



Sand Intermittent Filtration Technology for safer Domestic Sewage Treatment

*¹PRASAD, G; ¹RAJEEV RAJPUT; ²CHOPRA, A K

¹Department of Zoology and Environmental Science, Gurukula Kangri University, Haridwar, INDIA

²Department of Botany and Microbiology, Gurukula Kangri University, Haridwar, INDIA

ABSTRACT: The present investigation was undertaken to find out pollution reduction potential of Sand intermittent filtration bed in term of physico-chemical and microbiological characteristics of domestic sewage. The domestic sewage was filtered through Sand intermittent filtration beds of mixture of sand and soil at different ratio i.e. 1:1; 1:3; 3:1 and one set of 100% of each sand and soil were also taken. Results revealed that there was a significant pollution reduction in various physico-chemical and microbiological parameters of domestic sewage in sand soil mixture. In general sand and soil beds have shown better performance than only sand or soil bed for sewage treatment. Albeit Sand soil bed of 2 feet depth has been found better in term of pollution reduction ability than other depths used in the present study, but variation of pollution reduction potential has been recorded for different parameters in sand and soil bed of the same ratio. Mixture of Sand soil bed at ratio 3:1 has yielded better results in general than all other used ratio but for certain parameters stands equal with 1:1 ratio. Maximum percentage of reduction in pH i.e. 16.7% and in Temperature 27.9% was found at 2 feet depth in mixed sand and soil bed of 1:1 ratio. Maximum pollution reduction potential of intermittent filtration bed was recorded at 2 feet depth of sand and soil mixture at ratio of 3:1. Percentage of pollution reducing potential was found in CO₂ 83.4%, BOD 72.5%, COD 69.9%, Total alkalinity 37.9%, Total solids 88.5%, Total dissolved solids 86.1%, Total suspended solids 91.2%, MPN 82.4% and SPC 78.4%. Minimum reduction ability was found in 100% sand and soil bed without mixture. @JASEM

Water pollution is a current global burning problem as a large quantity of water of earth planet i.e. 97% is stored in sea. Marine water is not suitable for domestic use due to high salinity. Remaining 3% water is found in form of ice caps, surface water and underground water. Since a very small quantity of available water is being used in different way i.e. agriculture, industry and domestic purposes. Various types of pollutants such as industrial, domestic waste (solid and liquid) are reaching in surface water through different means. Most of the cities in India are situated on the banks of different rivers. These rivers are receiving both industrial and domestic sewage, which has high percentage of untreated sewage because most of the cities do not have an adequate sewage treatment system.

In India it is estimated that more than $8642 \times 10^6 \text{ m}^3$ of wastewater is generated per annum from 212 class I cities and 241 class II towns. Only 23% of wastewater is being treated mostly at primary level prior to disposal and 77% untreated water is discharged on land (Rajeswaramma and Gupta, 2002). Indiscriminate discharge of domestic and industrial effluent in the rivers has generated alarming water pollution as maximum water supply for domestic use is being obtained from these rivers. Efforts have been made by the government of India force to setup the treatment plants in different parts of country for the proper and efficient treatment of domestic sewage. But these treatment plants consume

lots of energy and require more money for its maintenance. Economy of developing country like India is not so good to afford such types of expensive treatment plants. Besides these irregular power supply and labours problem has affected the working and efficiency of the treatment plants. Sand filtration is one of the earliest forms of potable water treatment and remains an important process for water purification throughout the world (Campos *et al.*, 2002). Simplicity and low cost capital and operating cost are principal advantages of sand filtration compared with more sophisticated methods of water treatment. Keeping in view of the facts present investigation was undertaken to find out the treatment of domestic sewage. Some important contribution in this area has been made by some workers and important can be quoted here (Huisman and Wood, 1974; Zibell *et al.*, 1975; Bellamy *et al.*, 1985; Sarkar *et al.*, 1994; Setvik *et al.*, 1999; Weber-Shirk, 2002; Rooklidge and Ketchum, 2002; Ausland *et al.*, 2002). But in India very little work (Rao *et al.*, 2003) has been done on sand intermittent filtration. In present study efforts have been made to develop a cost effective and low maintenance model of sand intermittent filtration for the treatment of wastewater with a special reference to domestic sewage.

