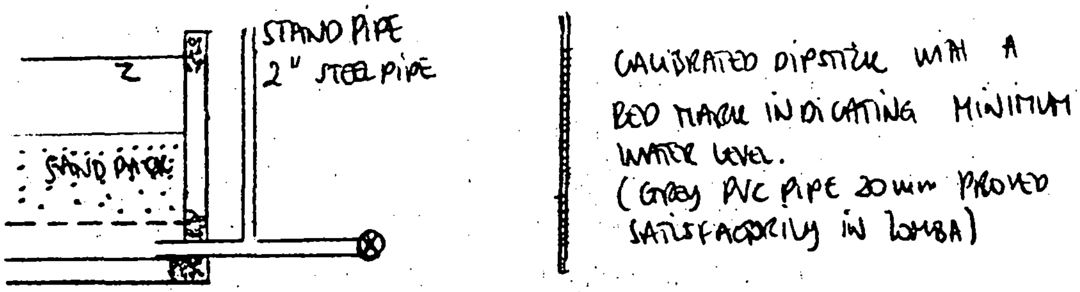
REFILLING OF TANKS

After cleaning filter tanks must ~~xxxxx~~ always be filled from the bottom upwards to prevent air from getting trapped in the sand pack/ This filling can be done very easily by allowing the moutflow of a parallel tank to fill the just cleaned tank up till just above the sand pack. Thus clean water is used to fill from the bottom, which will not affect the sand pack material. The valves could be temporarily arranged such that the flow into the next stage or Phase is stopped in order to fill up the parallel tank% filter.

It is obvious from the above point that the levels of the parallel tanks must be set very accurately to enable this backfilling to happen.

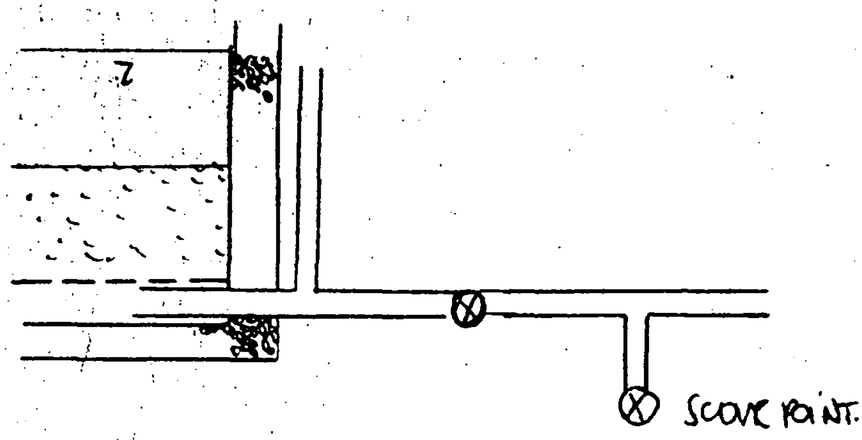
4. CLEANING OF TANKS/FILTERS

All filters should be outfitted with a standpipe (open) in the outlet pipeline, which reaches the top of the tankwall (see diagramme 2)



The level of water in this stand pipes should be measured daily by the plant operator with a dip stick which has a red mark on it indicating the minimum water level which is the lvelel at which the filter bed should be cleaned by removing the top 5 cm. of the sand pack.
The dip stick measurements must be taken daily and recorded on a record sheet for inspection by the engineer in charge.

When a filter needs cleaning, the supernatant water is allowed to drain away. The drain points are scour points in the outlet lines just beyond the control valves and the stand pipes of the tanks.(see diagramme 3).
As soon as the water level has dropped to some cm. below the filterbed surface cleaning can be started. It is very important not to allow the filter to be drained completely, since the refilling volume and time will be lehgthened linearly.



5. VALVE NUMBERING AND OPERATIONAL INSTRUCTIONS

It is very important to work out a good valve number system which should be used consequently to design the operational instructions for the different operations such as changing over from Filter 1 to Filter 2 in Phase 1,

the valve operations to clean or refill a filter etc.
The operational instructions should be in short and clear format for a minimum trained operator.

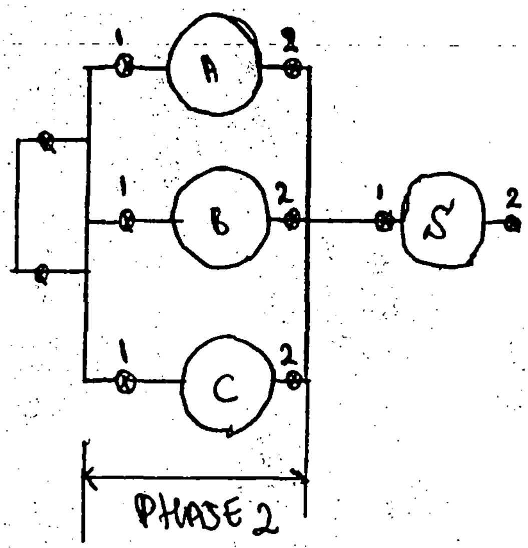
6. CLEANING OF SAND

The cleaning of the sand from the Phase 1 filterbeds can be done on site in a small cleaning tank using the clean outflow from the Phase 1 filters. The cleaning tank could be sited within the drain gully from the Filetrs. The sand can be cleaned by agitation with a shovel or other tool, and can be brought back onto the filter immediately afterwards.
Phase 2 sand should not be brought back immediately afterwards, which is according to the literature on this bad practise because it will destroy the biological top layer of the filterbed, thus reducing the removal efficiency.
Phase 2 filters should be cleaned until the resanding level is reached, which should be set at about 0.5 sand pack remaining. When this level is reached all sand should be removed and the sand pack replaced with clean sand.

7. EXAMPLE OPERATIONAL INSTRUCTION:

Refilling of Filter A Phase 2.

Lay out of plant and valves:



Assuming that Filters B and C are operational the refilling from the bottom is done with effluent water from Filetrs B and C.

Close Valve S-1

Open valve A 2

Allow the water to enter A up till level of water is above the sandlevel.

Close A 2 and open s 1 again.

Operation completed.

H.P.J. van Schaik
SENIOR WATER ENGINEER

Zomba 30.8.1983.