TREATMENT OF DOMESTIC WASTEWATER BY SOIL TRENCH SYSTEM

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Abstract. Soil trench system is a common tool to treat domestic wastewater because of its simplicity, stability, and low cost. A pilot system with height of 1.2 m, length of 9 m and width of 3 m, was built at National Institute for Environmental Studies in Japan. The system consists of three trenches and placed parallel. Nine samples from different points of the trench system were taken every week . The whole experiment lasted 4 weeks. The following physical and chemical parameters were analyzed: SS (Suspended solid), TOC (Total Organic Carbon, NH_4-N, PO_4-P, NO_{3+2}-N, NO_2-N, TN (Total Nitrogen), TP (Total Phosphorous). The results show that soil trench system provides very high efficiency for domestic wastewater treatment. The effluent quality meets effluent standard of Ibaraki- Japan (BOD<10 mg/l, T-N<10mg/l, T-P<0.5 mg/l). The removal efficiency (%) of NH_4-N, PO4-P, T-N, T-P, TOC, SS are 96.37, 99.64, 75.64, 98.45, 94.91, 99.81, respectively. To reduce treatment cost and time the soil trench system consisted of two trenches could be used because the effluent quality from trench 2 is almost the same as effluent quality from trench 3.

Key words: *Soil trench system, treatment efficiency, total phosphorous, total nitrogen, Biological Oxygen Demand (BOD)*

1. Introduction

Soil trench system is usually the best tool to treat domestic wastewater because of its simplicity, stability, and low cost. Under the proper condition, the soil is an excellent treatment medium and requires little wastewater pretreatment. This technology makes use of interaction among root of plant, soil animals and soil microbes in the soil layer several tens cm below the ground surface, where biota is most complex, diversified and dense.

Trenches are shallow, level excavations is usually 0.3 to 1.5 m deep and 0.3 to 0.9 m wide. The bottom is filled with 15 cm or more of washed crushed rock or gravel over which is laid a single line of perforated distribution pipe. Additional rock is placed over the pipe and the rock covered with suitable semi-permeable barriers to prevent the back-fill from penetrating the rock. Both the bottoms and side-walls of the trenches are infiltrative surfaces. Beds differ from trenches in that they are wider than 0.9 m and may contain more than one line of distribution pipes [1]. This soil trench system prevents pollution completely and can be applied to a small-scale or decentralized treatment. It also can be used effectively for existing large-scale equipment as an energy saving treatment method [2]

Because of effective utilization of soil microbes and anaerobic microbes, nitrogen and phosphorous can be removed from the wastewater, the amount of surplus sludge is as small as one fifth that of the conventional activated sludge process, and maintenance is easy

Since plants, animals and microbes are utilized integrally for preventing clogging of waste; the method can be applied to mass infiltration of high concentration wastewater and rain water under the ground [3].

The research aims:

• To study the treatment efficiency of soil trench system with three trenches to treat domestic wastewater

• To compare treatment efficiency of each soil trench in the system.

2. Material and methods

Experiment set-up

A soil trench system was constructed by International Water Environment Renovation Research Team- Regional Environment Division- National Institute for Environmental Studies of Japan. It is a concrete tank with height of 1.2 m, length of 9 m and width of 3 m. The tank consists of three trenches 1, 2 and 3

The layers of construction materials are laid from above to the bottom as follows:
- Soil level: 20 cm
- Distribution pile: 5cm
- Gravel and sand 35 cm
- Plastic film
- Collecting pile
- Plastic media or stone