MATERIAL AND METHODS

Experimental design of sand intermittent filtration tank: A septic metal tank of 35cm radius with 5 feet height with strong stand and a sieve of 0.5 mm fitted

1 feet above from base was constructed. A device was also made at the base of the tank to take out treated water for analysis of physico-chemical and bacteriological characteristics.

Filter media: Different mixture of sand and soil were used for the filtration of domestic sewage. Sand Intermittent Filtration tank was filled by different mixtures of sand and soil i.e. 100% sand, 100% soil, sand and soil 1:1, 3:1, 1:3. Different depth i.e. 1 feet, 1.5 feet and 2 feet of each kind of sand and soil mixture was used as sand intermittent filtration for filtration of domestic sewage.

Sampling site and sample collection: Sewage pumping station, located at the right bank of Ganga Canal at Ramnager opposite Swami Shraddhanand Chowk, Haridwar (Uttaranchal) was selected for the collection of domestic sewage. To obtain a composite sample of domestic sewage, the site was selected as pumping station contains a mixture of domestic sewage of different locality of Haridwar. Sampling was done 4 times in the morning between 7.30 to 11.00 am and a time composite sample was collected in plastic container and brought to the laboratory for analysis.

Analysis of domestic sewage and filtered domestic sewage: Domestic sewage and filtered domestic sewage through different Sand intermittent filter were analyzed for their various physico-chemical and bacteriological characteristics by standard methods (APHA, 1998).

RESULTS AND DISCUSSION

The values of different parameters of domestic sewage viz. Temperature, Turbidity, Total solids (TS), Total dissolved solids (TDS), Total suspended solids (TSS), pH, Total alkalinity, Free carbon dioxide (CO₂), Chemical oxygen demand (COD), Dissolved oxygen (DO), Biochemical oxygen demand (BOD), Standard plate count (SPC) and Most probable number (MPN) before filtration are given in Table 1 and values of these parameters of domestic sewage after filtration with Sand intermittent filtration are given in Table 2. Temperature of domestic sewage was recorded 25.98

°C. Maximum percentage of temperature reduction is 27.9% was observed after treatment with Sand intermittent filtration of ratio 1:1 at depth of 2 feet. Decrease in temperature may be due to the climatic conditions as the sewage was stored in a steel tank for filtration. Maximum fall in the temperature at 2 feet depth may be perhaps due to taking more time and long distance travelled by wastewater during filtration. Temperature reduction has positive correlation with retention time factor in the bed as evident by minimum temperature reduction in the sand at 1 feet depth. Turbidity of domestic sewage was found 85.0 mg/l before filtration. Complete reduction of turbidity was found in domestic sewage at 2 feet depth in all the combinations of the filtration bed. Turbidity decreases due to decrease in suspended solids and dissolved solids. Ojeda (1989) was found that turbidity was removed by 90% using slow sand filters. El-Taweel (2000) reported that 92% of turbidity was removed when slow sand filter was used for wastewater treatment. Slight variation of these findings, from Ojeda (1990) and El-Taweel (2000) may be due to variation of sand granules and soil particles size as well as the depth of the bed. Total solids of domestic sewage was recorded 2740.0 mg/l. Total suspended solids of domestic sewage was found 1300 mg/l. Total solids and Total suspended solids shows maximum reduction i.e. 88.5% and 91.2% respectively at 2 feet depth in 3:1 ratio while minimum reduction of Total solids was found i.e. 19.7% in soil only at 1 feet and minimum reduction of Total suspended solids was found i.e. 35.8% in sand only at 1 feet. These findings are in accordance to the findings of Ellis (1987). He has reported 90 % reduction of suspended solid when it was filtered through 3.5 feet sand filtration. Total dissolved solids of domestic sewage were recorded 1440 mg/l. Total dissolved solids shows maximum reduction i.e. 86.1% at 2 feet depth in 3:1 ratio while minimum was found i.e. 2.7% at 1 feet depth in soil only. Solids reduced after sand intermittent filtration because mixture of soil and sand works as a sieve. These results are in accordance with the findings of Kumar *et al.* (2003). Also due to retention time of sewage into Sand intermittent filter reduces total solids, total dissolved solids and total suspended solids

Table 1: Physico-chemical and microbiological parameters of Domestic Sewage before filtration (Values are mean \pm Standard Deviation of six observations).

