Indian Journal of Chemical Technology
Vol. 31, November 2024, pp. 941-948
DOI: 10.56042/ijct.v31i6.5716

Modified soak pit system for septic tank effluent treatment in a laboratory scale

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Received 21 September 2023; accepted 18 September 2024

The appearance of coliforms in drinkable water is viewed as a public health issue because of their identification related to either faecal contamination or exogenous contamination with enteric and other important microbial diseases. Housing densities have risen in tandem with worldwide population expansion. As a result, the size of plots available for construction of housing units turned very small. The majority of this housing is underserved by sewage systems; this garbage will mix with surface-water run-off, contaminating it and causing it to discharge into fresh water channels. A fresh and novel innovation is the silver impregnated sand filter for septic tank effluent treatment. In this research, a comparative study between various gradation of sand and impregnated sand has been done. The effect of various silver dosages is evaluated. Analysis of silver leakage is analyzed. Influent (synthetic septic tank effluent) is characterized at constant flow rate.

Keywords: Effluent treatment, Modified soak pit, Sand filter, Sewage systems, Silver impregnated; Silver leakage

Introduction

Septic tank outflow contamination of surface water and groundwater can be physical, microbial, or both[1]. Domestic well water sources' poor microbial purity is widely reported. The presence of *E. coli* in water indicates that there has been current wastewater or animal manure pollution. The presence of faecal coliforms in freshwater doesn't absolutely detect the presence of feces, but it does suggest a greater probability of pathogenic organisms in the water.

Septic tank effluent[2] is a toxic liquor containing soluble and insoluble both organic and inorganic wastes in a liquid matrix. In septic tank, phosphorous concentration[3] is high in water, coliform bacteria are not removed because reduction of ammonium to nitrate doesn't occur. Hence *E. coli* should be removed. The wastewater from a septic system has a higher level of organic waste, BOD_5, and coliform. Several of these inventions had failed owing to soil blockage that has resulted in surface failure and groundwater pollution[4-6].

Impregnation technique is defined as a method of depositing any material having germicidal effect with sand. Because of its high surface-area-to-volume ratio, silver in the state of silver nitrate, which provides silver ions very efficiently, has a strong bactericidal activity. Hence impregnating the sand with silver removes *E. coli* completely[6-7].

Septic tank effluent is a toxic liquor containing soluble and insoluble organic and inorganic wastes in a liquid matrix. It is typically classified by the ingredients that release harmful, which include nitrogen (ammonia, nitrite, and nitrate), phosphorus, total suspended solids (TSS), biochemical oxygen demand (BOD_5), & faecal coliform. The septic tank procedure transforms organic nitrogen molecules to ammonium; no transformation of ammonium to nitrate is envisaged[8]. Coliform bacteria are not removed because reduction of ammonium to nitrate does not occur. The wastewater from a septic system has a significant level of organic waste, BOD_5, and coliform. The elimination of bacterial contamination is a serious problem because the wastewater is to be cleaned by surface application, especially on a residential allotment[7,9,10]. Table S1 (Supplementary Information) displays the parameters for the septic tank effluent with its average and typical concentrations.

The oxygen in the water required by biological bacteria in the oxidation of biological materials is measured as BOD_5[(Ref.11)]. Ammonium nitrogen in the effluent is decomposed by the microorganisms to form Nitrite and Nitrate. Enhancement the distances between the soaking pit and water bodies to improve the likelihood of Phosphorus adsorption to soil, which is the best widely advised method of minimizing Phosphorus transport to surface water[12].

The majority of septic tank influent was already treated anaerobically before being routed to the soak pit. Intermittent sand filtration is a popular and efficient way to cleanse septic tank effluent. The current soak pit system is not much efficient in removing the nutrients from septic tank effluent. Additional issues include the need for the freshwater well to be at least 15 metres away from the soaking pit in order to maintain quality of the water[13-15]. This requirement was not met in the majority of housing communities due to rising population size. As a consequence, the coliform bacteria concentration in the surface waters is rising. Another important problem is, the bore well water which is thought to be free from *E. coli* is now found to be polluted at a greater scale. This scenario thus calls for a modification of current soak pit system was shown in Fig. 1.

