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Low-cost Sand Filter For Domestic and Stockwater Use

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Abstract

In this study a low-cost sand filter was, developed at WRRI-NARC, linked with hand pump and tested for its performance. In the process 1 m^3 of stock (Lawrancepur) sand was standardized in terms of water retention, pumpable water and sediment removal. 1 m^3 of sand was found to hold 353 litres of sediment-free water, 82 percent of which (290 lit) was pumpable. The filter was found quite effective for the removal of sediments and removed 100 percent sediments from an influent sediment concentration of about 14 gm/lit. The filter provided 1282 litres of clean water in five runs and infiltration rate was reduced to 18 percent of the initial at the end. The technology was found cost-effective and appropriate for domestic and stockwater use of rural communities where the need for clean water is even more.

Introduction

The technical advantages of slow sand filtration process, notably are its simplicity of design, construction and operation. It is therefore considered appropriate for small communities, as they lack skilled operators. In a study, on the performance of slow sand filters in terms of the removal of the suspended solids at laboratory scale model, it was concluded that filter units operated at different rates of filtration have efficiently removed the suspended solids, those which were operated at lower rates performed better in terms of the suspended solids removal than those operated at higher rates for the same influent quality (Khaliq *et al.*,1991). In addition, there is no need for coagulation facilities, equipment is simple and need not be imported, suitable sand is readily secured, supervision is simple, the effluent is less corrosive and more uniform in quality than chemically treated waters, and give effective bacterial removal (Cox,1969).

Unclean water is one of giant killers in developing states. Water borne diseases like cholera, typhoid, infectious hepatitis, diarrhoea and dysentery often assume epidemic like situation in many communities. It is estimated that 30 percent of all the reported cases of illness and 40 percent of deaths in Pakistan are attributable to water borne diseases. The rural areas may require appropriate technology suitable to local needs. The expensive and sophisticated system may not be feasible on large scale. Therefore paramount importance exists to develop low cost technology (Gillani *et al.*,1996).

Overall national rural water supply coverage in 1992-93 works out to 47 percent. In the 8th Five Year Plan (1993-) it has been proposed that water supply facilities will be extended to cover 70.5 percent of population in case of rural areas (GOP,1994). The coverage of water supply and sanitation to rural population has increased to 59.2 per cent and 26 per cent respectively in 1996-97 (GOP,1996-97).

The slow sand filter was first used in Great Britain early in the nineteenth century, and a number of plants of this type were constructed in the United States in the years 1890 to 19[illegible]0 (Steel and McGhee,1979). The slow sand filter units being constructed in brackish water zones of Punjab since 1953. These are constructed by Public Health Engineering Department and are working in Multan, Dera Ghazi Khan, Rahim Yar Khan, Bahawal Nagar, Faisalabad, Jhang, Sargodha, Jhelum and Kasur districts. In a study to elaborate the performance of slow sand filters in terms of the removal of the suspended solids by the application of solids-loading, a combination of high influent solids and low rate of filtration or high rate of filtration and low influent turbidity appeared to result in similar effluent quality in terms of suspended solids (Khaliq *et al.*, 1992).

Sedimentation from the watersheds affects water quality and its suitability for human consumption. Removal of sediments from water is an expensive and essential job but cannot be avoided (Gul and Khan,1995).

This study was aimed at the introduction of cost-effective, site specific, appropriate technology of slow sand filteration linked with hand pump, to provide clean sediment-free water in the rural areas for domestic and stockwater use. In the process 1 m^3 of sand was standardized in terms of water retention, pumpable water and sediment removal. Highly sedimented water was passed without any pretreatment because the filtration results due to dual effect of sand coupled with strainer of the hand pump. The performance of the filter was measured in terms of the removal of the sediments.

Materials and Methods

Tank Preparation: A tank of 1.25 m^3 volume was constructed with bricks, plastered with cement mortar and sealed as per specifications of the water-proofing concrete.The seepage through the side walls and bed of the tank was thus prevented.

Filter Media: The stock (Lawrancepur) sand was used as filter media in this experiment. 1 m^3 of air-dry sand was filled into the tank after installation of the hand pump. The cost of the locally purchased sand at the time of experiment (Aug.,1996) was Rs.177/m^3. The physical properties of sand were determined in the laboratory (Dewis and Freitas,1984) (Table 1).

Hand Pump Installation: A hand pump with strainer was installed in the tank. The strainer was diagonally positioned in the bed of the tank and pump being installed and tested

Table 1: Physical Properties of Sand.

S.No.	Property	Description
1.	Bulk density, B_d	1.55 gm cm^{-3}
2.	Specific Gravity, G (Particle density, P_d)	2.66 (gm cm^{-3})
3.	Saturation percentage, w	26.86 % on dry-mass basis *41.64 % on volume basis(Θ)
4.	**Porosity, P	41.72 %
5.	Initial sediment content	2.84 % (by weight)
6.	***Total initial sediment load in 1 m^3 of sand	44 kg

* $\Theta = w * B_d$ ** $P = (1 - B_d/P_d)\ 100$

*** 1 m^3 of sand weighs 1550 kg (B_d = 1.55 gm cm^{-3} = 1550 kg m^{-3})

before sand filling of the tank. 400 lit of water was added to the empty tank and the pump lifted 395 lit (98.75 percent) out of it.