Parameters	Before Filtration
Temperature ($^{\circ}$ C)	25.98 \pm 0.06
Turbidity (JTU)	85.0 \pm 0.0
Total Solids (mg/l)	2740 \pm 276.8
Total Dissolved Solids (mg/l)	1440 \pm 185.90
Total Suspended Solids (mg/l)	1300 \pm 293.66
pH	8.68 \pm 0.03
Total Alkalinity (mg/l)	423.33 \pm 3.72
Carbondioxide (mg/l)	143.73 \pm 1.03
Dissolved Oxygen (mg/l)	0.6 \pm 0.0
Biochemical Oxygen Demand (mg/l)	183.83 \pm 8.16
Chemical Oxygen Demand (mg/l)	314.66 \pm 4.13
Most Probable Number (MPN/100ml)	50833.33 \pm 7756.71
Standard Plate Count (Bacteria/ml)	254.22 $\times 10^3 \pm 11.51 \times 10^3$

pH of domestic sewage was recorded 8.68. Maximum decrease of 16.7% was recorded after treatment with Sand intermittent filtration in the mixture of sand and soil having ratio 1:1 and depth of 2 feet while minimum was found i.e. 0.57% in sand only at 1 feet depth. Total alkalinity of domestic sewage was recorded 423.33 mg/l. Maximum reduction of Total alkalinity i.e. 37.9% was found at 2 feet depth in 3:1 ratio while minimum was found i.e. 0.19% in sand only at 1 feet depth. Carbon dioxide of domestic sewage was recorded 143.73 mg/l before filtration. Maximum decline of CO₂ i.e. 83.4% was found at 2 feet depth in 3:1 ratio while minimum reduction was found i.e. 0.7% in 1:1 ratio of sand and soil at 1 feet depth. Since temperature decreases after Sand Intermittent Filtration, the growth of microorganisms along with decomposition of organic substances as well as the respiratory activity also slows down, this reduces the carbondioxide level in the effluent.

Dissolved oxygen of domestic sewage was found 0.6 mg/l before filtration. Low oxygen concentration is associated with heavy contamination by organic matter (Trivedy and Goel, 1995). Maximum increase in oxygen concentration from 0.6 to 3.91 mg/l was recorded after treatment with Sand intermittent filtration at 2 feet depth of ratio 3:1. Enhancement of dissolved oxygen in the sewage after treatment may be due to the minimization of organic pollution load and bacterial population due to their retention (organic pollutants and microbial population) in bed and simultaneously mixing of atmospheric oxygen. Biochemical oxygen demand (BOD) of domestic sewage was recorded 183.83 mg/l. Maximum percentage of BOD reduction i.e. 72.5% was