Impregnation technique is a low-cost technology for the septic tank effluent treatment[16]. A slight modification is made into the conventional soak pit system. The soak pit system is filled with sand material for the treatment. Sand's antibacterial & filtration properties might be significantly improved by coating it with metals like silver. Silver metal is also non-toxic and has anti-bacterial properties. More significantly, due to its broad-spectrum toxicity to bacterial &, possibly, fungus & viruses, in addition to its reputation for low toxicity to people, silver has additionally been utilized as a disinfection, for instance, in healing injuries and burns. Silver data indicate that such ions denature proteins (enzymes) in the targeted cell or organism by binding to reactive groups, causing precipitation & deactivation. Silver is infused in different grades of sand. The septic tank effluent is routed into the soak pit using impregnated substances. The wastewater that passes through the various sizes of sand particles and filtrates and hence after treatment the quality of effluent reduces in all the parameter. Ag^+ has a significant affinity for the negatively charged bacterial cell wall. Also, it causes bacterial mortality by producing reactive oxygen species & disrupting membrane permeability[17]. So, in this paper, the efficacy of silver impregnated sand in removing *E. coli* with and without impregnation was discussed. Analysis of silver leaching was also performed.

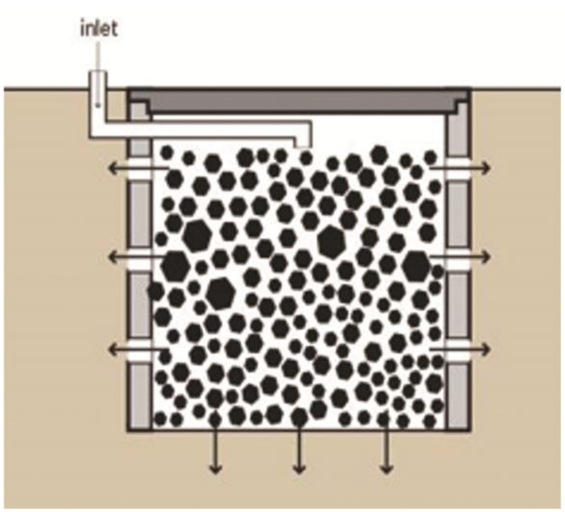

Fig. 1 — Conventional Soak Pit

Experimental Section

The set-up consists of plastic container (reactor) in which various gradation of sand was filled. In another reactor various gradation of sand was impregnated. The length of the reactor is considered to be about 30 cm and diameter of about 10cm in the ratio of about 1:10 from the standard soak pit. Normally in the field, soak pit dimensions are about 1.5-4 m depth and diameter of about 1-1.5 m. The tank was filled with filter media (sand). Table 1 shows the various gradation of sand used in the research.

In terms of achieving equal flow, the influent to the reactors was supplied from an above storage tank linked to a value. The flow rate was estimated to be 14 liters per day. The effluent collection was done on every 3rd day till 30th day for sand and till 15th day for impregnated sand. 30 days were considered as there is no significant variation in the *E. coli* removal after 30 days[19]. By 15th day the *E. coli* of impregnated sample shows around 1100 cfu/100 mL, which meets the irrigation standards, hence further days were not considered. During the impregnation procedure, for 500 g of graded, cleaned & dry sand, 1 g silver nitrate diluted in 1L filtered water was used. The above components were well combined & left to mature for

Table 1 — Various gradation of sand used

S. No	Particle type	Size (mm)	Weight (g)
1.	35 mesh	0.5 mm	…
2.	Medium to coarse sand	0.25-1	500
3.	Coarse sand	1-2	500
4.	Fine gravel	2-3.4	250

1 h. This combination was therefore processed with 2 g of NaOH, which was diluted in 50 mL of filtered water & properly mixed. The sand was processed with 10 mL of 1% NH_4OH solutions & 15 mL of reducing agent (9% sugar solution), which were properly mixed & left for 1 h. Following solar drying, the processed sand was rinsed with distilled water to pH 7 but then dried at 100-110 °C[16].

In the treatment method, dried silver coated sand was combined with cleaned, sieved, & processed sand[18]. 1 kg of sand (35 mesh, medium to coarse, coarse sand) was put in a cylindrical plastic container 10 cm in diameter & 30 cm in length (modified from conventional soak pit size to scale, i.e., 100 cm diameter and 300 cm length). Polyethylene screens with appropriate mesh sizes were installed at the bottom of the container to hold the sand. Contaminated feed water was routed through a plastic container filled with various gradations of treated sand. It is operated for 4 h per day at the flow rate of 14 per hour to pass a total of 56 L of feed water per day. Collected water is then left for microbiological test[14].The actions taken during the treatment method in process diagram were shown in Fig. 2.

