INTEGRAL FILTER SYSTEMS FOR RESERVOIRS OF SMALL EARTH DAMS

Volkhard W. Werner

Summary

At Waiya earth dam, Machakos District, a graded sand filter was placed into the alluvial deposits and decomposed rock strata of the reservoir to test the treatment capacity of an integral filter system. After 30 % impoundment of the reservoir, tests on yield, chemical and bacteriological treatment were performed. First results indicate a moderate yield of the filter system but substantial improvement of the water quality.

Introduction

Water development activities in rural areas of Kenya achieved quite some momentum during the past decades in order to reach the long range target of supplying all of Kenya's population with tapped water.

During this long and costly development process a number of interim solutions still will be required, especially in the arid and semi-arid regions of the country, where suitable water resources are scarce.

The objective of this paper is to demonstrate, how simple structures, such as a small rural earth dam, can be modified to serve the population such which

could be a first step on the way towards safer water. This paper does not originate out of a research programme, but out of practical experiences obtained during the ongoing implementation of a multi-sectoral rural development programme, whereby water development is a component amongst others.

Certainly, the results obtained up to now may be of individual and interim nature. But it is expected, that the paper will stimulate the planning and design engineers in the field of soil and water conservation to pay some additional thought to development possibilities of solutions, which are just termed conventional means in rural water supply for arid and semi-arid areas.

Under the EEC financed Machakos Integrated Development Programme (MIDP) the construction of small rural earth dams has been a major component during the initial stages of the project. In order to improve the water quality of the respective reservoirs, tests with an integral filter system incorporated into the bottom of the reservoir have been performed at Waiya Dam, Machakos District. First results of the performance of such a system are now available and are rather promising as shown in this paper.

WATER STORAGE BY SMALL RURAL EARTH DAMS

The water impounded by a small earth dam is generally not of the quality acceptable to human consumption. The poor raw water quality is further dimi-

nished by human and animal related contamination. The reservoirs of such dams are endangered by many water based infections, which increases the problem to use such reservoirs as a source for untreated water supply.

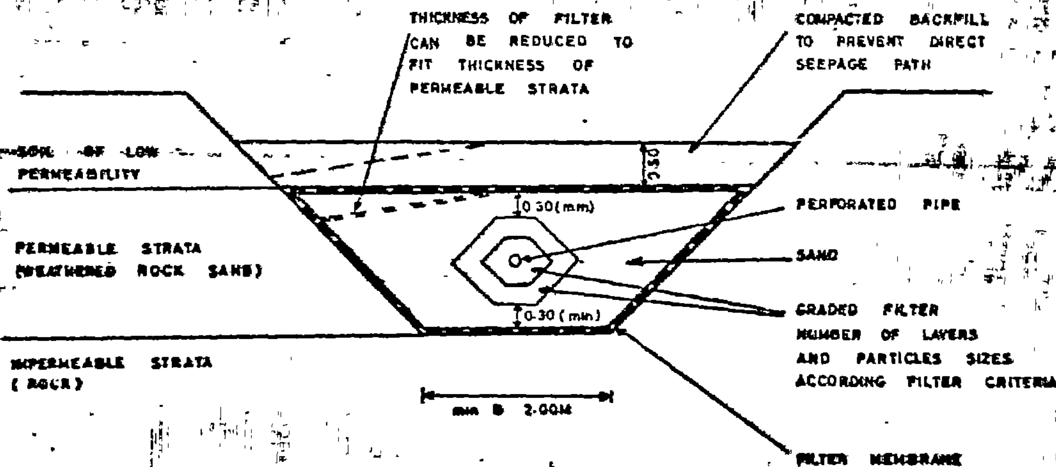
In most cases the storage capacity of these small dams is such that water treatment in the conventional sense can not be justified. The installation of a small treatment plant to produce water of chemical and bacteriological acceptable properties would be too costly. Furthermore the construction of such plants would lead eventually to a multitude of mini-Water projects being again too costly in terms of operation and maintenance, not to mention the logistical problems involved to keep them in proper operation, in the first place.

Under the MIDP water programme special emphasis was therefore devoted to the search of a treatment system which would use a minimum of operation and maintenance efforts. The integral filter system could offer such a solution.

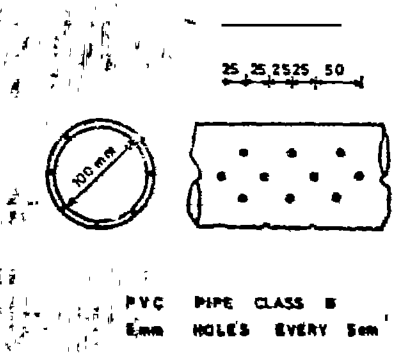
THE INTEGRAL FILTER SYSTEM

The Integral Filter System consists of a perforated PVC pipe of 100 mm diameter which is embedded in graded filter medium and placed at the bottom of the reservoir, see. Figure 1.