recorded at 2 feet depth in 3:1 ratio of sand and soil mixture while minimum was found i.e. 0.9% in sand only at 1 feet depth. 0.9% reduction was found in 100% sand at 1 feet depth but at the same time enhanced value was found at 2 feet depth of 100% soil i.e. 12.6%. It appears that depth of filtration bed was great impact on purification of wastewater as it is evident by table 2. Our conclusions are supported by Ellis (1987). He reported more than 65% reduction in BOD, when effluent was allowed to filter from 3.5 feet depth of sand filtration containing sand only of 0.3mm and then later 0.6mm in size. The variation from our findings may be due to variation in the component of filtration as in our case both sand and soil has been used in proportion of the filter. Maximum percentage of BOD reduction may be due to lowering of temperature, which minimizes the multiplication of microbial, (bacterial) population by generating unfavorable temperature resulted lowered uptake of oxygen and due to their retention in the bed. Chemical oxygen demand (COD) of domestic sewage was recorded 314.66 mg/l. Maximum reduction of COD i.e. 69.9% was found at 2 feet depth in 3:1 ratio while minimum was found i.e. 0.42% in 100% sand only at 1 feet depth. Reduction of COD may be due to the fact that most of the organic wastes were oxidized. Van Buuren *et al.* (1986) reported 76-82% removal of COD in wastewater by using intermittent slow sand filtration. Similar trends i.e. decrease in Chemical oxygen demand was also recorded by Rao *et al.* (2003) when wastewater was filtered through slow sand filter. The SPC found in domestic sewage was 254.6 $\times 10^3$ bacteria/ml.

TABLE 2: Pollution Reduction Potential of Sand-Soil bed at different ratios and depth of Sand Intermittent Filtration.