The effect of different silver dosage was also analysed. Sand particle size of 0.5 mm are impregnated and filled in the reactor of varying silver dosage (2.5 g, 2 g, 1.5 g) and effluent collection was done on 2, 4, 6, 8, 10, 12, 14th day treatment. The collected impregnated effluents were taken for the silver analysis. Because taking sewage tank effluent for testing proved challenging, synthetic septic tank wastewater was created in the lab[20,21]. Standard procedures were employed to gather and analyze effluents for BOD_5, *E. coli*, TSS, Ammonia Nitrogen, Nitrate Nitrogen & Phosphate.

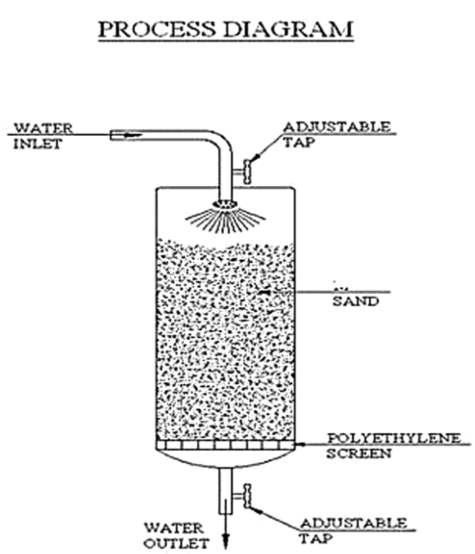

Fig. 2 — Process diagram[11]

Results and Discussion

Characteristics of synthetic septic tank effluent

Here the synthetic septic tank effluent was prepared by mixing laboratory reagents. Table S2 shows the composition of synthetic septic tank effluent. It was tested and characteristics obtained for synthetic septic tank effluent were as shown in Table 2.

Comparative study between with and without impregnation

The obtained results for BOD_5, *E. coli*, Ammonia Nitrogen, Nitrate Nitrogen, Phosphate and TSS without impregnation were analysed. Flow rate has great role on filtration efficiency. As the flow rate decreases, the filter efficiency increases. The flow rate was maintained constant at 14 L/h in this case. The above stated gradations of sand were taken in a reactor. 4 h were considered to be the peak hour. Hence treatment was continued to 4 h. Same gradation of sand was impregnated by above procedure and placed in the reactor and the treatment was continued and the effluent was analyzed. Table S3 shows the values obtained for the sand filter without impregnation.

Table S4 shows the values obtained for impregnated sand filter. The treatment continues for 15 days to reach the irrigation standards. Flow rate is kept constant throughout the treatment. It is a batch process.

Fig. 3(a) shows the removal efficiency of each parameter at constant flow rate. The treatment process is continued for 30 days without impregnation and 15 days for with impregnation. The analysis shows that as the number of days' increases 5-day BOD removal efficiency also increases. The biochemical

Table 2 — Characteristics of synthetic septic tank effluent

S. No.	Component	Unit	Value
1.	TSS	mg/L	63
2.	BOD5	mg/L	140
3.	Fecal coliform Bacteria	C.F.U/100 mL	24×10^5
4.	Ammonia Nitrogen	mg/L	47
5.	Nitrate Nitrogen	mg/L	2
6.	Phosphate	mg/L	12
7.	pH		6.53