The experiment was proceeded as follows: 60% of raw wastewater flows to soil trench 1, 40% to soil trench 2, and soil trench 3 received only effluent from soil trench 2. The detail of wastewater distribution is described as follows: Wastewater (1400 l/day) firstly flows to distribution tank from which 60% (840 l) flows to anaerobic biofilm 1 and 40% (560 l) flows to anaerobic bio-film 2. The retention time in the anaerobic biofilm is 24 hours. After that wastewater from anaerobic bio-film 1 flows to soil trench 1 through a distributing perforated pipe with diameter ~ 5 cm (the diameter of the hole is about 1.5 cm). The hydraulic retention time in the soil trench is about 24 hours. Wastewater (714 l, of which 126 l is remained in the soil) from soil trench 1. Then is collected by a pipe in the bottom of trench and flows to the anaerobic bio-film 2. Total amount of wastewater in the anaerobic bio-film 2 is 1274 l. The hydraulic retention time in the anaerobic bio-film 2 is also 24 hours. Second soil trench receives wastewater from anaerobic bio-film 2 and discharged a treated effluent with following characteristics: BOD<5mg/l, NO_3-N 10 mg/l, T-P<0.2 mg/l. The trench 3 was built parallel with soil trench 2. This soil trench receives effluent from soil trench 2 to improve the quality of the effluent.

Sample collection

Nine samples were taken every week and the whole experiment lasted 4 weeks. Figure 1 shows the wastewater distribution and sampling points

Sample 1: raw wastewater in the distribution tank

Sample 2: wastewater in anaerobic biofilm 1 before flowing to soil trench 1

Sample 3: effluent in collection pipe of soil trench 1 before flowing to anaerobic biofilm 2

Sample 4: wastewater in anaerobic biofilm 2 near the entering point of influent

Sample 5: wastewater from anaerobic biofilm 2 before flowing to soil trench 2

Sample 6: effluent from soil trench 2

Sample 7: effluent from soil trench 2 in anaerobic biofilm 3

Sample 8: wastewater from anaerobic biofilm 3 before flowing to soil trench 3

Sample 9: effluent from collection pipe of soil trench 3 as a treated wastewater

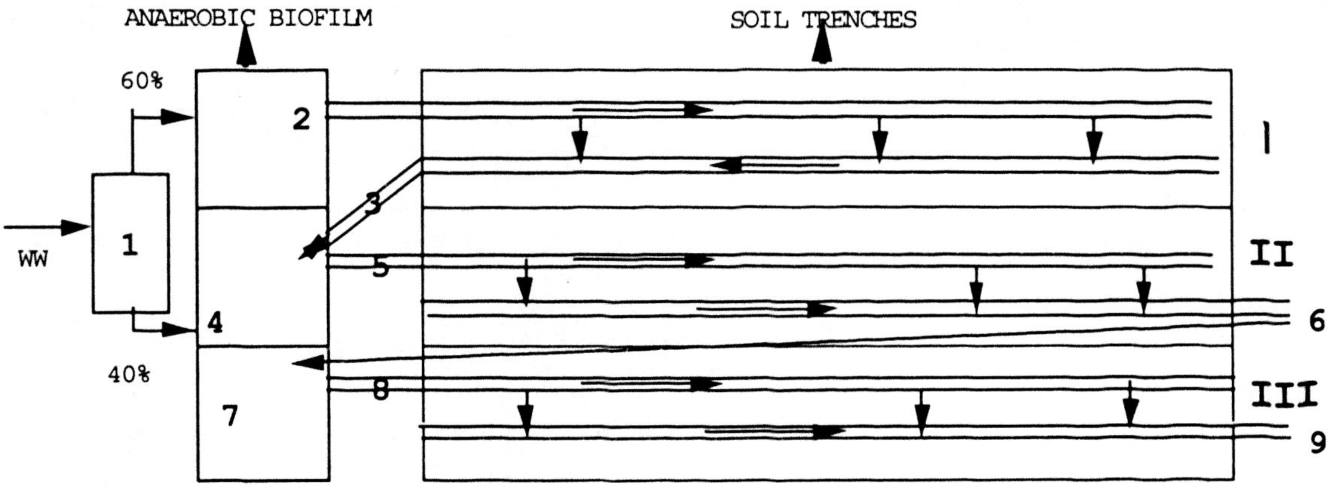

Figure 1: Soil trench layout (Number I to III on the right side) and sampling points (from 1 to 9)