Parameters	Sand Soil=1:1				Sand Soil=1:3				Sand Soil=3:1				Sand 100%				Soil 100%			
	I'	I.S'	2'	2'	I'	I.S'	2'	2'	I'	I.S'	2'	2'	I'	I.S'	2'	2'	I'	I.S'	2'	2'
Temperature (°C)	18.88 ±0.04 (-27.3)	18.85 ±0.05 (-27.4)	18.73 ±0.04 (-27.9)	21.45 ±0.08 (-17.4)	22.23 ±0.05 (-15.3)	21.98 ±0.07 (-15.3)	21.45 ±0.08 (-17.4)	24.43 ±0.09 (-5.6)	24.5 ±0.09 (-5.6)	25.65 ±0.05 (-1.80)	25.51 ±0.13 (-1.80)	25.0 ±0.08 (-3.77)	25.65 ±0.05 (-1.80)	25.51 ±0.13 (-1.80)	25.0 ±0.08 (-3.77)	25.65 ±0.05 (-1.80)	20 ±0.06 (-23.0)	19.98 ±0.07 (-23.0)	19.0 ±0.16 (-26.8)	19.0 ±0.16 (-26.8)
Turbidity (JTU)	30 ±0.0 (-64.7)	NIL	NIL	NIL	79.16 ±2.04 (-7.8)	NIL	NIL	NIL	25±0.0	NIL	NIL	NIL	25±0.0	NIL	NIL	NIL	85 ±0.0	NIL	NIL	NIL
TS (mg/l)	1600 ±326.5 (-41.6)	1193.33 ±27.48 (-56.4)	480 ±73.02 (-82.4)	966.66 ±30.11 (-64.7)	1613.33 ±32.65 (-41.1)	1093.33 ±20.65 (-60.0)	966.66 ±30.11 (-64.7)	380 ±86.1 (-86.1)	1066.66 ±149.56 (-61.0)	313.33 ±30.11 (-88.5)	1333.33 ±94.28 (-58.6)	800 ±70.8 (-70.8)	1833.33 ±179.5 (-33.0)	1333.33 ±94.28 (-58.6)	800 ±70.8 (-70.8)	2200 ±19.08 (-19.7)	2200 ±19.08 (-19.7)	1016.66 ±206.5 (-61.1)	95.09 ±95.09 (-62.8)	
TDS (mg/l)	960 ±51.63 (-33.3)	680 ±40.0 (-52.7)	280 ±51.63 (-80.5)	706.66 ±20.65 (-50.9)	1186.33 ±32.65 (-17.5)	780 ±21.9 (-45.8)	706.66 ±20.65 (-50.9)	206.66 ±0 (-85.6)	800 ±46.4 (-44.4)	200 ±0 (-86.1)	640 ±172.81 (-57.1)	620 ±44.72 (-56.9)	1000 ±305.5 (-30.5)	640 ±172.81 (-57.1)	620 ±44.72 (-56.9)	1400 ±19.08 (-2.7)	1400 ±19.08 (-2.7)	720 ±155.7 (-1.50)	700 ±155.7 (-1.50)	
TSS (mg/l)	640 ±278.0 (-50.7)	513.33 ±14.90 (-60.5)	200 ±23.09 (-84.6)	300 ±33.46 (-80.1)	426.66 ±60.22 (-67.1)	313.33 ±30.11 (-75.8)	260 ±33.46 (-80.1)	173.33 ±86.66 (-86.66)	266.66 ±131.99 (-79.43)	113.33 ±27.48 (-91.2)	493.33 ±82.19 (-62.05)	180 ±44.72 (-86.15)	800 ±242.67 (-35.8)	493.33 ±82.19 (-62.05)	180 ±44.72 (-86.15)	800 ±242.67 (-35.8)	800 ±242.67 (-35.8)	346.66 ±54.65 (-73.3)	316.66 ±54.65 (-73.3)	
pH	8.61 ±0.27 (-0.80)	7.43 ±0.04 (-13.8)	7.23 ±0.04 (-16.7)	7.86 ±0.05 (-12.6)	8.6 ±0.08 (-0.92)	7.86 ±0.05 (-12.6)	7.58 ±0.04 (-16.7)	8.08 ±0.08 (-6.9)	8.55 ±0.05 (-1.49)	8.01 ±0.13 (-4.9)	8.25 ±0.05 (-1.15)	7.98 ±0.06 (-8.0)	8.63 ±0.05 (-0.37)	8.25 ±0.05 (-1.15)	7.98 ±0.06 (-8.0)	8.58 ±0.11 (-1.15)	8.58 ±0.11 (-1.15)	7.85 ±0.05 (-9.5)	8.58 ±0.11 (-1.15)	
TA (mg/l)	417.5 ±2.73 (-1.37)	328.33 ±4.71 (22.4)	310 ±2.88 (-26.7)	298.33 ±2.58 (-19.8)	419.16 ±2.04 (-19.8)	313.33 ±2.58 (-25.9)	298.33 ±2.58 (-19.8)	385.33 ±2.55 (-33.0)	416.66 ±5.16 (-1.57)	262.5 ±2.55 (-29.5)	271.66 ±2.35 (-35.8)	265 ±4.08 (-37.4)	422.5 ±2.73 (-0.19)	271.66 ±2.35 (-35.8)	265 ±4.08 (-37.4)	418.33 ±6.05 (-1.18)	418.33 ±6.05 (-1.18)	360 ±5.16 (-14.95)	320 ±5.16 (-14.95)	