The specifications and cost of the strainer purchased from the local market were as under:

Dia	=	1-1/4 inches
Length	=	4 feet
Hole size	=	3/8 inches
Material	=	GI pipe with brass coring
Cost	=	Rs.150 per strainer (based on local market)

The performance parameters (Fraenkel,1986) of the hand pump were as under:

Suction	= 1-1/4 inches
Delivery	= 1-1/4 inches
Piston diameter (d)	= 2.5 inches(6.35 cm)
Stroke or length of piston travel (s)	= 5.6 cm
The swept area of the piston (A)	= $\pi d^2/4$
	= 31.67 cm^2
The swept volume per stroke (v)	= As
	= 177.352 cm^3
The average discharge per stroke (q)	= 165.30 cm^3

The volumetric efficiency ($E_{vol.}$), which is the percentage of the swept volume that is actually pumped per stroke is given as under:

$E_{vol.}$	= q/v
	= 165.30/177.352
	= 0.932 or 93.20 %
The slippage (v-q)	= 12.052 cm^3

Water Retention and Pumpable Efficiency for Sediment-free Water: The dugwell water at the site of WRRI-NARC, was used to find water retention of 1 m^3 of air-dry sand at saturation. After field saturation of the filter sand, water was pumped and pumpable water was determined, for sediment-free water. Volume of water lifted on the first day after saturation and the next day before saturation was recorded.

Sediments Removal by the Filter: The highest sediment concentration for Satrameel and Fatehjang watersheds are 7.675 gm/lit and 4.32 gm/lit respectively (Shafiq,1997). The study was based on sediment concentration of influent close to double that of the concentration Satrameel. This assumption was made on the basis to the filter quickly chocked and because the raw w quality was expected to be worst than this in the rural a (e.g., Rod-Kohi areas). Naturally deposited sediment by runoff water in the bed of the reservoir at Rawal watershed Satrameel was brought for this purpose. 15 gm/lit sediment was mixed in the dugwell water t the required influent turbidity. Gravimetric moisture co of the sediment was determined for each run and th sediment concentration of the influent was arou gm/lit. The effluent quality was *checked by ra* sampling bottles and lab. determination of th sediment concentration through filtration and dry implied addition of sedimented water to 1 m^3 saturation and lifting clean water out of that.

Results and Discussion

Air-dry sand was brought to saturation with se water and the field saturation percentage was 35.30 percent (353 lit/m^3) on volume basis (Tab Data for pumpable water efficiency (Table 2) reve the overall pumpable water efficiency was a percent. On the average 63 lit (18 percent) of th was not extractable and *290 lit* (82 percent) was pu out of 353 lit. About 68 percent was extractable first day after saturation and about 14 percent on th day before saturation of the sand. It gives us an ide water can be stored and conserved in the sand animals will not be able to drink from the pond w important for a community where human being animals use the same water. Moreover,the conserved can be used when there will be shortage of water. Data for sedimented water passing through the filter 3), revealed that the infiltration rate was subst reduced from 304 l/m^2-hr to 54.88 l/m^2-hr (18 perc the initial) in 5 runs. The infiltration trend appeare declining with each successive run. On the other h to 45 minutes of hand pumping was needed to lift th water after each run. The filter run length appeare very short i.e, 5 days, in case one pass was made p 1282 liters was cleaned out of 1364 lit of sedi water in 5 runs (93.98 percent). 82.33 percent clea was pumped on the same day and 11.65 per cent

Table 2: Data for pumpable water efficiency of sediment-free water.

Run No.	Q_i (lit)	Q_1 (lit)	Q_2 (lit)	Q_T (lit)	water not pumpable* (lit)	overall pumpable** Efficiency, E_p (%)
1	353***	275	25	300	53	84.98
2	309	238	47	285	68	80.74
3	309	238	47	285	68	80.74
4	346	260	40	300	53	84.98
5	300	230	63	293	60	83.00
6	290	240	47	287	66	81.30
7	290	220	64	284	69	80.45
8	286	227	60	287	66	81.30
Av.					62.875	82.18

* $353-Q_T$ ** $E_p = (Q_T/353)100$

*** 353 lit is the field saturation for 1 m^3 of sand

Q_i, volume added till saturation (lit)

Q_2, volume lifted on the next day before saturation (lit)

Q_T, total volume pumped (lit)

Table 3: Data for inflow volume, infiltration rate and total clean water pumpable volume, for sedimented water.