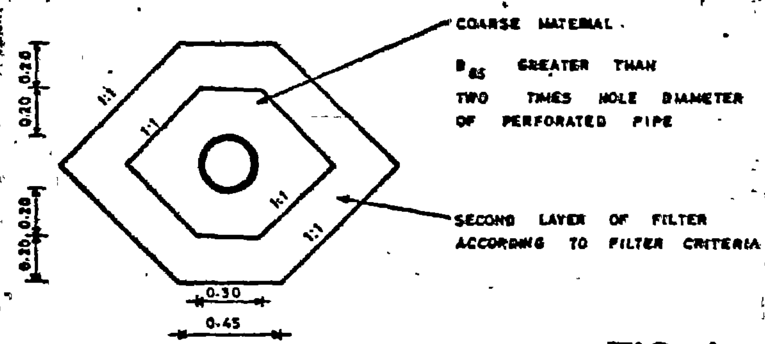
This filter package is placed into run-off the bank sand with a minimum thickness of 0.3 m at the bottom and 0.3 m at the top. The whole filter system including of the surrounding sand layer is wrapped by a



CROSS SECTION



DETAIL OF PERFORATED PIPE



DETAIL OF FILTER

FIG 1 DETAILS OF FILTERSYSTEM

spunbonded filter membrane to prevent eventual clogging of the filter layers.

The top of the filter is covered by about 0.5 m slightly compacted backfill to prevent development of a direct seepage path into the filter. The filter is preferably placed such that the permeable strata of the reservoir are adjacent to the filter. These permeable strata are frequently found in the old river bed, it's banks and in branches of the river, if any.

As the dam structure is normally located at the narrowest section of the valley, a bay type valley section is found upstream, accomodating the reservoir. Alluvial deposits of higher permeability are frequently encountered within this reach which favours the placing of the filter system.

The filter pipe is connected to a draw-off pipe which leads to the valve chamber located downstream of the dam. A public water point is connected with this valve chamber, see Figure 2. For supply of the cattle trough the conventional draw-off system should be chosen in order to safe the filtered water for human consumption.

Special attention has to be paid during the placing of the draw-off pipes and the construction of the core trench of the dam, as negligence during that stage of construction could lead to eventual piping and failure of the structure.