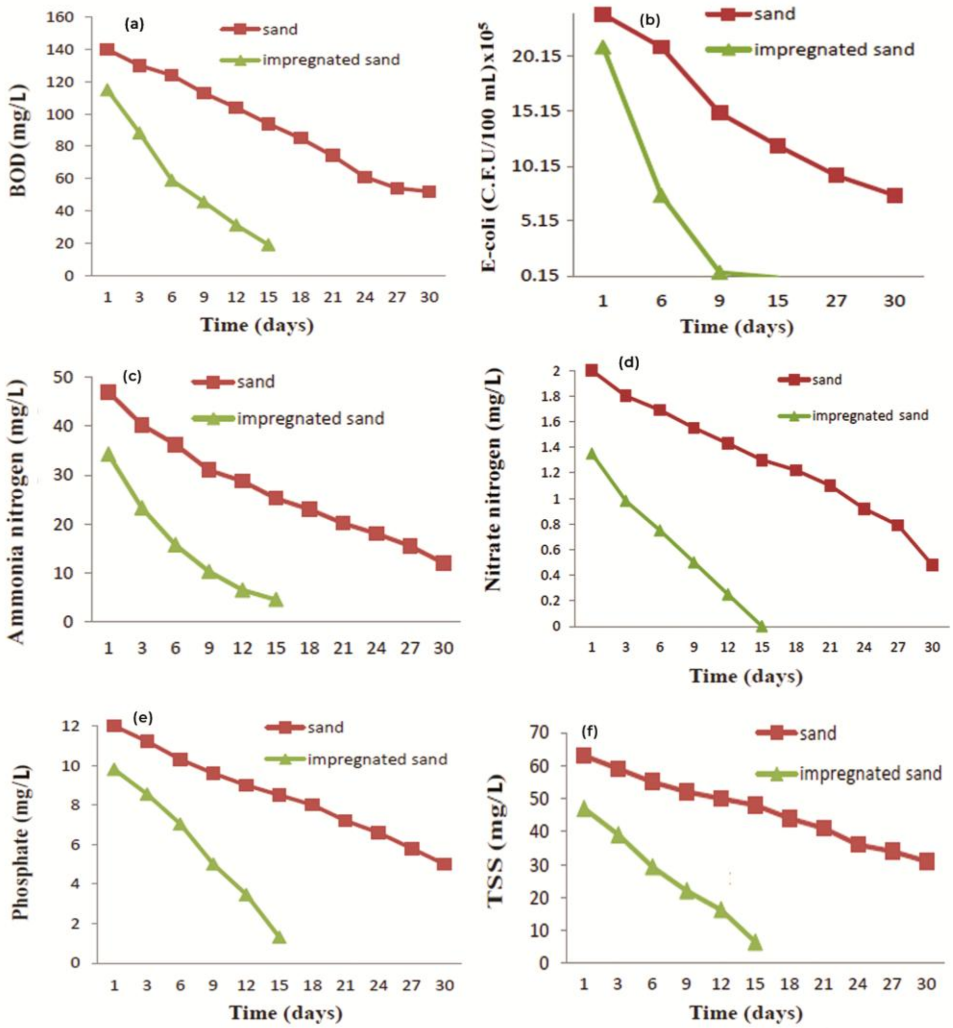

Fig. 3 — (a) BOD, (b) *E. Coli*, (c) Ammonia nitrogen, (d) Nitrate nitrogen, (e) Phosphate and (f) TSS variation with time at constant flow rate

oxygen demand, or BOD_5, measures the quantity of organic substances in wastewater. BOD_5 is a critical metric in the design and maintenance of wastewater treatment systems[22]. At 30 days of treatment without impregnation, the sand filter attains removal efficiency of 65.89% as the microorganisms present in the sand filter degrades the organic material whereas with impregnation, the sand filter attains removal efficiency of 86.42%. This is related to the activities of silver, as well as the microbes in the sand. This finding indicates that typically settable BOD_5 can be eliminated by physical methods such as sedimentation & filtering.

E. coli variation with time for synthetic septic tank effluentis shown in Fig. 3(b). Escherichia coli are a kind of faecal coliform bacteria typically discovered in the intestines of both mammals and humans. The appearance of *E. coli* in water indicates that there has been current wastewater or animal waste pollution[23]. Coliforms are utilized to detect wastewater contamination. The initial *E. coli* concentration in this experiment set is 2400000 C.F.U./100 mL. This was reduced to 1100 C.F.U./100 mL for sand filter with impregnation, i.e. a removal efficiency of 99.95% in 15 days of treatment. This is due to the fact that silver has germicidal property and helps in the removal of *E. coli*. In case of sand filter without impregnation, the removal efficiency is only 65% after 30 days of treatment and may be further improved by increasing the time.

Fig. 3(c) shows Ammonia Nitrogen variation with time for synthetic septic tank effluent. Ammonia Nitrogen's early concentration was 47 mg/L. This was decreased to 4.5 mg/L for sand filter with impregnation and 12 mg/L for sand filter without impregnation. Silver helps in denitrification and so the value of ammonia nitrogen gets decreased in case of impregnated sand.

Fig. 3(d) shows Nitrate Nitrogen variation with time for synthetic septic tank effluent. The removal efficiency of nitrate nitrogen is about 75% for sand filter without impregnation, whereas 100% for sand filter with impregnation in 15 days of treatment.

Fig. 3(e) shows Phosphate variation with time for synthetic septic tank. Human excrement, foodstuff leftovers, cleansers, & soaps all contribute to the presence of phosphorus in sewage[24]. Phosphorous removal in the septic system is minimal. For sand filter without impregnation the removal efficiency is about 52% in the case of impregnated sand filter the removal efficiency is about 79%.