Sample analysis

The following chemical parameters were analyzed:

TOC (Total Organic Carbon): by TOC 5000 Shimazu

NH_4-N, PO_4-P, NO_{3+2}-N, NO_2-N, TN (Total Nitrogen): , TP (Total Phosphorous): : by TRAACS analyzer

SS (Suspended solid): follows the procedure in Standard Method

3. Results and Discussion

Samples were taken 4 times with interval one week each. Results of physical and chemical parameter of four sampling times are presented in Table 1

Table 1. The data of wastewater samples of four sampling times

Sampling times	Sample No	Temperature	NH_4-N	PO_4-P	NO_{2+3}-N	$N0_2N$	T-N	T-P	TOC	SS (mg/l)
1	1	13	20.68	3.191	0.1745	-0.0612	28.67	3.99	31.06	42
	2	14.6	22.1	2.911	0.1682	-0.0426	27.64	3.37	37.77	36
	3	14.2	0.1073	0.01484	13.52	-0.0029	13.68	0.03	3.31	91
	4		4.752	0.4446	7.164	-0.0183	13.69	0.74	5.40	48
	5		5.42	0.4685	2.422	-0.028	15.89	1.20	7.6	78
	6	15.7	0.6063	0.00588	7.34	-0.0006	8.49	0.02	3.06	5
	7	15.9	1.099	0.0464	8.719	-0.0233	10.34	0.18	3.47	6
	8		1.59	0.0386	7.626	0.961	10.38	0.15	21.93	8
	9		1.408	0.00806	6.528	-0.0015	8.62	0.02	3.37	0.67
2	1	18	30.21	2.914	0.2345	0.0152	37.73	3.9	71.45	1550
	2	18	29.76	3.297	-0.004	0.302	37.4	4.09	39.02	102
	3	15	0.1913	-0.033	12.17	0.033	13.39	0.03	2.88	94
	4	16	17.05	1.806	3.414	0.0917	25.2	2.42	19.63	50
	5	16	9.219	0.9069	0.2425	0.074	11.18	1.12	8.76	36
	6	15	0.518	0.0261	6.727	0.0732	7.5	0.08	2.37	2
	7	16	1.162	0.0261	7.094	0.0602	8.54	0.2	7.25	2
	8	15	1.251	0.0072	5.912	0.2187	7.65	0.01	6.23	2
	9	14	1.157	0.0161	6.355	0.1082	7.45	0.11	2.05	0.8
3	1	16.5	28.29	3.4676	0.0535	0.0374	36.82	4.042	30.3	420
	2	17	28.03	3.306	0.0543	0.0337	34.12	3.693	32.57	138
	3	13	0.2319	0.0219	14.86	0.018	15.81	0.0571	2.67	50
	4	16	17.65	1.912	2.78	0.2089	26.68	2.321	14.08	38
	5	14	10.08	0.9714	0.1496	0.0219	14.33	1.275	4.685	30
	6	13.5	0.3676	0.0375	6.724	0.0555	9.386	0.0935	9.447	1
	7	14	0.5461	0.0494	7.381	0.0604	8.391	0.0784	1.12	2
	8	13	0.3145	0.0296	6.795	0.251	7.511	0.0635	-0.66	2
	9	12	0.5623	0.0474	7.081	0.0558	7.823	0.067	1.485	2.6
4	1	10	21.66	2.794	0.201	0.066	23.61	3.053	32.54	540
	2	16	27.19	3.238	0.178	-0.058	28.7	3.377	34.39	38
	3	14	0.326	-0.018	15.96	-0.022	16.39	0.011	1.918	232
	4	16	8.274	1.077	3.028	0.091	12.48	1.18	5.247	850
	5	15	11.71	1.457	0.397	0.05	12.21	1.473	34.39	22
	6	16	0.631	-0.006	7.267	0.018	7.977	0.114	4.502	1
	7	13	0.756	0.001	6.943	-0.019	7.356	0.045	4.494	2
	8	12	0.326	0.006	7.096	0.024	7.604	0.068	1.231	2
	9	14	0.534	-0.027	6.843	-0.005	7	0.036	1.521	0.7

