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Portable slow sand filter performance

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INTRODUCTION

The importance of safe water supply and sanitation facilities has been recognised and approved, although not applied universally. They are both major environmental issues that are mutually related to and complement each other. Many epidemics of the past have been caused by the contamination of raw water by disease causing organisms.

In Malaysia, all urban dwellers have or have access to treated piped water supplies. For rural communities, approximately 65% of house owners have piped water supply connections. Nonetheless, for many communities living in squatter settlements in the urban areas, the supply of piped water is often inadequate to meet their needs and many resort to using other nearby sources of water for a variety of end uses (Ref. 1). They include water from unprotected wells, river water, rain water and also water from disused mining pools. Such sources may be unsanitary and is usually not appropriate for domestic use without suitable treatment. Several short-term studies has been carried out to assess the suitability of a household slow sand filter (SSF) module to produce potable water from raw mining pool water and other waters. Some preliminary test results are presented in this paper.

MATERIALS AND METHODS

Location

Six mining pools were selected for the water quality survey. These pools were within easy reach of users, has easy access and were free of aquatic plants and debris.

Samples

Water samples were abstracted from a depth of 0.3 m from the surface and about 4 m from the bank using a pump and one inch diameter pvc pipes fitted with a suction valve and a wire mesh screen at the inlet end. Samples were stored in ice prior to analysis in the laboratory.

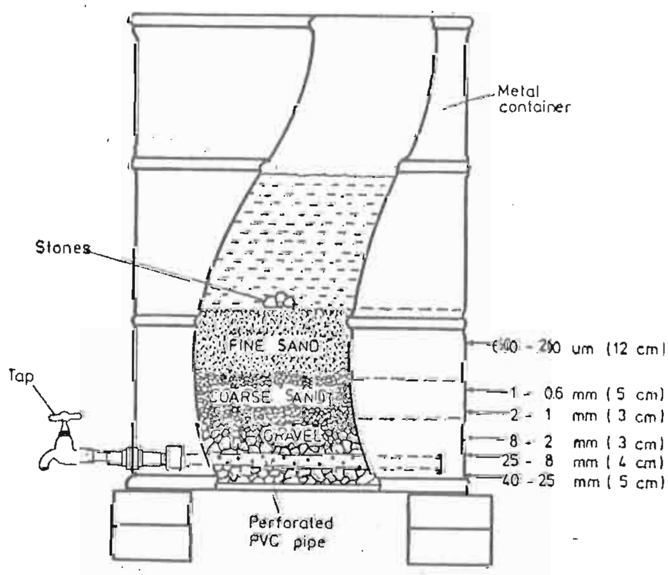
Slow Sand Filter (SSF)

The SSF module was constructed as show in Fig. 1. The module has a total volume of 0.21 m . The flow rate was maintained at a minimum of 0.01 m/h to 0.1 m/h (2 - 2.4 $m^3/m^2/d$) during the tests. The raw water feed tank was placed above the SSF and was manually stirred once every few hours. Samples were obtained from the outlet taps of both containers and analyzed as indicated below.

Analysis

All samples were analyzed for total coliforms (membrane filtration method), Biochenical Oxygen Demand (BOD 5 days), Nitrate Nitrogen , total solids, hardness, iron, lead, arsenic, turbidity, and temperature and pH (in-situ measurements). All analysis were carried out according to Standard Methods (Ref.2).

FIGURE 1 : THE SLOW SAND FILTER



RESULTS AND DISCUSSIONS

Theoretically, the water quality in any mining pool will depend on many factors such as the physical conditions surounding the pool, the type of vegetation in and around the pool, the age of the pool, and the geological nature of the soil, etc. However, their effects will be discussed in a general manner since detailed analysis of these

Table 1 : Average values of water quality at the pools studied.

Parameter/Pool No.	1	2	3	4	5	6
Coliform/100 ml	8983	7243	20275	7892	9650	8260
BOD (mg/l)	0.75	0.60	1.42	0.69	0.65	0.68
Total Solids (mg/l)	201.9	101.6	2003	135.2	158.3	144.0
Turbidity (NTU)	20	9	44	9	13	14
Hardness (mg/l)	84.4	80.2	100	74.8	81.0	76.0
NO3-N (mg/l)	0.28	0.23	0.37	0.28	0.30	0.25
Iron (mg/l)	0.89	0.52	1.23	0.53	0.58	0.55
Lead (mg/l)	0.02	0.03	0.01	0.02	0.02	0.01
Arsenic (mg/l)	0.01	0.01	0.00	0.01	0.00	0.01
pH	6.7	6.8	6.7	6.8	6.8	6.7
Temperature (C)	28.3	28.2	26.5	26.0	27.0	29.0

