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ANAEROBIC AND AEROBIC SUBMERGED BIO-FILTER SYSTEM FOR SMALL SCALE ON-SITE DOMESTIC SEWAGE TREATMENT

T. Watanabe, K. Kuniyasu and H. Ohmori

Japan Education Center of Environmental Sanitation, 33-2, Haramachi 3-Chome, Shinjuku-ku, Tokyo, Japan

Abstract

In order to prevent water pollution and satisfy the demands for flush toilets in regions where a public sewerage system has not been in service, some on-site small scale domestic wastewater treatment processes called GAPPEI JOHKASOU have been developed to treat black water and gray water together in an individual house. Prior to its technical development, the characteristics of wastewater discharged from individual houses should be measured.
The possibility of application of anaerobic filter is examined for processing organic wastewater at low concentration like in domestic wastewater, and an anaerobic filter is successfully developed to lengthen the sludge removal interval, since the flow rate of wastewater from individual houses is characterized by a large variation.
It is difficult to serve the centralized treatment systems in many regions. Thus, a small GAPPEI JOHKASOU has been developed and propagated for by individual houses in such regions.

Key Words

On-site treatment; Domestic gray water; Black water; Water pollution; Public sewerage system; BOD; Operation and maintenance(O&M);
Small scale facility; Anaerobic bio-filter; Aerobic bio-filter; Bio-film system; BOD loading; Hydraulic loading; Nitrogen Removal;
JOHKASOU: Small scale wastewater treatment systems for sanitary wastewater

Introduction

As one of the measures to prevent public water from pollution, the regulation of effluent from industries has brought significant effect. Domestic gray water, on the other hand, has been increasing and now this has become a new major source of water pollution.

To attack this issue, the construction of public sewerage systems has been promoted. However, it was too slow. In the regions where public sewerage systems have not been in service, growing demands for flush toilets have accelerated the spread of JOHKASOUs, which have been as popularized as public sewerage systems. JOHKASOUs are small scale wastewater treatment systems for sanitary wastewater. However, about 97.9 % of JOHKASOUs are a TANDOKU type which can treat black water only, draining domestic gray water without any treatment. Thus, this has become a major source of water pollution.

Through the various studies, the bio-film process was found to be ideal to treat domestic wastewater, because domestic wastewater from individual houses has wide ranges of water quality and flow fluctuation. In fact, the aerobic bio-filter process was found to be particularly effective for such treatment, incorporating the anaerobic bio-filter as primary process.

This process is based on the idea to reduce organic loads to the following aerobic bio-filter.

Further, nitrogen removal in an anaerobic bio-filter is enhanced by returning nitrified wastewater from aerobic bio-filter to the anaerobic bio-filter.

Situation of Sewer Service and Treatment of Domestic Wastewater in Japan

The treatment of domestic wastewater in Japan can be classified into the groups as illustrated in Fig. 1.

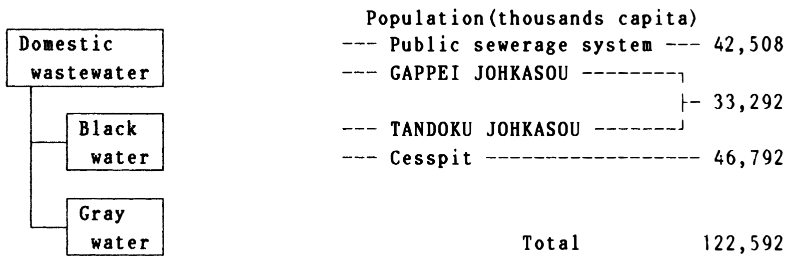


Fig. 1 Treatment Method for Domestic Wastewater.