Fig. 3(f) shows TSS variation with time for synthetic septic tank effluent. Total suspended solids are all of the particles suspended in water that can flow through a filter. About 89% elimination efficiency is achieved within 15 days of treatment in impregnated sand filter. Without impregnation the removal efficiency is less and 55% solids are not filtered properly. Because a portion of the suspended solids were therefore extracted as BOD_5, impregnated sand has high extraction efficiency. Table S5 shows evaluation of percentage removal of each parameter with and without impregnation.

As shown in Fig. 4, the removal effectiveness of different variables, with impregnation having a higher extraction efficiency than sand without impregnation as the time is enhanced. Impregnated sand achieves average of 90% removal efficiency over the 15 days of treatment and without impregnation 65% of removal efficiency over the 30 days of treatment.

Comparative study between with and without gradation of sand

Fine gravel, Coarse sand, medium to coarse sand, 0.5 mm sand are impregnated and placed in different depth. Fine gravel is placed at the bottom of the container for 5 cm, coarse sand is filled next to it for 5 cm, medium to coarse sand is filled next to it for 5 cm,35 mesh is filled for 10 cm. Expect fine gravel all other sand particles are impregnated. The treatment is carried out for 15 days at the flow rate of 1.4 L/h. Tables 3 and 4 show the values obtained for various gradation of sand.

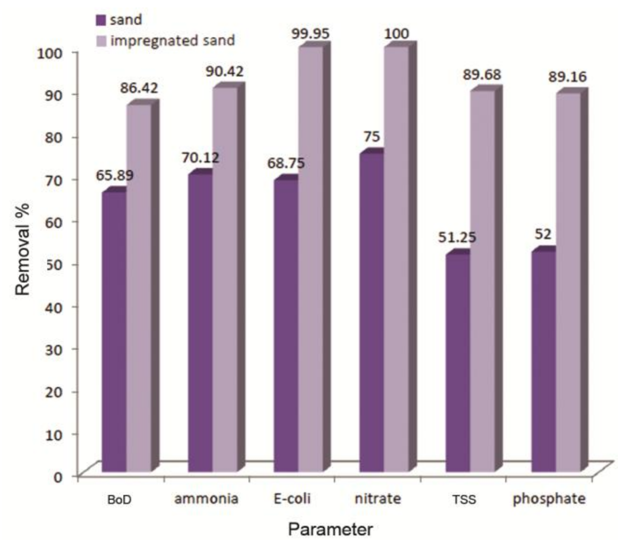

Fig. 4 — Percentage removal efficiency of parameter at constant flow rate with sand and impregnated sand

Table 3 — Effluent concentration for various gradations of sand

Time (days)	TSS (mg/L)	Phosphate (mg/L)	Ammonia nitrogen (mg/L)	BOD (mg/L)	Nitrate (mg/L)	*E. coli* (C.F.U/100 mL)x 10^5
1	47	9.8	34.54	115	1.35	21
3	39	8.54	23.25	88.254	0.98	12
6	29.25	7.03	15.69	59	0.75	7.5
9	22	5	10.25	45.5	0.5	0.46
12	16.25	3.46	6.45	31.25	0.25	0.21
15	6.5	1.3	4.5	19	0	0.011

Table 4 — Values obtained for without gradation -0.5 mm sand

Time (days)	TSS (mg/L)	Phosphate (mg/L)	Ammonia nitrogen (mg/L)	BOD (mg/L)	Nitrate	nitrogen (mg/L)
1	52.56	12	40.25	129.21	1.68	21
3	45.25	9.8	30.89	100.85	1.25	15
6	35.69	8.54	21	81.45	0.95	12
9	29.63	7.03	15.58	65.89	0.75	7.5
12	19	4.5	10.25	42.28	0.45	0.24
15	9.25	2	6.5	25	0.1	0.15

Comparison between varying silver dosage

Impregnation ratio is defined as the ratio between weights of silver nitrate to that of the weight of dried sample. 35 mesh (0.5 mm) sand weighing 1500 g were placed in the reactor[25]. At the bottom of the reactor fine gravel were placed to prevent the escape of sand particles through polythene mesh. From the actual procedure, 3 g of silver nitrate was used for the impregnation but due to leaching, silver content was reduced say 2.5 g, 2 g, 1.5 g. Hence the impregnating ratios are 0.0016, 0.0013, and 0.001. Tables S6-S8 show the values obtained for various silver dosage.