The average values of four above data are shown in Table 2

Table 2. The average values of four sampling times

Sample No	NH_4-N	PO_4-P	NO_{2+3}-N	$N0_2N$	T-N	T-P	TOC	SS (mg/l)	C/N
1	25.21	3.09175	0.166	0.01425	31.7075	3.746	41.338	638	1.295
2	26.77	3.188	0.099	0.05875	31.965	3.633	35.938	78.5	1.141
3	0.214	-0.0035	14.1275	0.0065	14.8175	0.034	2.6948	116.8	0.186
4	11.932	1.31	4.0965	0.0935	19.5125	1.665	11.089	246.5	0.53
5	9.1073	0.95075	0.803	0.0295	13.4025	1.267	13.859	41.5	1.102
6	0.5308	0.016	7.0145	0.03625	8.33825	0.078	4.8458	2.25	0.562
7	0.8908	0.0305	7.53425	0.0195	8.65675	0.126	4.0835	3	0.482
8	0.8703	0.0205	6.85725	0.36375	8.28625	0.073	7.1828	3.5	0.75
9	0.9153	0.011	6.70175	0.0395	7.72325	0.058	2.1055	1.193	0.268

The average values are illustrated in Figure 2. It can be seen that the results of four sampling times are quite consistent and they have followed the same tendency.

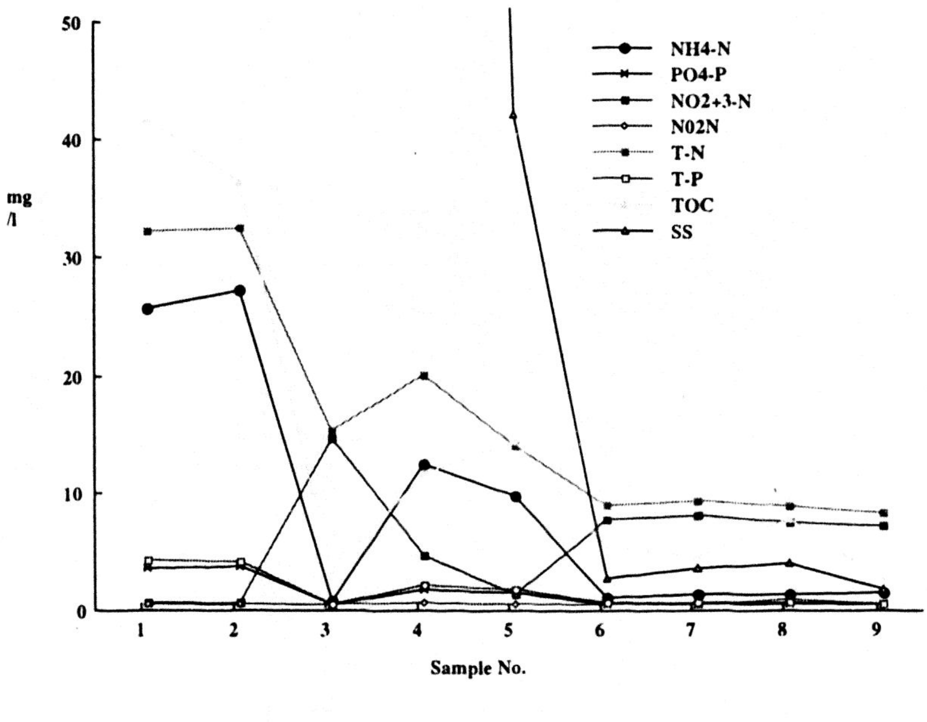

Figure 2: The average values of all parameters

These soil trenches have a great efficiency for BOD and nutrient removal. The results are analyzed and discussed in detail below:

BOD removal

The relationship between BOD and TOC was previously studied for this soil trench system and the ratio of $BOD_{in} = TOC_{in} * 3.2$ and $BOD_{out} = TOC_{out} / 2.3$ was found. The initial BOD and BOD of three effluents calculated from average data of Table 2 are presented in Table 3.