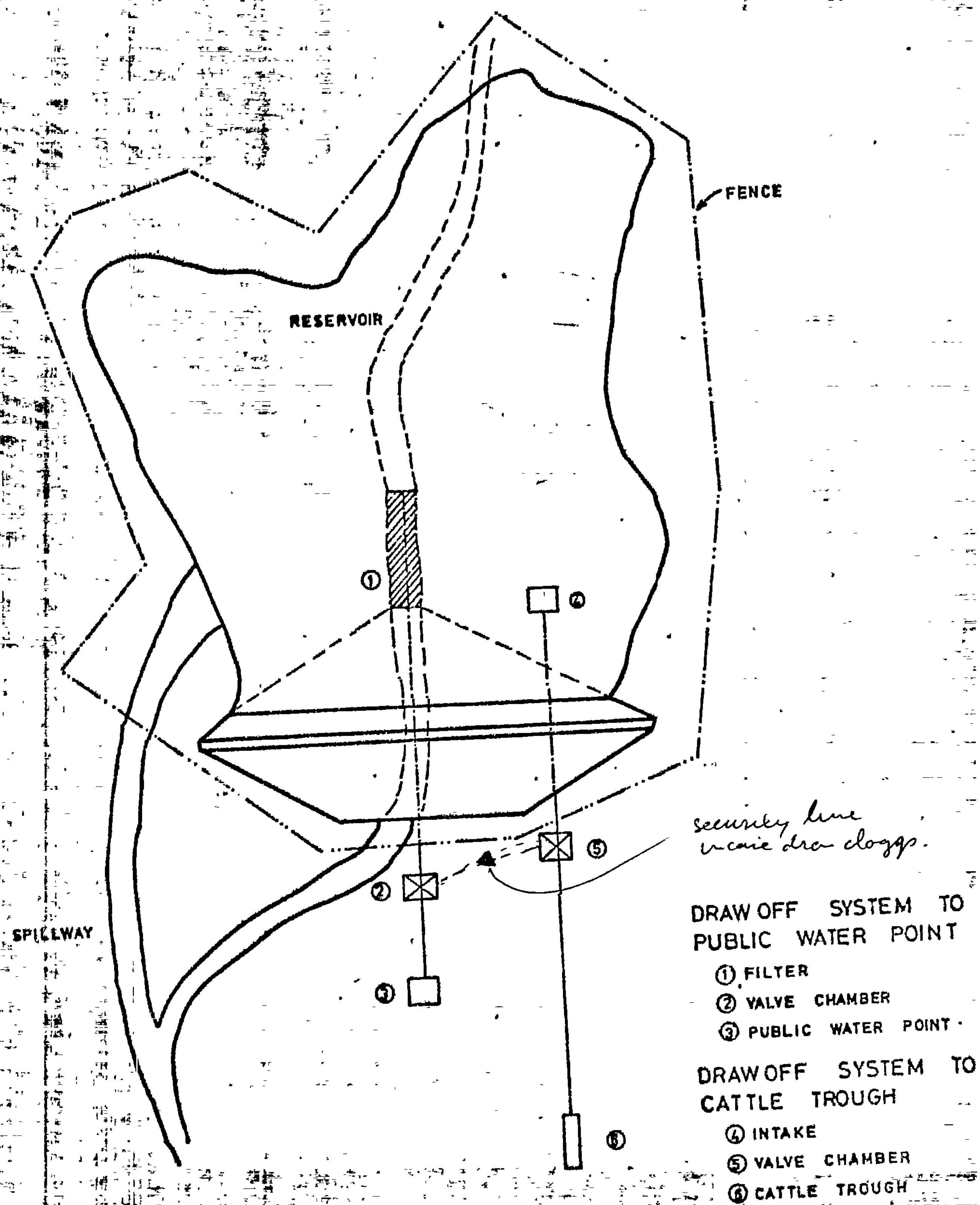


FIG.2 GENERAL LAYOUT

SUB-SOIL CONDITIONS AND PERFORMANCE OF THE INTEGRAL FILTER SYSTEM

The test series on the Integral Filter System was started at Waiya Dam and is followed at Kakuyuni, Mekilingi and Muthetheni dams, which are presently under construction. The salient features of all four projects are shown in Table 1.

Tab. 1

MIDP Dams with Integral Filter Systems

Salient Features		Waiya	Kakuyuni	Mekilingi	Muthetheni
Catchment Area	km^2	2.5	8.3	12.6	7.3
Ave. Annual Rain-fall	mm	700	560	550	600
Ave. Annual Pot. Evaporation	mm	1,990	2.030	2.050	1.990
Ave. Annual Run-off	m^3	112.000	186.000	272.000	500.000
Gross Storage	m^3	70.000	143.000	202.000	207.000
Reservoir Area	ha	3.8	6.1	7.6	9.9
Dam Height	m	8.8	9.5	12.5	10.6
Dam Length	m	168	176	244	320
Embankment Volume	m^3	20.000	23.000	50.000	55.000
Spillway Capacity	m^3/s	25.5	42.1	49.0	51.0

The subsoil conditions throughout the reservoir will be of decisive importance for the performance of the filter system. In the four cases mentioned before the sequence and thickness of strata encountered at the dam sites was sometimes quite different. At Waiya a top soil layer of 0.2 - 0.5 m is overlying red soil of 0 - 1.0 m, followed by laterite (murram) of 0 - 1.4 m and then by highly decomposed rock of clayey silty sand composition. The left river bank is formed by alluvions of 2.4 m thickness. The river bed itself is covered by alluvions of 1.0 m. The total thickness of the strata overlying the weathered rock is in the range of 1.0 - 3.6 m.

At Mekilingi the strata encountered were top soil, red soil, laterite (murram), black cotton soil, decomposed rock. The total thickness of these strata overlying the weathered rock is in the range of 1.2 to 2.5 m. At Muthetheni the respective range is 1.5 to 3.3 m. The encountered bed rock material was in all cases granitoide gneiss, which is predominant in the Machakos area.

The sub-soil conditions encountered at the various dam sites certainly may change throughout the respective reservoirs. Sample cross-sections are presently investigated in the reservoir-areas of the three dams under construction to confirm the prevailing conditions. These results will be used to establish a first relationship between the possible amount of seepage water in the reservoir basin and the filter yield. It is obvious, however, that not all seepage water will reach eventually the filter system. Quite an amount will percolate into deeper strata and will be lost for extraction.

Impounding of the Waiya reservoir started with the onset of the short rains in October 1981. The short rains seased in November/December 1981 and filled the reservoir to 30 % of it's capacity.

First chemical water tests were performed on 2nd December 1981. Samples were taken from the reservoir and from the filtered water as well. The results are shown in Table 2.