factors is beyond the scope and objectives of this study. The data in Table 1 shows that the coliform counts were highest for pool no. 3 compared to the other pools. This may be attributed to the discharge of sullage water from the houses located at the edge of the pool and possibly also due to run-off and contamination from pit latrines located near the pool. In comparison, the other pools exhibited markedly lower coliform concentrations with pool 2 showing the lowest value. The close values between pools 2 and 4 is rather surprising since their surroundings differ markedly ; pool 2 is located beside a major highway and has no houses located within 500 m of the edge of the pool whereas pool 4 has many squatter houses built on the edges of the pool. The BOD values of the pool waters were relatively low with a maximum of 1.42 mg/l ; waters with BOD values between 0.75 - 1.50 mg/l are considered suitable as sources of potable water (Ref. 3). With respect to solids, the highest concentration was found in pool 3. This may be due to sediment run-off from some construction and development activities on the eastern side of the pool during the study period. The lower total solids concentrations in the other pools may be attributed to the lack of similar activities and also because settling can occur easily in these quiesent deep pools with little recharge of solids from the bottom sediments. Except for pools 1 and 3, the turbidity values for the other pool waters did not exceed 14 NTU (average 18 NTU) and may be considered suitable as a potable water source. The relatively higher turbidities in pools 1 and 3 may be caused by the same factors as discussed earlier for the total solids concentrations. The water hardness and metals concentrations (except iron) are all within acceptable limits of the WHO guidelines for drinking water quality (Ref. 4). In general, the results of the survey of the water quality in the six disused mining pools indicate that the raw water is suitable for use as a potable water source after appropriate treatment. The extent and nature of the treatment would depend on the initial raw water quality characteristics and whether it is for individual house use or for community use. The presence of harmful contaminants must be carefully examined and evaluated against the treatment system to be applied to determine it's suitability.

For the SSF study, the water from pool 1 was used because it's water quality approximated the mean values of the water quality in all the pools studied and also because of it's location near (7 km) to the laboratory. Table 2 and Table 3 shows the removal efficiency for the selected water quality parameters after treatment in the SSF module on the 10th and 20th day of operation respectively.

The 94 to 97 per cent total coliforms removal after treatment shows that the SSF module has a good potential for producing potable water from disused mining pool water. Although the increase in filter efficiency was only 2 % from the 10th to the 20th day, the gains in terms of absolute numbers of bacteria removed was significant. It is not possible to relate this removal with biological processes since the Schmutzdecke layer was not developed yet. Therefore the reduction in bacterial counts must have taken place as a result of physical straining of the water through the different layers of sand in the filter. Another factor could be the natural die-off of the microorganisms in the water as a result of nutrient starvation and other factors. It would be reasonable to assume that the bacterial removal efficiency will increase with time with the formation and maturation of the Schmutzdecke layer. Unfortunately, this was not confirmed in this study due to time constraints. In terms of absolute values, the 345 coliforms per 100 ml water on the 20th day of operation shows that the water is still unsafe for direct consumption without additional treatment such as disinfection or boiling.

Reductions in BOD is essentially a biological process which involves the breakdown of complex organic substances into simple inorganic constituents by microorganisms. The 51 % BOD removal after the 20th day is most probably due largely to settling and entrapment of organic particles in the sandbed accompanied by some microbial decomposition. The soluble BOD fraction passes through the filter and may be further degraded through biological action when the sand bed becomes matured. Nonetheless, the 0.48 mg/l BOD in the treated water is within the limits set for drinking water quality.

The solids removal closely paralleled the reductions in turbidity. The 89% and 83% reductions in the solids and turbidity levels

Table 2 : SSF Removal Efficiency After 10 Days Operation.

Parameter	Unit	Raw Water	Treated Water	Removal (%)
Coliforms	/100 ml	10,859	645	94.0
BOD5	mg/l	1.2	0.6	52.2
Turbidity	FTU	15	3	80.0
Total Solids	mg/l	250.5	31.3	87.5
Hardness	mg/l	95.8	43.8	54.3
Nitrate N	mg/l	0.3	0.25	19.3
Total Iron	mg/l	0.75	0.15	80.0
Total Lead	mg/l	0.03	0.02	33.3
Total Arsenic	mg/l	0.01	0.01	-
pH		6.85	6.70	-

Table 3 : SSF Removal Efficiency After 20 Days Operation.