122,592,000 people out of the total population (124,043,000) are living in the designated area. About 62 % or 75,800,000 people are using flush toilets, while the rest, 38 % or 46,792,000 people, are using cesspits. 56 % of people using flush toilets are supported by public sewerage systems, while the other 44 % are using JOHKASOUs. Public sewerage systems have been constructed with a large amount of budgetary support. However, the plan is quite slow. Further, the construction of public sewerage systems is spreading towards agricultural regions. Since houses are scattered in a large agricultural region, tremendous costs are incurred to build collection pipes. On the other hand, flush toilets are indispensable for residents' comfort. JOHKASOUs do play an important role in meeting such demand, as JOHKASOUs have been as popular as public sewerage systems.

JOHKASOUs can be roughly classified into two types: a TANDOKU and a GAPPEI.

As of March, 1989 the numbers of TANDOKU and GAPPEI types of JOHKASOUs installed are

6,378,529 and 139,518 respectively. About 97.9 % of total JOHKASOUs are TANDOKU type which can treat black water only, implying that domestic gray water is directly drained without any treatment.

TABLE 1 shows numbers of JOHKASOU installations classified by the number of users. Most of JOHKASOUs are TANDOKU type which has the capacity of 500 P.E. or less. In particular, about 85 % of TANDOKU JOHKASOUs are small capacity for 20 P.E. or less.

TABLE 1 Number of Installed JOHKASOUs

Capacity	Total Nos.	Classified Nos.
Up to 20 P.E.	5,527,188	TANDOKU: 6,378,529
21 ~ 200 〃	927,730	GAPPEI : 125,778
101 ~ 500 〃	63,129	
501 ~ 1,000 〃	7,998	
1,001 ~ 2,000 〃	3,608	
2,001 ~ 5,000 〃	1,630	TANDOKU:≒ 0
5,001 or over 〃	504	GAPPEI : 13,740

(Data by Ministry of Health and Welfare)

Roles of Small GAPPEI JOHKASOU

Fig. 2 shows the BOD discharge from TANDOKU and GAPPEI JOHKASOUs.
The BOD amount of black water is 13 g per capita per day, while domestic gray water's is 27 g per capita which is far larger than that of black water. The effluent quality of TANDOKU JOHKASOU is BOD 90 mg/l or less based on the BOD removal rate of 65 % or higher. On the other hand GAPPEI JOHKASOU's effluent is BOD 20 mg/l or less based on the BOD removal rate of 90 % or higher. Thus a GAPPEI JOHKASOU provides a high quality effluent. In the case of a TANDOKU JOHKASOU, 13 g of the BOD per capita per day is loaded and the removal rate is as low as 65 %, hence 4.5 g of the BOD per capita is discharged. Since domestic gray water is not treated, the BOD of domestic gray water should be added to the amount of BOD discharge, and so a total of 31.5 g of the BOD per capita is discharged. With a GAPPEI JOHKASOU, the BOD discharge is only 4 g per capita, or one eighth of that of a TANDOKU type.

TANDOKU JOHKASOU	Black water 13gBOD/c·d ⟶	BOD removal rate 65% ⟶	4.5gBOD/c·d
	Gray water 27gBOD/c·d ⟶	(untreated) ⟶	27 gBOD/c·d
	Total 40gBOD/c·d ⟶	⟶	31.5gBOD/c·d
GAPPEI JOHKASOU	Black water 13gBOD/c·d + Gray water 27gBOD/c·d ⟶	BOD removal rate 90% ⟶	4 gBOD/c·d

Fig. 2. BOD Discharge from TANDOKU and GAPPEI JOHKASOUs.

Maximum Hourly Wastewater Discharge, Maximum Three Hours Wastewater Discharge, and Peak Coefficient

The wastewater discharge from an individual house is generally characterized as a function of time having double peaks: one is in the morning due to laundry and drainage of bath tub, and the other is in the afternoon due to cooking and bath taking. TABLE 2 shows the characteristics of wastewater discharge.