Table 3. The BOD removal from the effluents 1, 2, 3

BOD	Values (mg/l)	BOD removal (%)
Influent-sample No. 1	132.28	0
Effluent 1 -sample No. 3	1.17	99.11
Effluent 2 -sample No. 6	2.11	98.41
Effluent 3 -sample No. 9	0.92	99.31

Comparing the BOD of effluent from three soil trenches, it can be concluded that with aspect of BOD removal, high efficiency can be achieved after only one soil trench where about 99.11 % of BOD were removed. The reason of high BOD removal is related to suspended solid and TOC removal

Suspended solid and TOC removal

The relationship between TOC and suspended solid is shown in Figures 3.

Until the end of soil trench 2, the higher suspended solid the higher the TOC content can be observed. It means that some amount of organic carbon is in the form of suspended solid. In soil trench 3 the TOC is only in the form of dissolved organic carbon.

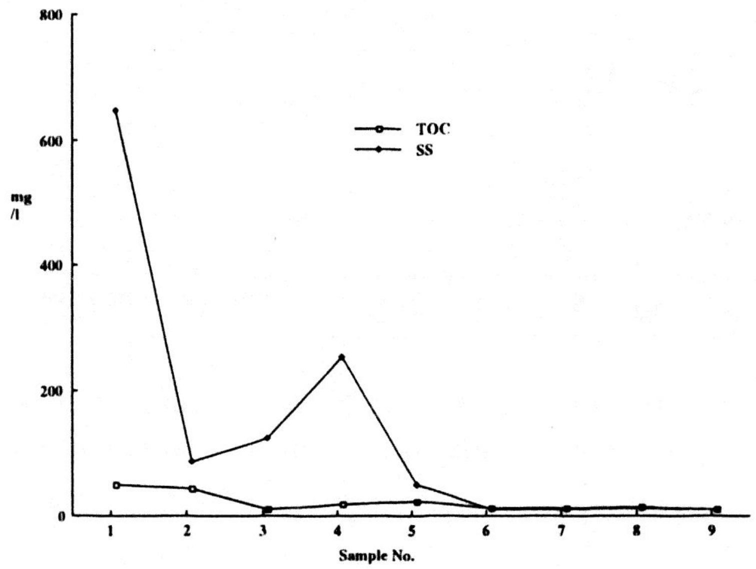

Figure 3: The average values of TOC and suspended solid

The lower suspended solid removal of soil trench 1 may due to the way of sampling. Since the water level in sampling pipe is very shallow therefore when sucking the water to the cylinder the soil in the bottom of the pipe was also sucked in with water so that it make the suspended content higher than it would be.

The suspended solid and TOC removal of soil trench 2 and 3 is almost the same. It means that only a little improvement of treated wastewater made by soil trench 3.

Nitrogen removal

Figure 7 show that the high efficiency of wastewater treatment could be achieved in the soil trench system consisted of two trenches.