Run No.	Q_i (lit)	inf. rate m^3/m^2-hr	inf. rate lit/m^2-hr	Q_1 (lit)	Q_2 (lit)	Q_T (lit)	cumulative volume cleaned (lit)
	304	0.3040	304.00	240	28	268	268
	268	0.1786	178.66	242	23	265	533
	265	0.1325	132.50	231	34	265	798
	280	0.09333	93.33	220	25	245	1043
	247	0.05488	54.88	190	49	239	1282
Total 5	1364	-	-	1123	159	1282	-
% pumpable				82.33	11.65	93.98	

inflow volume till sat. (lit)

outflow after sat. (lit)

outflow on the next day (lit)

total volume lifted (lit)

Table 4: **Per cent sediment removal by the filter from the sedimented water.**

Run No.	C_1 (gm/lit)	Q_i (lit)	*Sed.load removed/run (kg)	cumulative sed.removed (kg)	C_2 (gm/lit)	% sed. removal(R)**
	13.83	304	4.2043	4.2043	0	100
	13.8975	268	3.7245	7.9288	0	100
	13.725	265	3.6371	11.5659	0	100
	14.3175	280	4.009	15.5749	0	100
	14.2800	247	3.5271	19.1020	0	100

influent sed. conc. (gm/lit)

effluent sed. conc. (gm/lit)

inflow vol. till sat. (lit)

sed. load removed per run (kg) = $C_1 * Q_i/1000$

$$\% R = \frac{(C_1 - C_2)\,100}{C_1}$$

day before the next run, thus the overall pumpable water efficiency was about 94 percent at the end of runs (Table 3).

performance of the filter in terms of sediments removal found excellent. The filter removed 100 percent sediments from an influent sediment concentration of about 14 gm/lit. On the average 3.82 kg of sediment was removed per run and the total sediment removed from 1364 lit of sedimented water(14 gm/lit) was 19.1020 kg at the end of 5 runs (Table 4).

Management Options: Turbidities can be reduced by plain sedimentation. Assuming, 300 lit containing 1.4 gm/lit sediment concentration is passed through this system, it will yield 246 lit clean water (82 % pumpable) and cleaning of the filter after about 47 days will be required. Taking the world average of 50 lit per capita per day water consumption (Rangwala, 1992), this filter will be working satisfactorily for a family of 5 persons. If a family of 10 persons uses this filter, scraping off the sand and washing or replacement would be needed after 23 days, if 2 runs are made per day.

Two such systems have been constructed in DI Khan (NWFP) and Musa Khail (Baluchistan) target areas and are working satisfactorily. The communities are managing the systems as per local conditions. It appears that two desirable goals, i.e, water conservation and water quality improvement may be simultaneously achieved. The following conclusions were drawn from this study.

- 1 m^3 of sand can hold 353 lit of sediment- free water at saturation and out of this 290 lit (82 percent) was pumpable.

- The filter resulted in a 100 percent sediment-free water with a highly turbid influent (14 gm/lit).

- The costs are low and the technology is feasible on large scale.

- The technology is site specific, it can be used in Rod-Kohi areas, where water-borne diseases are common and the water is highly sedimented.

- The technology is appropriate because hand pump is very common with rural community and there is no need of skilled operators. Construction, operation, and maintenance is very simple and the design is based on the existing facilities suitable to local needs.

- There is need to improve the performance of the filter in terms of filter run length. It includes cost-effective and simple means for scraping off the top layer, washing and replacement of the sand.

References

Cox, C. R., 1969. Operation and Control of Wat
*Treatment Processes. WHO, Geneva. pp:*1-392.

Dewis, J. and F. Freitas, 1984. Physical and Chemic
Methods of Soil and Water Analysis. FAO Soils Bullet
10, Rome, Italy. pp: 33-60.

Fraenkel, P. L., 1986. Water Lifting Devices. FAO
Irrigation and Drainage Paper 43, Rome, Italy. pp:
295.

Gillani, S. N. A., M.A.Tahir and A.Rashid, 1996. Nation
Commitment for Safe Drinking Water and Shallow W
Water Supplies. J. Sci Tech and Development, vol.1
No.4, Oct.--Dec., Pakistan Council for Science an
Technology, Islamabad. pp: 36-40.

Government. of Pakistan, 1996-97. Economic Surve
Finance Division Economic Adviser's Wing, Islamaba
pp: 138.

Government. of Pakistan, Planning Commission,199
Eighth Five Year Plan (1993-98). Islamabad. pp: 29

Gul, R. and D. Khan, 1995. Effect of Vegetative Covers
Sediment Yield. J.E.A.S., vol.14, No.2, July--De
NWFP, UET, Peshawar. pp:35-40.

Khaliq, F., A.Jabbar and A.Naeem, 1991. Effect of Rate
Filtration on the performance of Slow Sand Filters
terms of the removal of the suspended solids. J.E.A
vol. 10 No.1 Jan.--Dec., NWFP, UET, Peshawar. pp:8
93.

Khaliq, F., A.Naeem and A.Ali, 1992. The Effect of Soli
Loading on the Performance of Slow Sand Filte
J.E.A.S., vol.11, No.1, Jan.--June, NWFP, U
Peshawar. pp: 23-27.

Rangwala, S.C., 1992. Fandamentals of Water Supply
Sanitary Engineering Charotar Publishing House, o
Amul Dairy, Court Road, India. pp: 1-711.

Shafiq, M., 1997. A personally communicated informati
WRRI, NARC, Islamabad.

Steel, E. W. and T.J. McGhee, 1979. Water Supply
Sewerage (Fifth edition). McGraw-Hill Book Compa
Singapore. pp: 1-665.