1. Introduction

Recently, there have been drastic changes in the conditions surrounding night soil treatment technology in Japan. One change is the movement led by the Ministry of Health and Welfare towards organizing "Sludge reclamation treatment centers". The policy seeks the establishment of technology to effectively use organic waste generated at individual regional sites through the acceptance of kitchen garbage by regional night soil treatment plants. Kitchen garbage is mixed with dehydrated sludge to augment methane fermentation and composting. Another change arises from the increased annual rate of introduction of flush toilet systems in agricultural, mountain, and fishing village areas. This requires technology that can accommodate the increased rate of septic sludge from household septic tanks charged into night soil treatment facilities. The paper describes technology that responds to this increased mixing rate of septic sludge.

Relatively new night soil treatment facilities mainly

2. Experimental method

2.1 Pilot plant facilities and flowchart

The pilot plant was installed in the Utsumi Numakuma Wide Area Administration Association Clean Center (Utsumi Cho, Numakuma Gun, Hiroshima Prefecture). The pilot plant was operated with a throughput ranging from 1.0 to 1.5 kl/d and mixing percentages of septic sludge from 50 to 100%. **Fig. 1** shows an outline of the target process of the pilot plant test and of the basic process, which is the conventional membrane separation type, heavy load denitrification treatment process. The major differences between these two processes are listed below.

(2) The influent coming into the main treatment stage is switched from night soil after relatively large solid matter is removed for the basic process to treated water after the pre-reaction stage for this process.

(3) In the basic process, sludge is withdrawn at two points: the biological treatment tank and the coagulation sedimentation tank. In this process, however, sludge is withdrawn only at the sedimentation separation tank in the pre-reaction stage by recycling the excess activated sludge from the main treatment stage to the pre-reaction stage.

(4) For the advanced treatment stage, the basic process uses a coagulation treatment unit, the membrane separation unit, and an activated carbon adsorption treatment unit. This process, however, uses only the activated carbon adsorption treatment unit.

The individual treatment stages of the pilot plant facilities is outlined below.

(1) Feed storage stage

The feed storage stage comprises storage tanks for

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(4) Advanced treatment stage

Since dephosphorus treatment and denitrification treatment are conducted in the pre-reaction and main treatment stages, the advanced treatment stage consists only of the activated carbon adsorption treatment unit.

(5) Sludge treatment stage

The sludge treatment stage comprises a sludge storage tank, a sludge centrifugal separator, and a separated liquid storage tank. The sludge withdrawn from the sedimentation separation tank in the pre-reaction stage is introduced to the sludge storage tank, and the sludge is dewatered about three times a week. The resulting centrate is recycled into the primary anoxic tank of the main treatment stage.

2.2 Experimental conditions

Table 2 lists the conditions for the pilot plant test period. A continuous operation test for about 1 month was performed for each of the different seasonal conditions and septic sludge mixing percentages. A total of 8 conditions were tested.

nitrate nitrogen, nitrite nitrogen, kjeldahl nitrogen, MLSS, MLVSS, number of coliform group, color, and water content. For each condition, the analysis and determination were performed at a frequency of 3–4 in conformance to the sewer test method and other standards.

3. Result and discussion

3.1 Feed properties

Table 3 shows the properties of night soil used for the pilot plant test after removing relatively large solid matter through a fine, 1 mm opening sieve, along with the properties of the septic sludge. Variations in septic sludge properties have been reported, particularly in the SS concentration[1]. The septic sludge tested in the pilot plant also showed this feature distinctively. As seen in **er pa7pu7Q2npC]EHEzv6qMEQ27oemuC7vzqQ55Qmu**

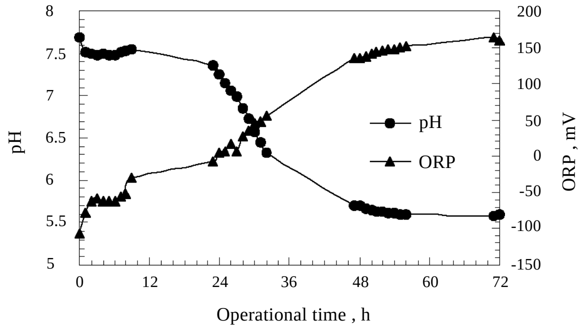

Fig. 2 Changes in pH and ORP during a batch test in the pre-reactor

Fig. 3 shows the changes in concentration of inorganic nitrogen (NO_3^--N, NO_2^--N, NH_4^+-N) and COD with time during the batch test. The figure shows that, at 24 hours after the start of the test, NH_4^+-N decreased and NO_3^--N increased. However, after 48 hours, the concentration and composition of inorganic nitrogen showed very little change. On the other hand, the COD gradually decreased from the start of the test until 48 hours. These findings clearly show that the pre-reactor provides COD removal and nitrification reaction.