In Table 5, the removal efficiency of each parameter ranges from 70-80% if silver content decreases. The treatment days can be increased comparing with the three dosages. 2.5 g has the leaching effect higher and their removal efficiency is increased. In all the three dosage TSS removes in the same range. This is because of the more amount of washed-out particles is removed at first as shown in Fig. 5.

Analysis of silver leaching

When the sand is impregnated with silver, silver leaching is noticed. If the Silver concentration in the effluent is disposed to the natural water the concentration range should be from 0.35 ng/L to 500 ng/L. silver leaching was analyzed for various gradation of sand and for the various silver dosage[26] and is shown in Fig. 6. shows the silver leaching for 0.5 mm impregnated sand particle with silver dosage of 3 g. 1st day silver leaching is about 450,000 ng/L within 15 days the leaching of silver is reduced to 25000 ng/L. Very fine sand particle (0.5 mm) were coated with silver and hence the outer layer of coating gets leached off. In account of high leaching the removal efficiency of each parameter is about 85 – 90%. Only drawback is that leaching is higher and cannot be disposed to natural water. Hence the effluent may cause the health problems and so silver dosage should be reduced in order to protect the environment[27].Silver dosage of 2.5g attains leaching of about 8000 ng/l which cannot be disposed to the natural water. The outer coating of silver gets leached off but there is no decrease in the removal efficiency of the parameter[28]. For the silver dosage 2 g attains leakage about 5000 ng/L which cannot be disposed to the natural water. Silver dosage of 1.5 g attains

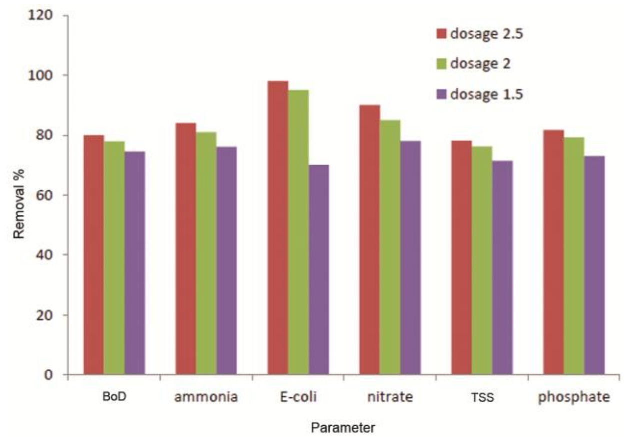

Fig. 5 — Percentage removal efficiency of parameter at constant flow rate with different dosage

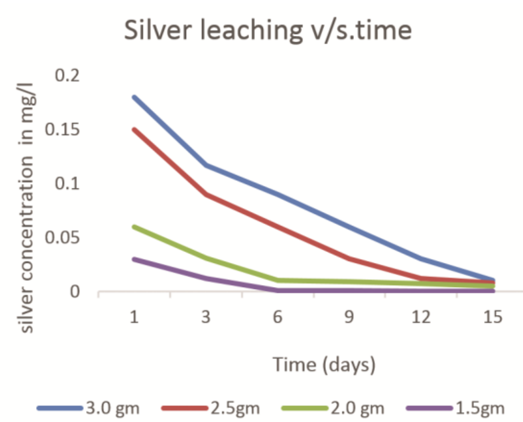

Fig. 6 — Silver leaching for various silver dosages Add the plot for Silver dosage 3 g

Table 5 — Evaluation of percentage removal

Parameter	Concentration before treatment	Dosage 2.5 g		Dosage 2 g		Dosage 1.5 g	
		After treatment	% removal	After treatment	% removal	After treatment	% removal
BOD (mg/L)	140	28	80	30.89	77.9	35.69	74.50
Ammonia nitrogen (mg/L)	47	7.5	84.4	8.98	80.98	11.23	76.10
E. coli (C.F.U/100 mL) x 10^5	24	0.46	98	1.1	95	7.5	70
Nitrate N_2 mg/L	2	0.2	95	0.3	85	0.45	78
TSS mg/L	63	13.78	78.12	15	76.19	18	71.4
Phosphate mg/L	12	2.2	81.66	2.5	79.16	3.25	73

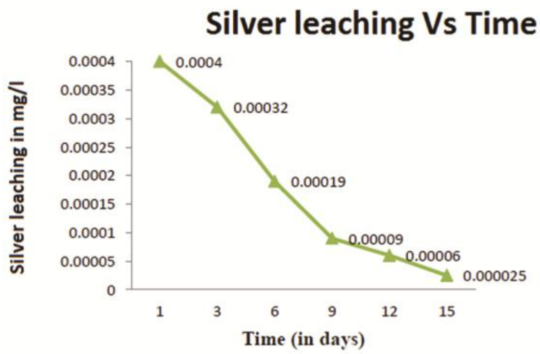

Fig. 7 —Graph shows silver leaching for impregnated sand with gradation

leaching of about 380 ng/L and that is under the permissible limit for disposal to water. The removal efficiency of 1.5 g silver dosage is around 75% on average and can be increased by increasing time.

