Analysis of Relationship among the Influent load, Micro biota and Purification Function in the Wastewater Treatment System Coupled with Disposer

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Abstract

The number of wastewater treatment systems coupled with disposers which are used in apartments in urban areas has been increasing in recent years. However, no analysis has been made as to the relationship among the microfauna/purification function in aeration tanks and the influent load in these systems. This study was aimed to analyze the relationship between influent loads and treatment performance and that between the microfauna and purification function in wastewater treatment systems using dispersion type disposers, which were introduced into rural areas. Consequently, influent loads varied greatly depending on the family, and the influent BOD load per person was $22.0 \text{ g} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$. The BOD load was found to vary significantly, depending on the presence/absence of disposers, and a 2-fold increase in the BOD load was observed when a disposer was used. For the quality of treated water, 75% of all samples had a BOD of $30 \text{ mg} \cdot \text{l}^{-1}$ or less. For the relationship between the microfauna and purification function, the proportions of organism from activated sludge, intermediate activated sludge and non-activated sludge were found to be prone to variation, depending on influent loads into disposers. In short, these results suggest that microscopic animals that thrive in slightly aerobic and anaerobic environments when the influent load into disposers increases and they prey on decomposer bacteria and contribute to improving the purifying capacity. Moreover, microscopic animals could be used as a biological indicator to evaluate the performance of biological treatment system in terms of purification capacity.

Key words: disposer, micro biota, purification function, influent load

INTRODUCTION

The usage of wastewater treatment systems including a disposer has been increasing in urban apartments because of the need to reduce garbage and enhance convenience¹⁾. The number of the systems with disposers has increased rapidly since 2000, when a

third-party certifying organization started to assess this system performance in a demonstration test²⁾, and about 70% of newly-built apartments in the metropolitan area have the system preinstalled.

Unlike a direct-discharge system, whereby crushed garbage from a disposer is directly

introduced into the sewerage system, the wastewater treatment systems coupled with a disposer provide a pretreatment system intended to avoid increases in influent pollutant loads into the sewerage system. The BOD of the effluent water must be $300 \text{ mg} \cdot \text{l}^{-1}$ or less, SS $300 \text{ mg} \cdot \text{l}^{-1}$ or less, and n-Hex extract $30 \text{ mg} \cdot \text{l}^{-1}$ or less³⁾. The raw wastewater to be introduced into the system consists of the crushed garbage from the disposer and kitchen wastewater and is characterized as a high influent BOD concentration of $340 \text{ mg} \cdot \text{l}^{-1}$ and a low water content. However, no analysis has yet been done concerning the relationship between the influent load and treatment characteristics or the microfauna in the biological treatment tank. As described in the studies carried out by Curds *et al.*⁴⁻⁷⁾, microscopic animals are thought to contribute to the clarification of the treated water and the reduction in sludge and are highly important organisms in evaluating the system function. This study was therefore aimed at analyzing the relationship between influent loads and treatment performance/microfauna to evaluate the relationship between the microfauna and purification function in actual wastewater treatment systems coupled with a disposer on the site.

MATERIALS AND METHODS

Structure of a wastewater treatment system using a disposer A purification tank for five persons was used because aerobic biofilm contact aeration systems with anaerobic/aerobic solubilization tanks are commonly

used for wastewater treatment systems coupled with a disposer. The treatment flow is shown in Figure 1. Kitchen wastewater and the crushed material from the disposer flow into a solid-liquid separation tank. The solid-liquid tank is partitioned with a baffle. The upper compartment is filled with contact materials for aerobic treatment of influent organic matter, and dissolved organic components are digested in the lower compartment, which contains precipitated sludge. The residual organic component from the treatment compartments undergoes aerobic treatment in contact aeration tank. The solid-liquid separation tank has an overall capacity of 564 l , the contact aeration tank 183 l , and the sedimentation tank 9.7 l , respectively. The BOD volumetric load for the contact aeration tank was set at $0.46 \text{ kg} \cdot \text{m}^{-3} \cdot \text{day}^{-1}$. Aeration intensity in the contact aeration tank is $6.5 \text{ m}^3 \cdot \text{m}^{-3}$ or more.