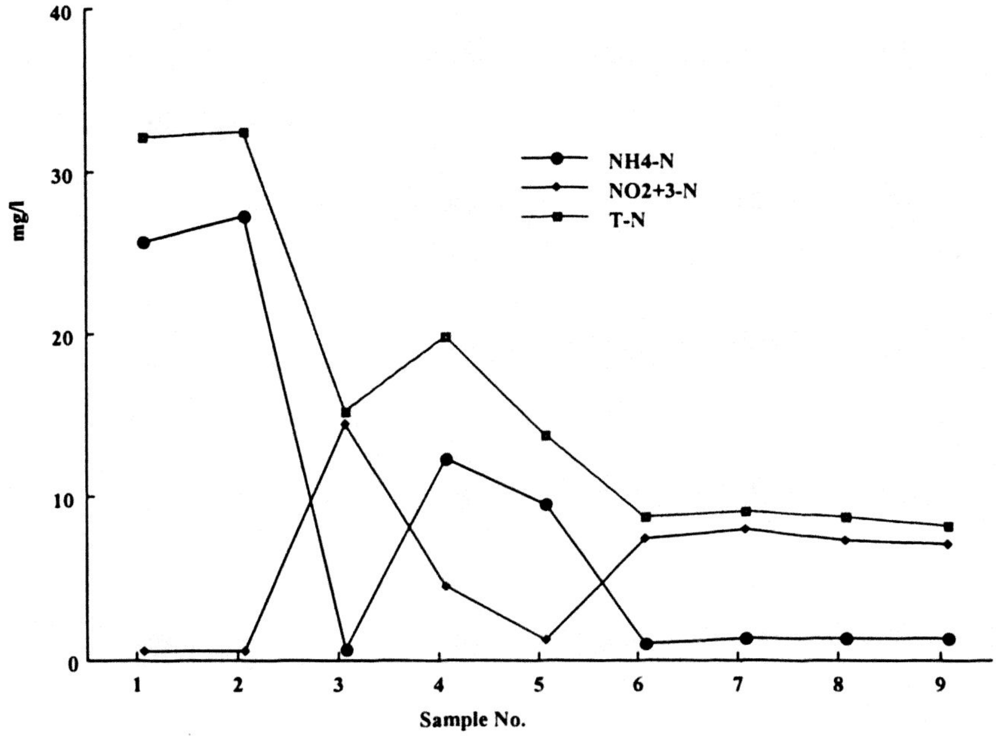

Figure 4: The average values of nitrogen parameters

It is clearly seen from Figure 4 that almost all amount of ammonia was converted to NO_x (mainly NO_3) by nitrification process in the end of soil trench 1. This indicates that the aeration condition in the soil trench is very good. There is sufficient amount of oxygen to oxide all NH_4 to NO_x

The de-nitrification is taking place mainly in the anaerobic bio-film 2 because there is favorable condition for nitrification: anoxic condition and sufficient carbon source (from additional amount of influent, thought it is still not the most favorable rate as 1:1 or 2:1 as TOC:T-N). According to Williams and Perce [4] the de-nitrification potential of wastewater is primarily a function of available organic carbon, which is usually expressed as COD/N or BOD/N ratio. Theoretically, it has been established that, under anoxic conditions with biodegradable organic substrate present, the COD consumption is 8.67 mg COD to reduce 1 mg NO_3-N. The COD/N ratios required for satisfactory or complete de-nitrification in practice are 4-15 g COD/g N and a minimum ratio of 3.5-4 is mentioned [5]. Torsten [6] proved that the higher ammonia content the more rapid de-nitrification process because the de-nitrification occurs in the inner parts of the bio-film at high load due to oxygen depletion. Ammonium is being adsorbed into the bio-film when the load increases and de-adsorbed at approximately the same rate when the load decreases

Inside the soil trench 2 both nitrification and de-nitrification was taking place at the same time because total nitrogen was decreased, thought with moderate rate because of low carbon content. The nitrification process was taking placed more strongly because amount of NH_4 was decreased and NO_3 increased rapidly. The total reduction of total N was also so due to reduction of suspended solid, which can contain some amount of nitrogen.

The efficiency of soil trench 3 is not high since the quality of influent (secondary treated effluent of two soil trenches) is quite good. It is almost no great improvement between influent and effluent in soil trench 3. This result is in agreement with a study in nitrifying trickling filter where the author found that under stationary conditions the effluent total concentrations of dissolved nitrogen (ammonium, nitrite and nitrate) were almost equal to the corresponding influent concentrations at low ammonium loads [6].