CO ₂ (mg/l)	142.63 ±1.51 (-0.7)	37.4 ±1.27 (-73.9)	24.2 ±1.96 (-83.1)	39.7 ±1.20 (-79.3)	96.8 ±1.96 (-32.6)	33.73 ±1.13 (-76.5)	39.7 ±1.20 (-79.3)	29.7 ±2.76 (-79.3)	86.9 ±1.1 (-39.5)	23.83 ±2.66 (-83.4)	32.63 ±2.34 (-77.2)	24.2 ±3.81 (-83.1)	81.4 ±2.54 (-43.36)	32.63 ±2.34 (-77.2)	24.2 ±3.81 (-83.1)	93.13 ±1.13 (-35.2)	93.13 ±1.13 (-35.2)	37.03 ±2.16 (-4.23)	28.6 ±2.16 (-80.10)	
DO (mg/l)	0.94 ±0.52 (-56.66)	2.0 ±0.0 (+233.3)	2.49 ±0.10 (-31.5)	3.07 ±0.08 (-400.0)	0.84 ±0.39 (+40.0)	3.0 ±0.08 (-400.0)	3.07 ±0.08 (-411.6)	2.9 ±0.27 (-383.3)	1.14 ±0.32 (-90.0)	3.91 ±0.16 (-551.6)	1.11 ±0.10 (+85)	1.48 ±0.16 (-146.6)	0.63 ±0.08 (+5.0)	1.11 ±0.10 (+85)	1.48 ±0.16 (-146.6)	1.14 ±0.10 (+90.0)	2.97 ±0.10 (-395)	2.97 ±0.10 (-395)	3.03 ±0.12 (-405)	
BOD (mg/l)	175.5 ±10.48 (-4.5)	165.5 ±8.36 (-9.9)	132.16 ±11.69 (-28.1)	107.16 ±10.32 (-11.7)	180.5 ±8.94 (-1.81)	107.16 ±10.32 (-11.7)	95.5 ±15.78 (-48.0)	105.5 ±10.48 (-42.6)	170.5 ±12.64 (-7.2)	50.5 ±12.64 (-72.5)	172.16 ±7.52 (-6.3)	160.5 ±6.32 (-12.6)	182.16 ±4.08 (-0.90)	172.16 ±7.52 (-6.3)	160.5 ±6.32 (-12.6)	178.83 ±7.52 (-2.7)	153.83 ±5.16 (-16.3)	120.5 ±8.94 (-34.4)	120.5 ±8.94 (-34.4)	
COD (mg/l)	312.66 ±3.93 (-0.6)	232.66 ±4.67 (-26.0)	182.66 ±4.84 (-41.9)	170.66 ±3.26 (-45.7)	311.33 ±5.88 (-1.05)	170.66 ±3.26 (-45.7)	134.0 ±5.51 (-57.4)	129.33 ±4.84 (-58.8)	307.33 ±3.01 (-2.3)	94.66 ±3.26 (-69.9)	298.66 ±3.26 (-5.08)	258.33 ±4.13 (-9.3)	313.33 ±4.84 (-0.42)	298.66 ±3.26 (-5.08)	258.33 ±4.13 (-9.3)	309.33 ±3.26 (-1.6)	309.33 ±3.26 (-1.6)	201.33 ±2.06 (-36)	151.33 ±2.06 (-51.9)	
MPN (MPN/100ml)	33166.6 ±4490.7 (-34.7)	26000 ±3098.3 (-48.8)	18000 ±2000 (-64.5)	17500 ±2449.4 (-58.6)	25333.3 ±2065.5 (-50.1)	21000 ±2449.4 (-58.6)	17500 ±2449.4 (-58.6)	13166.6 ±408.2 (-74.0)	13666.6 ±2581.8 (-73.1)	8900 ±774.5 (-82.4)	13166.6 ±408.2 (-74.0)	8900 ±774.5 (-82.4)	47666.6 ±9811.5 (-6.2)	35833.3 ±49337.6 (-29.5)	33833.3 ±2837.7 (-33.4)	28166.6 ±4119 (-44.5)	28166.6 ±4119 (-44.5)	24666.6 ±1632.9 (-51.4)	11500 ±1224.7 (-77.3)	
SPC (X10 ³ Bacteria/ml)	124.3 ±4.4 (-51.1)	119 ±12.0 (-53.2)	109.8 ±12.2 (-56.8)	136 ±22 (-50.1)	136 ±22 (-46.5)	127 ±22 (-50.1)	104.5 ±20.5 (-58.9)	82.3 ±10.2 (-67.6)	106.8 ±10.2 (-58.0)	54.8 ±10.2 (-78.4)	129.3 ±8.3 (-49.2)	114.5 ±8.6 (-55.03)	135 ±10.2 (-46.9)	129.3 ±8.3 (-49.2)	114.5 ±8.6 (-55.03)	132 ±10.1 (-48.1)	132 ±10.1 (-48.1)	107.5 ±15.3 (-51.5)	107.5 ±15.3 (-51.5)	