Structure and characteristics of the involved families

A wastewater treatment system coupled with a disposer was installed at 20 sites in Miho-mura, Ibaraki Prefecture, located in the northern part of the Kanto region. The control sample included 4 families with no disposer. The families consisted of 2 to 8 family members, with an average of 4.0. The area was a rural area, with an age structure indicating an increasingly aging population (average age about 50 years), and characterized by a high proportion of part-time rice farmers. The effluent from the wastewater treatment systems using a disposer was connected to the rural

Fig. 1 Schematic diagram of wastewater treatment system using disposer

community sewerage via piping.

Measurement items and evaluation of the purification function

Wastewater from the disposer and kitchen wastewater from the families using the treatment systems with a disposer were stored temporarily in an inflow adjustment storage tank buried underground, and then periodically transferred in given quantities to a wastewater tank using a submerged pump. The influent wastewater was stored in the wastewater tank after the entire wastewater had been discharged from the tank, followed by washing, the day before the survey. The BOD, T-N, T-P and SS of the influent wastewater and the BOD, D-BOD, $\text{NO}_{2+3}\text{-N}$, $\text{NH}_4\text{-N}$, T-N, $\text{PO}_4\text{-P}$, T-P and SS of the effluent from wastewater treatment systems coupled with a disposer were analyzed in the water quality according to JIS K0102 and the sewage water testing method⁹⁾. The quantity of wastewater that accumulated within a day was also measured to determine the amount of BOD load by multiplying the BOD concentration by the quantity of wastewater.

Observation and assessment of micro-fauna

Biofilm samples were taken at 10 or more locations on the corrugated contact material in the aerobic tank and mixed before examination for microfauna. The amount of biofilm was determined by measuring MLSS and the identification of organisms and determination of the population size were carried out under a microscope (Nikon ECLIPSE E1000). The population density was calculated as the population size per mg of biofilm⁹⁾.

RESULTS AND DISCUSSION

Influent load characteristics of the wastewater treatment system coupled with a disposer

The influent load flowing into wastewater treatment systems coupled with a disposer was measured six times a year. The result shown in Table 1 is the average of these measurements. No. 1, 3, 10 and 11 were statistically processed as control systems, receiving only kitchen wastewater and not including wastewater from the disposer. But these measurements were

included in the survey of treatment performance and microfauna.

The range and average of the BOD, SS, T-N and T-P load were 29.9–302.4 (96.5), 10.0–118.8 (34.9), 0.8–7.0 (3.0) and 0.19–1.90 (0.67) $\text{g}\cdot\text{family}^{-1}\cdot\text{day}^{-1}$, respectively. For BOD, the influent BOD load per person was $22.0 \text{ g}\cdot\text{person}^{-1}\cdot\text{day}^{-1}$, which was lower than the design influent load of $45.5 \text{ g}\cdot\text{person}^{-1}\cdot\text{day}^{-1}$ calculated in the development of a garbage recycling system using a disposer, a project led by the former Ministry of Construction¹⁰⁾. While pollutant loads from a combination of disposer and kitchen wastewater were surveyed in this study, BOD pollutant loads per unit production from disposer wastewater were also surveyed elsewhere. For example, the value was $16.9 \text{ g}\cdot\text{person}^{-1}\cdot\text{day}^{-1}$ in Okinawa Prefecture¹¹⁾ and $17.0 \text{ g}\cdot\text{person}^{-1}\cdot\text{day}^{-1}$ according to the Urban Development Corporation¹²⁾. A social experiment¹³⁾ of the direct discharge system which was carried out in Utanobori-cho, Hokkaido, showed that the load from the disposer wastewater, excluding kitchen

Table 1 Influent load of target wastewater treatment facility using disposer

No	BOD	SS	T-N	T-P
1	24.1	12.0	1.06	0.36
2	29.9	13.8	1.67	0.19
3	31.4	7.4	0.94	0.16
4	32.9	17.2	1.55	0.41
5	33.7	14.1	1.37	0.32
6	39.3	10.0	0.82	0.20
7	38.2	12.7	1.08	0.19
8	41.6	17.8	2.16	0.67
9	62.9	29.7	2.72	0.61
10	63.2	17.3	2.02	0.35
11	77.0	26.5	5.03	0.49
12	87.9	34.0	1.78	0.46
13	97.5	32.6	2.83	0.68
14	98.9	34.7	2.70	0.57
15	100.7	31.4	2.64	0.62
16	114.1	50.9	3.70	0.85
17	134.9	48.7	4.07	0.85
18	155.0	38.2	4.89	1.05
19	173.9	54.0	6.96	1.17
20	302.4	118.8	7.01	1.90