The relationship between de-nitrification and C/N ratio is expressed in Figure 5. It can be observed that almost all high values of NO_{2+3} are found in place where C/N ratio is less than 1. The higher C/N ratio the higher de-nitrification rate or content of NO_{2+3} is reduced more rapidly)

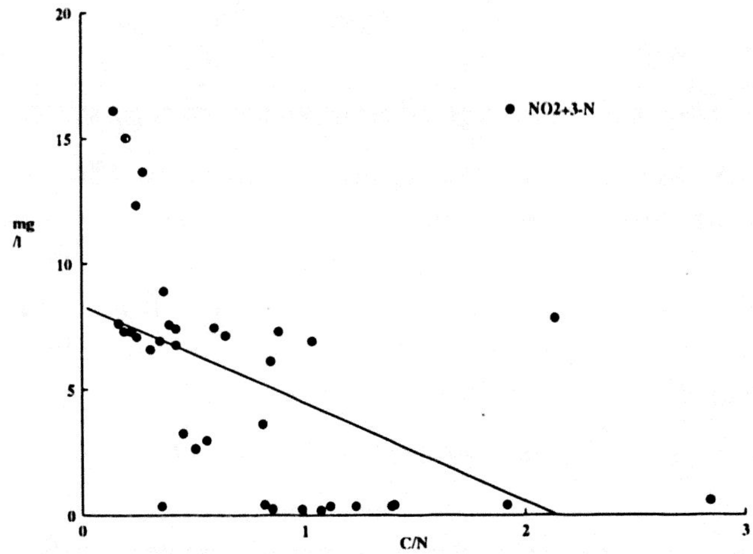

Figure 5 The relationship between de-nitrification and C/N ratio

Phosphorous removal

The phosphorous removal was consistent during four sampling times. Results show that almost all phosphorous content is in the form of orthophosphate and some in the suspended solid, because the big differences between T-P and PO_4 contents can be found in sampling points 1, 2 and 4, 5. In those points raw wastewater, which has high suspended solid content, was added.

In other samples, phosphorous content is dominated by orthophosphate form. Phosphorous removal is achieved right after soil trench 1. It indicates the high adsorption capacity of soil matrix for phosphorous removal.

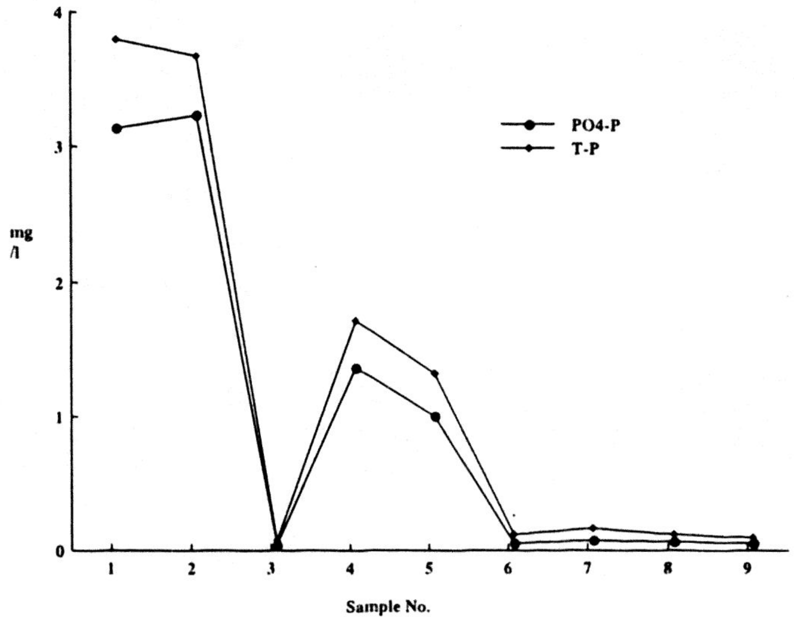

Figure 6. The average values of phosphorous parameter

It can be seen very clearly from average values in Figure 6 that phosphorous removal is achieved only after one soil trench. Approximately all amount of phosphorous is removed in the end of soil trench 1. Phosphorus content was increased at beginning of soil trench 2 due to addition of 40% of influent but it is removed in the end of this soil trench. Soil trench 3 has no effect in phosphorous removal because previous trenches removed all of it.