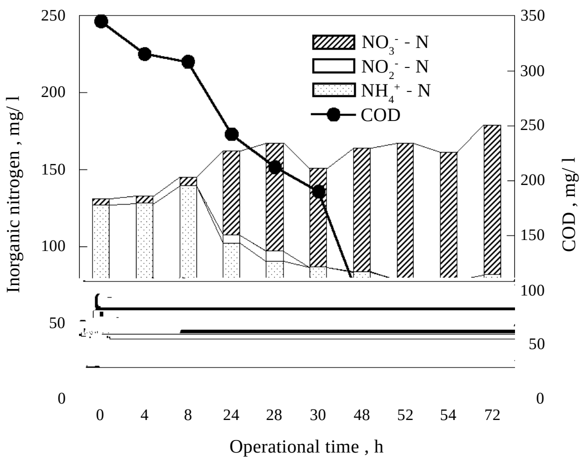

Fig. 3 Changes in concentration of inorganic nitrogens and COD during a batch test in the pre-reactor

(2) Operating status viewed from biota

Photo 1 shows protozoa in the sludge from the pre-reactor. The presence of both *Epistylis*, which normally appears in an activated sludge in good condition, and *Vorticella* can be seen in **Photo 1**. This phenomenon proves that the pre-reactor provides relatively good biological treatment reactions.

3.2.2 Changes of MLSS concentration with time

Fig. 4 shows changes of the MLSS concentration with time observed in the pre-reactor and the primary anoxic tanks. As shown in the figure, the MLSS concentration in the pre-reactor showed significant

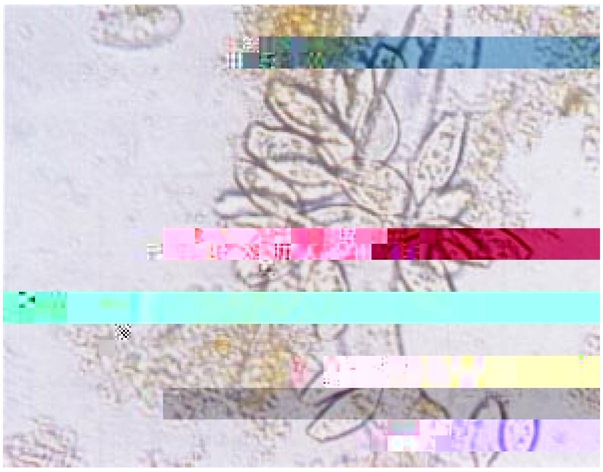

Photo 1 Protozoa seen in the pre-reactor

changes. This phenomenon probably arises from the changes in the properties of septic sludge, particularly changes in the SS concentration. On the other hand, the changes in MLSS concentration in the primary anoxic tank was less than that in the pre-reactor, making the MLSS concentration relatively stable. The SS concentration in the treated water from the reaction stage of this process is at a stable, low level, in a range of 620–1200 mg/l. Thus, the pre-reaction stage should also facilitate operational control of the main treatment stage, making control of the sludge particularly easy.

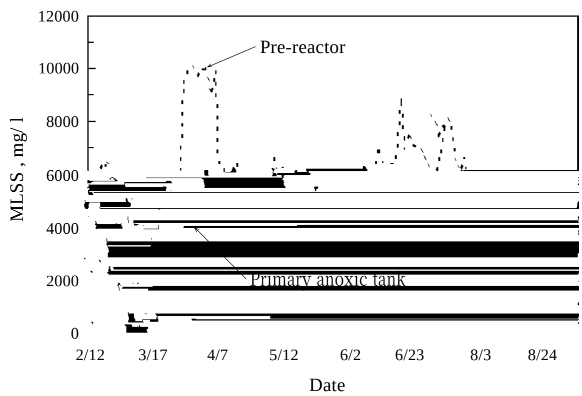

Fig. 4 Changes in concentration of MLSS in the pre-reactor and the primary anoxic tank

3.2.3 Removal treatment performance

Fig. 5 shows the rate of pollutant removal in the pre-reaction stage during the continuous feed test. As the figure shows, every case with a septic sludge mixing ratio greater than 50% had a pollutant removal rate of 80% or more except for total nitrogen. This clearly shows that the pre-reaction stage reduces the load to the succeeding main treatment stage. This stage also appears to help stabilize the main treatment stage.