($\text{g}\cdot\text{family}^{-1}\cdot\text{day}^{-1}$)

Note; control:without using disposer No.1,3,10,11

wastewater, was $11.2 \text{ g} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$. Consequently, the pollutant load per person per unit production in this study was higher compared to previous reports, even considering that the target area was a rural area and garbage was applied onto fields as an alternative to fertilizer. Although this study employed a different methodologies, in which the entire volume was surveyed, the results were accurate. In either case, the pollutant load per unit production is considered to reflect regional characteristics, such as differences in dietary habits due to aging. According to the survey, the amount of kitchen waste was $151 \text{ g} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$, and 73% of the total household garbage was treated by the disposer. The influent BOD load was $56 \text{ g} \cdot \text{family}^{-1} \cdot \text{day}^{-1}$ for the control system and $94 \text{ g} \cdot \text{family}^{-1} \cdot \text{day}^{-1}$ for the disposer system and the load volume was twice, although it varied according to the influent waste load by the type of actual use.

Treatment characteristics of the wastewater treatment system coupled with a disposer The treatment performance of the wastewater treatment system coupled with a disposer was analyzed by the concentration of BOD, T-N, T-P and SS. The quality of treated water varied significantly with the influent load and the range and average of the BOD, T-N, T-P and SS concentrations were 2.2–693 (81.6), 1.4–42.6 (10.4), 1.3–26.9 (4.9) and 1.0–147 (24.0) $\text{mg} \cdot \text{l}^{-1}$, respectively. The relationship between the influent load and the BOD concentration of the effluent is shown in Figure 2. The BOD concentration exceeded the effluent standard of $300 \text{ mg} \cdot \text{l}^{-1}$ in two families. The reason in one case was that the actual number of family members using a purification tank for five persons was seven, thus generating 1.4 times the normal load. The reason for the SS value of $358 \text{ mg} \cdot \text{l}^{-1}$ for treated water, from a system that exceeded the SS effluent standard of $300 \text{ mg} \cdot \text{l}^{-1}$, was that biofilm detachment occurred in the control low-load system. However, 75% of the total was below $30 \text{ mg} \cdot \text{l}^{-1}$ for BOD, so the water quality was sufficiently high to attain the effluent quality goal. Meanwhile, 80% of the total was below $10 \text{ mg} \cdot \text{l}^{-1}$ for D-

Fig. 2 Relationship between influent BOD load and effluent BOD

BOD(dissolved BOD), a fact indicating efficient decomposition of the dissolved organic matter. The concentration of ammonia nitrogen which was found to inhibit biological treatment was about $1 \text{ mg} \cdot \text{l}^{-1}$ in all systems except for one with overloading, and no inhibition due to ammonia was observed. This appropriate biological decomposition was probably due to a properly balanced influent load C:N:P ratio of about 100:5:1.

Microfauna analysis for the wastewater treatment system coupled with a disposer Microfauna in a biological treatment tank are known to serve as a biological indicator closely related to BOD as treatment function. It must be noted that BOD is divided into the type of BOD that contains suspended matter and the dissolved post-filtration type, referred to as D-BOD. If these flocculant and dissolved types of BOD are used as indicators, it is necessary to consider to improve the role of microfauna as a predator on the filterable and flocculant matter and its solid-liquid separating function through the production of biopolymers. Because suspended and dissolved BOD characteristics vary as load conditions, the influent BOD loads from the houses included in this study were classified into four types: $70 \text{ mg} \cdot \text{family}^{-1} \cdot \text{day}^{-1}$ or less (type I), 70 – 140 (type II), 140 – 280 (type III) and 280 or more (type IV). The influent load conditions thus varied but were generally low. Of the 20 families, 19 were classified as type I to III with a D-BOD of $5 \text{ mg} \cdot \text{l}^{-1}$ or less. A common factor among systems with low BOD values