In summary, the total nutrient removal of three soil trenches is presented in Table 4

Table 4: the nutrient removal efficiency of three soil trenches (%)

Sample No	NH4-N	PO4-P	T-N	T-P	TOC	SS
3 (soil trench 1)	99.15	100	53.27	99.11	93.48	81.70
6 (soil trench 2)	97.89	99.48	73.70	97.93	88.28	99.65
9 (soil trench 3)	96.37	99.64	75.64	98.45	94.91	99.81

The percentage showed that after being treated by soil trench 1 the wastewater has quite good quality. The nutrient removal efficiency is almost the same as that by soil trench 2 and 3 except T-N and suspended solid.

The addition of 40% amount of wastewater into soil trench 2 helps to accelerate the de-nitrification process in the effluent of soil trench 1. The de-nitrification process occurs mainly in anaerobic biofilm 2. The rate of de-nitrification would be higher if more carbon source is added.

The results of this experiment indicate that the combination of two soil trenches is good enough to treat the domestic wastewater. The third soil trench plays very little role in increasing quality of treated wastewater. No significant differences between results from soil trench 2 and 3.

4. Conclusion

The following conclusion are drawn from experiment results:

• This soil trench system provides very high efficiency for domestic wastewater treatment. The final effluent are: BOD<10 mg/l, T-N<10mg/l, T-P<0.5 mg/l

• The removal efficiency (%) of NH_4-N, PO4-P, T-N, T-P, TOC, SS are 96.37%, 99.64%, 75.64%, 98.45%, 94.91%, 99.81%

• For treatment of domestic wastewater in practice, the soil trench system consisted of two trenches could be used.

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XỬ LÝ NƯỚC THẢI SINH HOẠT BẰNG HỆ THỐNG HÀO ĐẤT

Nguyễn Thị Loan

Khoa Môi trường, Đại học KH Tự nhiên, Đại học quốc gia Hà Nội

Hệ thống hào đất là một công cụ thông dụng để xử lý nước thải sinh hoạt vì nó đơn giản, bền vững và chi phí thấp. Một hệ thống pilot với chiều cao là 1,2 m, chiều dài là 9 m và chiều rộng là 3 m được xây tại Viện Nghiên cứu Môi trường Quốc Gia Nhật Bản. Hệ thống này gồm 3 hào đất đặt song song với nhau. Chín mẫu từ các vị trí khác nhau trong hệ thống được lấy hàng tuần. Toàn bộ thí nghiệm kéo dài trong 4 tuần. Các thông số hoá, lý sau được phân tích: cặn lơ lửng (SS), Các bon tổng số (TOC), NH_4-N, PO_4-P, NO_{3+2}-N, NO_2-N, tổng Ni-tơ (TN), tổng phốt pho (TP). Kết quả chỉ ra rằng hệ thống hào đất có hiệu quả xử lý nước thải sinh hoạt rất cao. Chất lượng dòng ra đáp ứng được chỉ tiêu của Tỉnh ở Nhật Bản (BOD<10 mg/l, T-N<10mg/l, T-P<0.5 mg/l). Hiêu quả xử lý (%) của NH_4-N, PO4-P, T-N, T-P, TOC, SS là 96.37, 99.64, 75.64, 98.45, 94.91, 99.81. Để giảm chi phí và thời gian xử lý có thể xử dụng hệ thống với hai hào đất và chất lượng dòng ra từ hào 2 gần giống như chất lượng dòng ra của hào 3.