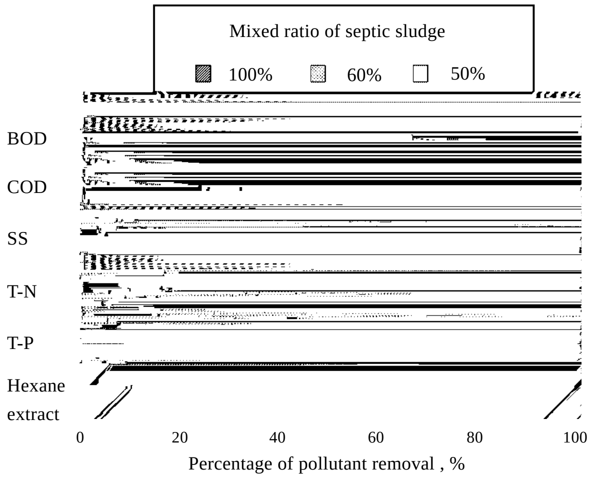

Fig. 5 Removal ratio of pollutant in the pre-reaction stage

3.3 Main treatment stage

3.3.1 Biological treatment reactions

(1) Denitrification treatment

Table 4 compares the inorganic nitrogen concentration in the main treatment stage for this process to that for the basic process. The amount of inorganic nitrogen, particularly NH_4^+-N, in the incoming water to the main treatment stage was one third or less that of the basic process. Thus, the load of NH_4^+-N to the biological treatment reaction tank was very light. This finding suggests that the addition of the pre-reaction stage stabilizes treatment in the main treatment stage, even when a large quantity of septic sludge with significant variations in properties is processed, and that the denitrification target is readily achieved.

Table 4 Changes in concentration of inorganic nitrogen in the main reactor

	Process	Inorganic nitrogen		mg/l
		NH_4^+ - N	NO_2^- - N	NO_3^- - N
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(2) Operating stage viewed from biota

Photo 2 shows metazoa resembling *Rotaria* that was observed in the sludge of the main treatment stage oxic tank. *Metazoa* are said to contribute to reduction of the sludge[2]. The occurrence of *metazoa* that were not found in the pre-reactor suggests that the condition of activated sludge in the main treatment stage is better than that in the pre-reactor.

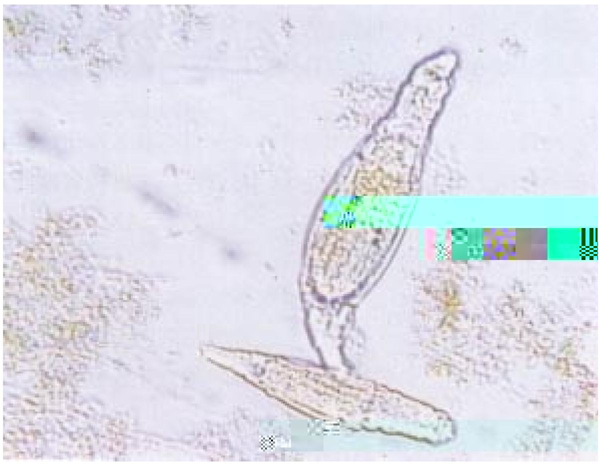

Photo 2 Metazoa seen in the oxic tank

3.3.2 Membrane filtration

Table 5 shows the quality and composition of membrane filtrate from the pilot plant test for the UF and MF membranes. There is no significant difference in water quality between the two kinds of membrane filtrate. Accordingly, either method should provide similar quality of treated water.

Table 5 Average qualities of filtrates

		By UF (N=26)	By MF (N=22)
BOD	mg/l	1.4	1.4
COD	mg/l	38.0	41.7
SS	mg/l	0.0	0.5
T-N	mg/l	8.6	7.6
T-P	mg/l	0.5	0.7
Color	mg/l	173	148

3.4 Advanced treatment stage

Table 6 shows a comparison between the average quality of water treated by activated carbon adsorption unit and the target quality of effluent for septic sludge mixing ratios of 100%, 60%, and 50%. The water quality treated by activated carbon adsorption satisfied all requirements for the effluent. The difference between the maximum and minimum values for each water quality criterion was small, indicating that the treatment is consistent. In particular, the average value of total nitrogen in water treated by activated carbon never exceeded 10 mg/l, regardless of differences in the septic sludge mixing ratio; i.e., the biological denitrification reaction in the main treatment stage was favorably maintained.

3.5 Sludge treatment stage

3.5.1 Properties of centrate

For a 50% septic sludge mixing ratio, **Fig. 6** shows a comparison of the sludge loads between the centrate obtained from dehydrating the withdrawn sludge and the supernatant from the pre-reaction stage sedimentation separation tank. As seen in the figure, pollutant loads from the centrate were lighter than those coming from the supernatant in the sedimentation separation