Silver leaching for impregnated sand with gradation

In Fig. 7, the silver leaching is about 450 ng/L on the 1st day and decreases to 25 ng/L on 15th day and still leaching gets decreases and the effluent can be disposed to the natural water[29]. The outer coating of silver gets leached off but there is no decrease in the removal efficiency of the parameter[30]. The removal efficiency of impregnated sand with various gradations is around 85-95% on average and can be increased by increasing time.

Conclusion

Impregnation method is a low cost approach with great promise for treating septic tank effluent and particularly successful at removing *E. coli*, Nitrate nitrogen, Biochemical Oxygen demand, Total suspended particles, & phosphate. The analysis indicates that when the amount of treatment periods improved, so did the removal effectiveness of different parameters. The increase in the removal efficiency of impregnated sand may be due to the surface-area-volume contact and the germicidal effect of silver. Various sizes of sand particles are used and impregnated with silver. The removal efficiency of sand without impregnation are 65% of BOD, 68% of *E. coli*, 70% of ammonia nitrogen, 75% of nitrate nitrogen, 52% of phosphate, 52% of TSS with 30 days of detention time. The removal efficiency of each parameter with impregnation are 86% of BOD, 90% of ammonia nitrogen, 99.95% of *E. coli*, 100% of nitrate nitrogen, 90% of TSS, 89% of phosphate. This high removal efficiency is due to the coating effect of silver and various sizes of sand particles. The whole treatment efficiency is above 85% for the detention time of 15 days. The findings of a comparative analysis among sand particle gradation but no gradation (0.5 mm) revealed that sand particle gradation produces superior outcomes than neither. The movement of effluent through the various gradations of sand particles which are impregnated removes *E. coli*, nitrate nitrogen, Ammonia nitrogen, TSS in large extent due to the various properties of sand whereas without gradation 0.5 mm sand were impregnated. The removal efficiency is nearer to the various gradation of sand but leaching is high in case of 0.5 mm (without gradation) but less in case of various gradation of sand. Due to high leaching, the reduction of silver dosage is done. High removal efficiency for 2.5 g of silver dosage compared with other dosage (2 g, 1.5 g) is reported. Hence less silver dosage results in less leaching which does not harm to human and environment. Based on the findings, it is feasible to conclude that impregnating the sand particles has a substantial impact on the processing of septic tank effluent.

Supplementary Information

Supplementary information is available on the website http://nopr.niscpr.res.in/handle/123456789.

References

1 Wilhelm S R, Schiff S L & Robertson W D, Chemical fate and transport in a domestic septic system: Unsaturated and saturated zone geochemistry, *Environ Toxicol Chem: Int J*, 13 (1994) 193.

2 Henry H, Treatment of septic tank effluent using the Puraflo peat biofiltration system. In *Proceedings of the Eleventh Annual on-Site Wastewater Treatment Conference Minimizing Impacts, Maximizing Resource Potential*, (1996).

3 Corbett D R, Dillon K, Burnett W & Schaefer G, The spatial variability of nitrogen and phosphorus concentration in a sand aquifer influenced by onsite sewage treatment and disposal systems: A case study on St. George Island, Florida, *Environ Pollut*, 117 (2002) 337.

4 Hanes N B, Bratina I C & Brown L C, Lead removal and bacterial growth in home water purifiers. In *Proc. AWWA Ann. Conf., Atlantic City, NJ,* (1978).

5 Patterson R A, Peat treatment of septic tank effluent, In *Proceedings of On-site*, 99 (1999) 293.

6 Robertson W D, Schiff S L & Ptacek C J, Review of phosphate mobility and persistence in 10 septic system plumes, *Groundwater*, 36 (1998) 1000.

7 Kling S, *Determination of Domestic Wastewater Chracteristics and Its Relation to the Type and Size of Developments* (Doctoral dissertation, Universiti Teknologi Malaysia), (2007).