for treated water, such as those classified as types I and II in particular, was that *Vorticella convallaria*, *Rotaria* spp., *Lepadella* sp., *Colurella* sp., *Cepharodella* sp., *Monostyla* sp., *Aspidisca sulcata*, *Petalomonas* spp., *Peranema* spp., *Euglypha* spp., *Monostyla* sp. and *Aeolosoma hemprichi* were dominant or semi-dominant species. The reason the type III system had high purification performance may be that *Rotaria* spp., which acted through filtration and ingestion, dominated. In type III systems with a BOD of treated water of $360 \text{ mg} \cdot \text{l}^{-1}$ and a D-BOD of $190 \text{ mg} \cdot \text{l}^{-1}$, *Paramecium aurelia* and *Heteronema* sp. were dominant species, and in those with a BOD of $83 \text{ mg} \cdot \text{l}^{-1}$ and a D-BOD of $53 \text{ mg} \cdot \text{l}^{-1}$, *Cyclidium* sp., *Metopus* sp. and *Cyathomonas* sp. were dominant species. Because these microscopic animals prefer slightly aerobic or anaerobic conditions, oxygen deficiency was suspected. In the type IV high-load system, only *Cyathomonas* sp. was present. The biota, which was very poor in both quality and quantity and consisted almost exclusively of bacteria, and the odor both suggested an insufficient purification function, resulting from the predatory function of the microfauna. All the control systems were classified as type I. In wastewater treatment facilities, activated sludge organisms are used as an indicator to determine biological treatment function to manage proper operating conditions, while organisms that appear in poor treatment conditions are referred to as non-activated sludge organisms⁴⁾. Typical activated and non-activated sludge organisms are shown in Table 2. The proportions of activated and non-activated sludge organisms, and intermediate activated sludge organisms occurring during the treatment performance recovery phase were determined based on the microflora from the 20 families. Figure 3 presents the results in ascending order of influent load. As shown in the figure, the proportion of non-activated sludge organisms was high in system Nos. 5, 14, 18 and 20. Excepting the high-purification performance case of No. 5, in which *Monas* sp. was present at a density of $170,000 \text{ N} \cdot \text{mg-MLSS}^{-1}$, the proportion of activated sludge organisms decreased as the influent load

increased. Categorization of the influent load, and the relationship between the proportion of activated sludge organisms and the BOD concentration in treated water are shown in Figure 4. As shown in the figure which summarizes the results of activated sludge organisms in Figure 3, non-activated sludge organisms were abundant in Nos. 18 and 20 due to high influent BOD loads, resulting in a treated water BOD concentration of $360 \text{ mg} \cdot \text{l}^{-1}$ and $690 \text{ mg} \cdot \text{l}^{-1}$, respectively. No. 19 displayed efficient biological decomposition in spite of high loads, due in part to a relatively

Table 2 Classification of activated sludge organisms and non-activated sludge organisms

Activated sludge organisms (attaching property • crawling property)	Ciliata	<i>Vorticella</i> sp., <i>Euplotes</i> sp., <i>Aspidisca</i> sp., <i>Coleps</i> sp.
	Sarcodina	<i>Arcella</i> sp., <i>Euglypha</i> sp.
	Flagellata	<i>Entosiphon</i> sp., <i>Peranema</i> sp.
	Rotatoria, Chaetonotus, Oligochaeta, Macrobiotus	
Non-activated sludge organisms (free swimming property)	Ciliata	<i>Paramecium</i> sp., <i>Colpidium</i> sp., <i>Metopus</i> sp.
	Flagellata	<i>Heteronema</i> sp., <i>Trigonomonas</i> sp., <i>Monas</i> sp.