TABLE 2 Characteristics of Wastewater Discharge Rate

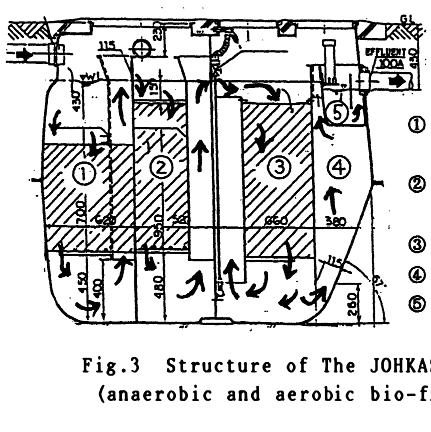
parameter	number of samples	average	standard deviation	non-excess probability 50%	75%	84%
wastewater discharge per capita per day (l/c·d)	124	250	110	230	295	340
maximum hourly wastewater discharge (l/hr)	125	312	199	255	350	450
maximum 3 hourly wastewater discharge (l/3hrs)	125	503	315	430	580	660
peak coefficient* (—)	125	6.8	2.4	6.4	8.2	9.2

* maximum hourly wastewater discharge divided by 24 hour average

At the development of a small GAPPEI JOHKASOU, the following requirements have to be satisfied. At first, the feed water quality must be as constant as possible. Secondly, easy operation and maintenance can be accomplished. Thirdly, the costs for construction and operation must be reasonably low.

The Facility of Anaerobic and Aerobic submerged Bio-filter System.

The structure of this system is shown in Fig.3



① Anaerobic bio-filter first stage
② Anaerobic bio-filter second stage
③ Aerobic bio-filter
④ Sedimentation tank
⑤ Disinfection tank

Fig.3 Structure of The JOHKASOU
(anaerobic and aerobic bio-filter system)

Actual on-site performance data of this system is given in TABLE 3 as an example. The actual classified family members for this tests are also given in TABLE 3.

TABLE 3 The Facility in This Study and Performance of Wastewater Discharge

Facility Actual Family Members	No.1 adults 3, children 2			No.2 adults 2, children 3		
	min.	max.	ave.	min.	max.	ave.
total discharge (l/c·d)	436 ~	1382	930	576 ~	1470	950
hourly discharge(max.) (l/hr.)	141 ~	335	240	86 ~	400	280
3 hourly discharge(max.) (l/3hrs)	224 ~	516	389	200 ~	736	488
peak coefficient (-)	4 ~	9.5	6.5	3.6 ~	12.4	7.1

Fig. 4 shows the example of the day-to-day variation.

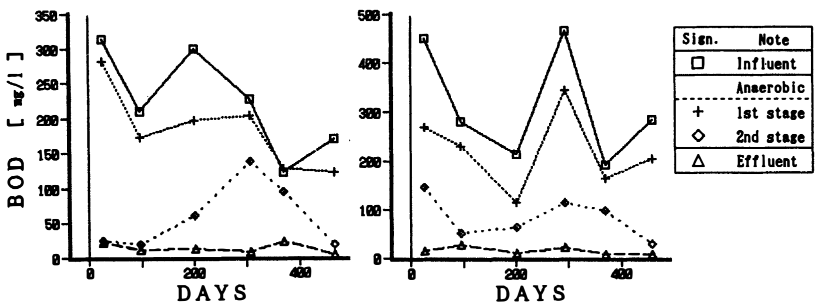


Fig. 4 Monthly Test Data of The Facility No.1 and No.2

The BOD in feed into the 1st stage bio-filter greatly fluctuated by 200 mg/l. The reason for high BOD discharge is mainly from the kitchen disposal by the use of "kitchen disposer".

The effluent BOD from the 2nd stage ranged from 20 to 150 mg/l.

Despite the above BOD fluctuations, BOD of the final effluent has been stabilized to 20 mg/l or less.

TABLE 4 shows the performance data of this system.

The removal rate of SS is about 90 % , and BOD over 90 %. Therefore this system assures effluent quality of 20 mg/l BOD or lower, which is as clean as that of municipal wastewater treatment plants.