± = Standard Deviation, % Increase and Decrease given in parentheses

' = Feet

Reduction of 82.4% was observed in the ratio 3:1 having a depth of 2 feet while minimum was found i.e. 6.2% in sand only at 1 feet depth. Bacterial population decreases due to depletion of organic components, which serve as nutritive substances and due to fall in temperature, which does not support bacterial multiplication. Bomo *et al.* (2003) were found that Sand filters removed 99.9% of bacteria. Since a significant reduction in most of the parameters related with pollution load of sewage has been recorded after passing through Sand Intermittent Filtration, therefore it is desirable to investigate its ability under different conditions in order to make a program to treat the sewage on overhead stabilization pond to protect under ground water reservoir and inland surface water.

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REFERENCES

- APIHA. (1998). *Standard Methods for the examination of water and wastewater*. 14th Ed. Washington DC.
- Ausland,G; Stevik,T.K; Hanssen,J.F; Kohler,J.C; Jenssen,P.D. (2002) Intermittent filtration of wastewater-removal of fecal coliforms and fecal Streptococci. *Wat. Res.* 36, 3507-3516.
- Bellamy,W.D; Hendricks,D.W; Logsdon, G.S (1985). Slow sand filtration: influences of selected process variables. *J. Am. Water Well Assoc.* 12, 62-66.
- Bomo, A.M; Husby, A; Stevik, T.K; Hanssen, J.F (2003). Removal of fish pathogenic bacteria in biological sand filters. *Wat. Res.* 37, 2618-2626.
- Campos, L. Cl; Su, M.F.J; Graham, N.J.D; Smith, S.R (2002) Biomass development in slow sand filters. *Wat. Res.* 36, 4543-4551.
- El-Taweel, G.E; Ali, G.H (2000). Evaluation of roughing and slow sand filters for water treatment. *Water Air Soil Pollu.* 120(1-2), 21-28.
- Ellis,K.V (1987). Slow sand filtration as a technique for the tertiary treatment of municipal sewages. *Wat. Res.* 21(4), 403-410.
- Huisman,L; Wood,W.E (1974). *Slow sand filtration*. Geneva: World health Organization. 20-46.
- Kumar,A; Singhal,V; Joshi,B.D; Rai,J.P.N. (2003). Lysimetric approach for ground water pollution control from pulp and paper mill effluent using different soil textures. *Ind. J. Sci. Ind. Res.* 63, 429-438.
- Ojeda,P (1990). Treatment of turbid surface water for small community supplies. *Dissertation Abstracts International.* 51(3), 1471-B.
- Rajeswaramma,C; Kapil,Gupta (2002). Hydraulic design of a constructed wetland for an urban area. *J. Wat. Works. Asso.* 149-152.
- Rao,R.Ravinder; Reddy,R.C; Rama Rao, K.G; Kelkar,P.S (2003). Assessment of slow sand filtration system for rural water supply schemes-A case study. *Indian J. Environ. Hlth.* 45(1), 59-64.
- Rooklidge,S.J; Ketchum,Jr L.H (2002). Corrosion control enhancement from a dolomite-amended slow sand filter. *Wat. Res.* 36, 2689-2694.
- Sarkar,A.K; Georgiou, G; Sharma,M.M (1994). Transport of bacteria in porous media. I. An experiment investigation. *Biotechnol. Bioeng.* 44, 489-497.
- Stevik,T.K; Ausland,G; Jenssen,P.D; Siegrist,R.L (1999). Removal of *E. coli* during intermittent filtration of wastewater effluent as affected by dosing rate and media type. *Wat. Res.* 33, 2088-2098.
- Trivedy,R.K; Goel,P.K (1995). Chemical and biological methods for water pollution analysis studies. *Environ. Publications, Post box no. 60 Karad.* 1-247.
- Van Buuren,J.C.L; Willers,H; Luyten,L; Van Manen, M (1986). The pathogen removal from UASB-effluent by intermittent slow sand filtration. In: *Anaerobic treatment a grown-up technology, conference papers.* Aquatech. 86, 707-709.
- Weber-Shirk,M.L (2002). Enhancing slow sand filter performance with an acid-soluble seston extract. *Wat. Res.* 36, 4753-4756.
- Zibell,W.A; Anderson,J.L; Bouma,J; McCoy,E (1975). Fecal Bacteria: Removal from sewage by soil. Winter meeting, ASAE publication, Chicago, IL, paper no. 75-2579.