Tab. 2
Test Results of Raw and Filtered Water

Substance or Characteristic		Sample Date 2. 12. 1981 R.W.	F.W.	WHO permissible level
PH-Value		6.5	7.9	6.5 - 9.2
Turbidity	T.U.	325	< 5	5 - 25
Conductivity	µS	62	680	
Total Hardness	mg/l $CaCO_3$	126	376	100 - 500
Iron	mg/l	0.3	0.6	0.1 - 1.0
Manganese	mg/l	0.1	0.5	0.05 - 0.5
Calcium	mg/l	1.3	114	75 - 200
Magnesium	mg/l	3.3	22	
Sodium	mg/l	3.8	58	
Total Alkalinity	mg/l $CaCO_3$	12	174	
Chloride	mg/l	2.3	41	200 - 600
Fluoride	mg/l	0.4	0.4	0.7 - 1.0

R.W. = Raw Water, F.W. = Filtered Water

The results clearly indicate the influence of the various strata through which the water is percolating on it's path to the filter system at the bottom of the reservoir. The question remains, whether a wash-out effect would be achieved after a longer pe-

riod of operation which could result in a decrease of such parameters like PH-value, conductivity, total hardness etc. shown in Table 2.

A bacteriological test was performed on 24th February 1982, which gave satisfying results of the bacteriological treatment performance of the filter as shown in Table 3.

Tab. 3
Bacteriological Properties of Raw and Filtered Water

Test		R.W.	F.W.
Presumptive Test	MPN/100 ml Water	1800+	5
Confirmative Test	"	1800+	NIL
E. coli Test	"	25	NIL

MPN = Most Probable Number

According to WHO standards for the quality of drinking water the raw water is not suitable for human consumption. It contains both coliform organisms (1800+ per 100 ml of the original water) and E. coli (25 per 100 ml of the original water). The filtered water is satisfactory bacteriologically. It neither contains coliform organisms nor E. coli.

A filter yield test was performed on the same day. The initial average discharge during the first five minutes was 29 l/min. The discharge decreased to 22 l/min after two hours and remained constant at 22 l/min up to the end of the test after three hours of full opening of the filter pipe. The test results are shown in Table 4.

Tab. 4

Filter Yield of Waiya Dam at 30 % Reservoir Filling

Time in Minutes from Test Start	5	10	15	30	60	90	120	180
Average Yield in l/min	29	25	25	24	24	23	22	22

The yield of the filter system will increase with further reservoir filling, up to the designed normal storage capacity. But a decrease has to be expected over time, when part of the reservoir will be filled by sediments of various nature. Certainly, this process will be slower than in most cases of similar reservoirs elsewhere in the country, since a substantial soil conservation programme is linked to water development activities under MIDP, thus for the Waiya catchment as well.

SOIL AND WATER CONSERVATION PLAN FOR WAIYA CATCHMENT

A concise soil and water conservation plan[1] was established already in 1980 and it's implementation started immediately thereafter with substantial assistance of MIDP. A summary of the action plan is shown below.

Pasture improvement with rural afforestation	111 ha
Reafforestation	14 ha
Terrace improvement (slight)	88 ha
Terrace improvement (major)	33 ha

1) M. A. ZOEBISCH, Concise Soil and Water Conservation Plan for Waiya Catchment, MIDP, 1980

Total length of cut-off drains	5.6 km
Total length of road drainage improvement	4.6 km
No. of major gullies to reclame	4
No. of bulking plots for trees	1
No. of bulking plots for Bana Grass	1
No. of Demonstration plots for pasture reclamation	2

It is expected that the impact of these measures will increase over time reducing the siltation process of the reservoir considerably.

COST FOR CONSTRUCTION, OPERATION AND MAINTENANCE

The cost for integral filter, conventional draw-off system, public water point and cattle trough are shown in Table 5.

Tab. 5

Cost (in 1,000 KShs) for Filter, Conventional Draw-off, Public Water Point and Cattle Trough at 1981/82 Prices

Item	Project			
	Waiya	Kakuyuni	Mekilingi	Muthetheri
Filter Length (m)	21	24	30	100
Filter	76	126	244	450
Draw-off	27	42	44	84
Cattle Trough	8	9	9	18
Public Water Point	6	8	8	18
Total Cost	117	185	305	570
Total Cost in % of Project Cost	7	10	12	15
Filter Cost in % of Project Cost	4	7	9	12

1 $ US = 10.5 KShs

The cost of the integral filter is about 3 to 6 times that of the conventional draw-off for raw water.

Operation cost for the filter will practically not arise due to it's design. The day to day operation of the small dams rests with local water committees causing no expenditures either. There could be eventually some maintenance required for the valve chamber of the filter. But this would be included in the routine maintenance of the project, the cost therefore would be very low. It should be more a logistical problem to get the maintenance on site at the time of requirement.

CONCLUSION

The integral filter system placed at the bottom of Waiya reservoir is producing water of substantially improved quality and appears to be a viable step towards safer water supply in arid and semi-arid areas.

Though the first results are very encouraging, there is urgent need to continue the test series to establish long term results on filter yield and treatment capacity. Further information is required on extend and permeability of the soil and decomposed rock strata in the reservoir basin to assess the filter capacity in relation to such parameters.

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Volkhard W. Werner
c/o Machakos Integrated Development Programme
P. O. Box 662
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