TABLE 4 Performance Data of This System

Components	Facility No.1 Influent mg/l	Facility No.1 Effluent mg/l	Facility No.1 Removal %	Facility No.2 Influent mg/l	Facility No.2 Effluent mg/l	Facility No.2 Removal %
SS	94.4	13.5	85.7	154.0	7.8	94.9
BOD	212.0	20.0	90.6	307.0	14.0	95.4
s-BOD	132.0	5.0	96.2	109.0	7.0	93.6
COD	127.0	20.0	84.3	134.0	16.1	88.0
s-COD	84.4	13.9	83.5	61.6	11.3	81.7
TOC	140.0	31.6	77.4	149.0	16.4	89.0
s-TOC	85.2	13.7	83.9	70.9	11.6	83.6
T-N	23.9	31.4	−	33.4	20.0	40.1
NOx-N	1.1	18.0	−	0.7	13.0	−

Experimental Equipment for Nitrogen Removal

Fig. 5 shows the outline of the Equipment for the nitrogen removal tests. The system consists of the equipment shown in Fig. 5 and the additional flow Equalization and Liquid Returning Device.

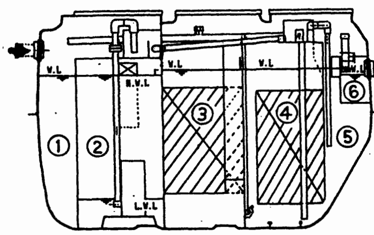


Fig.5 Structure of The Experimental Equipment for Nitrogen Removal

As shown in TABLE 5, BOD removal rate was stabilized by the addition of Flow Equalization, and nitrogen removal was attained by returning the liquor from aerobic bio-filter compartment to anaerobic bio-filter compartment.

TABLE 5 Performance Data of The Experiment

Outflow of each unit	SS mg/l	BOD mg/l	T-N mg/l	NOx-N mg/l
Sedimentation-separation	61.0	99.8	39.3	0.0
Flow equalization	61.0	104.0	39.3	0.0
Anaerobic bio-filter	23.0	33.6	17.3	8.6
Sedimentation	18.0	9.0	17.6	12.2

As the result, satisfactory effluent quality of BOD 20 mg/l and T-N 20 mg/l was attained. The research work is still going on for sludge handling in order to maintain the stablity.

Subsidy of Small GAPPEI JOHKASOU

Now a program for subsidy has been issued by Japanese national and local governments to cover the differential cost between installations of a TANDOKU and a GAPPEI JOHKASOU. Up to today, many local governments in Tokyo and 41 prefectures have been subsidizing the differential cost. TABLE 6 shows the subsidies by the national government from 1987 to 1991.

TABLE 6 Subsidies of Small GAPPEI JOHKASOUs

fiscal year	1987	1988	1989	1990	1991*
Local governments	55	211	480	769	1,119
Number of systems	543	3,385	9,521	16,233	25,897
Subsidies(million yen)	100	500	2,060	3,200	5,000

*Based on budget (Data by Ministry of Health and Welfare)

Although the number of the GAPPEI JOHKASOU is still small, it starts to clean the wateras soon as it is installed, playing an important role in the prevention of water pollution.

Conclusions

It is a highly effective way to prevent water pollution that the domestic wastewater is treated at private homes in areas where a public sewerage system is not in service.

However, it is not easy to treat domestic wastewater with on-site treatment facility because the flow rate and the characteristics vary greatly from time to time. By considering the above it was decided to adopt the anaerobic and aerobic submerged bio-filter system for such treatment. As the result, 90 % or higher BOD removal and 20 mg/ℓ or lower effluent BOD have been attained by the domestic on-site facility, which is as good as those of municipal wastewater treatment plants. Since this facility can be installed much more speedily than the public sewerage system, it is not only a quick and economical way but also more importantly an effective means for the improvement of areal environment when the treatment of domestic wastewater is planned in each city or town.

Now a subsidy program has been issued by Japanese national and local governments for on-site domestic wastewater treatment facilities.

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