Fig. 3 Ratio of activated sludge organism in comparison with total organisms

Symbols; ■, Activated sludge organisms
 □, Middle-activated sludge organisms
 □, Non-activated sludge organisms

small volume of wastewater and a consequent increase in the retention time. The relationship between the proportion of activated sludge organisms and the BOD concentration in treated water is shown in Figure 5. These figures suggest that the BOD concentration in treated water decreases as the proportion of activated sludge organisms increases and vice versa. In these cases it is natural that the influent BOD concentration and the reaction tank volume load are closely related to the biota. The proportion of activated sludge organisms is high in the control system, and load conditions were found to influence the qualitative and quantitative characteristics of the microfauna. These indicate that in a wastewater treatment system using a disposer, as in conventional

Fig. 4 Relationship between ratio of activated sludge organisms in the different influent concentration and effluent BOD
Symbols; ●, BOD;
□, Activated sludge organisms

Fig. 5 Relationship between ratio of activated sludge organisms and effluent BOD

treatment systems, purification performance can be assessed by using biological classifications, such as activated sludge organisms, as indicator organisms and considering the influent BOD concentration and the reaction tank volume load.

Assessment based on both microfauna and purification performance

Microscopic animals are known as biological indicators to assess wastewater treatment performance. The microscopic animals in a biofilm treatment system are divided into those occurring under low-load conditions, the type occurring at biofilm renewal, and the type occurring under oxygen-deficient conditions. In each of these types, a balanced coexistence of microscopic animals feeding on filtered matter and those feeding on flocculated matter that occur under continuous aerobic conditions seems to be important in improving treatment efficiency. In wastewater treatment systems coupled with a disposer, four systems, i.e. a system consisting of bacteria, a system containing anaerobes, such as *Metopus* sp. and *Paramecium* sp., one consisting of mainly *Ciliata* and *Mastigophora*, and one consisting of mainly *Ciliata*, *Hypotrichida*, *Peritrichida* and *Rotatoria*, were identified, and these were identical to the results reported previously, concerning the biofilm process and without using disposer. In particular, the coexistence of organisms feeding on filtered matter, as represented by *Rotaria* sp., and those feeding on flocculated matter, as represented by *Aeolosoma hemprichi*, was found to contribute toward improving the

Fig. 6 Relationship among BOD load, Biodiversity and amount of activated sludge organisms

purification performance. Results from this study are summarized in Figure 6. It shows that biological diversity, the proportion of activated sludge organisms and treatment performance decreased as the influent BOD load increased.

CONCLUSIONS

The sources of loads flowing into a wastewater treatment system coupled with a disposer were surveyed, and the relationship between the microfauna occurring in a reaction tank and purification performance was analyzed. Results were as follows:

- 1) For influent loads, the range and average of the BOD, SS, T-N and T-P values were 29.9–302.4 (96.5), 10.0–118.8 (34.9), 0.8–7.0 (3.0) and 0.19–1.90 (0.67) $\text{g} \cdot \text{family}^{-1} \cdot \text{day}^{-1}$, respectively. For BOD, the influent BOD load per person was $22.0 \text{ g} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$.
- 2) According to the survey, the amount of kitchen waste was $151 \text{ g} \cdot \text{person}^{-1} \cdot \text{day}^{-1}$, and 73% of the total household garbage was treated by the disposer.
- 3) The range and average of the BOD, T-N, T-P and SS values of treated water were 2.2–693 (81.6), 1.4–42.6 (10.4), 1.3–26.9 (4.9) and 1.0–147 (24.0) $\text{mg} \cdot \text{l}^{-1}$, respectively, and those for the control system were 4.6–185 (53.7), 1.8–31.9 (10.6), 1.8–8.5 (4.6) and 3.0–385 (99.9) $\text{mg} \cdot \text{l}^{-1}$, respectively.
- 4) A common factor among systems with low BOD values for treated water was that *Vorticella convallaria*, *Rotaria* spp., *Lepadella* sp., *Colurella* sp., *Cepharodella* sp., *Monostyla* sp., *Aspidisca sulcata*, *Petalomonas* spp., *Peranema* spp., *Euglypha* spp., *Monostyla* sp. and *Aelosoma hemprichi* were dominant or semi-dominant species.
- 5) *Paramecium aurelia*, *Heteronema* sp. and *Metopus* sp. were dominant species in high-influent load types. Because these microscopic animals prefer slightly aerobic or anaerobic conditions, oxygen deficiency was suspected. However, these microscopic animals were considered to prey on decomposer bacteria and contribute toward improving purifying capacity.
- 6) In a wastewater treatment system coupled with a disposer, as in conventional treatment systems, purification performance could be assessed by using biological classifications, such as activated sludge organisms, as indicator organisms.

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