Parameter	Unit	Raw Water	Treated Water	Removal (%)
Coliforms	/100 ml	9.755	345	96.5
BOD5	mg/l	0.98	0.48	51.0
Turbidity	FTU	14	3	82.8
Total Solids	mg/l	278.8	30.5	89.1
Hardness	mg/l	89.5	42.3	52.7
Nitrate N	mg/l	0.3	0.25	16.6
Total Iron	mg/l	0.85	0.15	82.4
Total Lead	mg/l	0.03	0.02	33.3
Total Arsenic	mg/l	0.01	0.01	-
pH		6.85	6.75	-

respectively on the 20th day indicates that the sand size used in the sand layers in the SSF is sufficient to trap suspended and turbid matter from the water. These solids are removed principally by straining and other transport and attachment mechanisms operating in the filter.

Removal of nitrate-nitrogen was negligible. Nitrates may be removed by adsorption and biochemical processes, but in this "young" filter, the former is probably more pronounced. On the other hand, nitrate is also the end product of the breakdown of nitrogenous organic compounds. Nitrate removal did not change appreciably after the longer operation but it can be expected to increase as the filter becomes more matured.

Metals removal ranges from 28 to 33% for arsenic, 33% for lead and 80 to 82% for iron. The high removal for the total iron concentration in the water may be attributed to the nature of the crystalline quartz sand particles which has an overall negative charge and is thus able to attract positively charged particles of colloidal matter (such as crystals of carbonates and flocculi of iron and alluminium hydroxide) as well as cations of iron, manganese, alluminium and other metals. For iron, the removal efficiency increased to 82.4%. This is due to the continuing process of charge reversal (Ref. 5). In this process the sand with the negative charge attracts the iron and when saturation occurs, anions are attracted. This reversal of charge continues throughout the life of the filter once started. The exact mechanisms for the removal of the heavy metals is not well understood.

Comparison of the quality of the treated water from the 20 day old filter with the WHO guideline values for drinking water quality shows that the water is still "unsafe" for direct human consumption. This is because the presence of high coliform counts also implies the probable presence of pathogenic organisms in the treated water. In a conventional SSF water treatment plant it is well known that the efficiency of removal of bacteria, viruses and dissolved organics is very high, frequently reaching 100%. In an efficiently operated plant, more than 95% of samples taken over regular time intervals show negative results for coliforms. This efficiency is attributed to the development of the Schmutzdecke layer on top of the sand filter. Therefore it is fair to assume that the model SSF module will be able to remove bacteria more efficiently as it matures. The exact time required for this "maturation" to occur will depend on the microbial flora in the raw water and will be determined in later trials in the field. In the preliminary trials of the SSF module, the low filtration rates probably restricted the supply of oxygen and nutrients thus slowing down the rate of formation of the Schmutzdecke layer. Another factor which could have contributed towards the high bacterial counts in the treated water is the depth of sand in the filter. According to the literature, the minimum sand depth should be 50 cm and 60 cm is necessary to ensure the removal of all viruses together with complete oxidation of ammonia. However, the sand depth in this SSF module was only 20 cm. It would also be interesting to observe the effect of accumulating concentrations of metals on the microbial flora in the Schmutzdecke layer in a matured filter.

CONCLUSIONS

1. Disused mining pool water has a potential as a water resource since they do not contain excessive amounts of impurities and provided suitable treatment systems can be made available. Initial raw water turbidity values do not seem to be a problem.

2. The trial household SSF module has a high potential to treat raw mining pool water into

potable water but further studies are needed to determine the period required for it to reach maturity and the ensuing water quality.

3. In describing the results of experimentation involving raw and drinking water, absolute values should be reported together with percentage removal efficiencies. Although high percentage removals (> 99%) may be reported, they create a false sense of confidence especially when high initial concentrations of pollutants are involved.

RECOMMENDATIONS

1. The SSF module need to be run for longer periods to examine the development of the biological active layer on top of the sand bed.

2. Different sand depths should be tested to achieve a more complete removal of pollutants and also to balance with costs factors.

3. To assist the removal of metals, the use of a pre-filter such as a crushed heated charcoal bed should be considered. It can be incorporated on top of or at the bottom of the sand bed or in a separate module altogether.

4. For field applications, a number of SSF units could be assembled and fed continuously using a diesel operated pump. The treated water could be stored collectively for distribution to several households. Multiple filtration units helps to save costs and also has the advantage that when one unit is out of order, it will not cause a disruption in supplies. The SSF can also be used to treat other sources of raw water e.g. rain water, well water, etc.

5. Finally, proper sanitation practices must be adopted to prevent gross pollution of the mining pools by sewage.

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