8 Han Z Y, Liu D & Li Q B, A removal mechanism for organics and nitrogen in treating leachate using a semi-aerobic aged refuse biofilter, *J Environ Manag*, 114 (2013) 336.

9 Narmadha D & Kavitha M S, Treatment of domestic waste water using natural flocculants, *Int J Life Sci Biotechnol Pharm Res*, 1 (2012) 206.

10 Mpenyana-Monyatsi L, Mthombeni N H, Onyango M S & Momba M N, Cost-effective filter materials coated with silver nanoparticles for the removal of pathogenic bacteria in groundwater, *Int J Environ Res Public Health*, 9 (2012) 244.

11 Bandara W M K R T W, Nanayakkara K G N, Premananth P & Werellagama D R I B, Development of an upflow anaerobic biological filter for domestic use in tropical countries, *Ann Res J SLSAJ*, 8 (2008) 6.

12 Hosseini S M & Tosco T, Transport and retention of high concentrated nano-Fe/Cu particles through highly flow-rated packed sand column, *Water Res*, 47 (2013) 326.

13 Fiore J V & Babineau R A, Effect of an activated carbon filter on the microbial quality of water, *Appl Environ Microbiol* 34 (1977) 541.

14 Tobin R S, Smith D K & Lindsay J A, Effects of activated carbon and bacteriostatic filters on microbiological quality of drinking water, *Appl Environ Microbiol*, 41 (1981) 646.

15 Bodkhe S Y, A modified anaerobic baffled reactor for municipal wastewater treatment, *J Environ Manag*, 90 (2009) 2488.

16 Kariuki F W, Kotut K & Nganga V G, The potential of a low cost technology for the greywater treatment, *The Open Environ Eng J*, 4 (2011) 32.

17 Mahmood S N, Naeem S, Basit N & Usmani T H, Microbial evaluation of silver coated/impregnated sand for purification of contaminated water, *Environ Technol*, 14 (1993) 151.

18 Sheet I, Holail H, Olama Z, Kabbani A & Hines M, The antibacterial activity of graphite oxide, silver, impregnated graphite oxide with silver and GO-coated sand nanoparticles against waterborne pathogenic *E. coli* BL21, *Int J Curr Microbiol App Sci*, 2 (2013) 1.

19 Rababah A, Hydroponics removal of wastewater's contaminants for the generation of commercially valuable plants and environmentally sound effluent for the dead sea communities, *Jordan J Civil Eng*, 1 (2007) 273.

20 Adler P R, Summerfelt S T, Glenn D M & Takeda F, Mechanistic approach to phytoremediation of water, *Ecol Eng*, 20 (2003) 251.

21 Garg S K, Sewage disposal and air pollution engineering, *Environ Eng J*, 2 (2012) 877.

22 Manual D, Constructed wetlands and aquatic plant systems for municipal wastewater treatment, *United States Environ Prot Agency*, 625 (1988) 1.

23 Narcis B, Valentin N & Gabriel L, Current stage of domestic wastewater treatment in small plants, *J Eng Stud Res*, 17 (2011) 13.

24 Zurawsky M A, Robertson W D, Ptacek C J & Schiff S L, Geochemical stability of phosphorus solids below septic system infiltration beds, *J Contam Hydrol*, 73 (2004) 129.

25 Tilton R C & Rosenberg B E R N A R D, Reversal of the silver inhibition of microorganisms by agar, *Appl Environ Microbiol*, 35 (1978) 1116.

26 Babu R, Zhang J, Beckman E J, Virji M, Pasculle W A & Wells A, Antimicrobial activities of silver used as a polymerization catalyst for a wound-healing matrix, *Biomaterials*, 27 (2006) 4304.

27 Beal C, Gardner E & Menzies N, Septic absorption trenches: Are they sustainable, *Water*, 32 (2005) 22.

28 Craun G F, Waterborne disease-A status report emphasizing outbreaks in ground-water Systems[a], *Groundwater*, 17 (1979) 183.

29 Tilley E, Lüthi C, Morel A, Zurbrügg C & Schertenleib R, Compendium of Sanitation Systems and Technologies Dübendorf, *Zwitzerland, Swiss Federal Institute of Aquatic Science and Technology (EAWAG)*, (2008).

30 Zurawsky M A, Robertson W D, Ptacek C J & Schiff S L, Geochemical stability of phosphorus solids below septic system infiltration beds, *J Contam Hydrol*, 73 (2004) 129.