EFFECT OF AQUATIC WEEDS ON NUTRIENT REMOVAL FROM DOMESTIC SEWAGE

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ABSTRACTS
During recent years, utilization has been considered a suitable method to control the weed, and it has become a part of the strategy for management of the weed. Especially aquatic weeds have received most attention for its use in wastewater treatment systems. The purpose of this paper is to introduce some artificial systems employing aquatic weeds in the treatment of domestic sewage.

A small-scale pilot study to investigate the use of aquatic weeds in removing nutrients from domestic sewage was established Jointly at the prefectural public health center, the town office and Okayama university, Okayama, Japan. The system consist of a stabilization trench covered with *Eichhornia crassipes,* lined, two soil filled trenches which have been designed to have aquatic weeds of 13 species, and three catalytic oxidation trenches. Aquatic weeds used include *Iris pseudacorus, Scirpus fluviatilis, Pharagmites japonica, Phalaris arundinacea, Cyperus iria, Typha angustifolia, Coix lacryma-jobi, Juncus effusus, Hydrocharis dubia, Polygonum thunbergii, Oenanthe javanica, Acorus gramineus* and *Elodea nuttallii.*

Effective removal of COD, SS, N and P has been achieved in the system over one year study period. They recorded 58 % reduction in total N, 46 % reduction in Inorg.-N, 80 % in total P and 56 % in Inorg.-P, respectively. It was observed that the tissue concentrations of both nitrogen and phosphorus were much higher in *Oenanthe javanica, Elodea nuttallii, Hydrocharis dubia and Eichhornia crassipes.*

INTRODUCTION

During recent years, utilization has been considered a suitable method to control the weed, and it has become a part of the strategy for management of the weed. Especially aquatic weeds have received most attention for its use in wastewater treatment systems. *Eichhornia crassipes,* floating weeds, has been extensively investigated for wastewater treatment (Stewart et al., 1987). It has also led to the design of constructed aquatic systems with some aquatic weeds as well as *Eichhornia crassipes* for the treatment of wastewater (Wolverton et al., 1983). Interest in the use of emergent weeds such as *Phragmites communis* for waste water treatment has increased greatly in Japan, however, the ability of emergent or submerged weeds to treat wasterwaters has not been yet evaluated.

The primary objectives of this project study are 1) to examine the capability of this wastewater treatment system using aquatic weeds to reduce nutrient concentrations of domestic wastewater effluent, and 2) to investigate the efficiency and feasibility of year-round wastewater treatment.

Description of study

A small-scale pilot study to investigate the use of aquatic weeds in removing nutrients from domestic sewage was established jointly at the Prefectural Public Health Center, the Town office and Okayama University, Okayama, Japan. The system was designed to treat 25 m^3 /day of domestic sewage from thirty houses, and to flow through trenches by overflow. The system consist of a stabilization trench covered with *Eichhornia crassipes,* lined, two clay soil filled trenches which have been designed to have aquatic weeds of 13 species, and three catalytic oxidation trenches filled up oyster shells, fishing nets and bricks, respectively (Fig.1.). Each trench is 1.5 m wide and 5.1 m long except a stabilization one (1.5 m (W) X 2.5 m (1,)).

Aquatic weeds cultured in trench I are *Iris pseudacorus Scirpus fluviatilis, Pharagmites japonica, Phalaris arundinacea, Cyperus iria, Typha angustifolia,* while in trench II are *Coix lacryma-jobi, Juncus effusus, Hydrocharis dubia, Polygonum thunbergii, Oenanthe javanica, Acorus gramineus. Elodea nuttallii,* submerged weeds, invaded into both trenches by chance. Twenty four adult plants of *Iris, Scirpus, Hydrocharis,* 30 plants of *Juncus,* 12 plants of *Typha* and 18 plants of other species were planted at 25 cm intervals in August 1990. The water depth is maintained around 20 cm in trench I while around 10 cm in trench II.

This system has been in operation since August 28, 1990, at that time, a stabilization trench was stocked with 2.67 kg FW/m^2 of *Eichhornia crassipes.* For the initial 4 months of operation, water samples were taken from wastewater to analyze for pH, BOD, SS, Total-N and Total-P every 2 weeks. At the same time, plant growth was checked and some plant samples were collected to analyze for Total-N and Total-P. From January 1991, samples of both water and plant were collected monthly.

RESULTS AND DISCUSSION

CONCENTRATION REDUCTIONS: For the initial three month, COD, BOD and SS were reduced effectively, however, the total-N and Total-P removal rates were in the range of 14 to 44 % of input loads. These results were obtained in systems with poor plant cover. As aquatic weed populations were more established, effective removal of Total-N and Total-P has been achieved in the system. Especially the best performance occurred in the summer of 1991 when 83 % of Total-N and 92 % of Total-P were removed (Table 1).

EICHHORNIA CRASSIPES SYSTEM: In this system when the raw sewage is transferred to a stabilization trench, E. crassipes populations were observed to have a beneficial effect on water quality. Though *E. crassipes* is cold sensitive, they maintained large standing crop, and also showed higher contents of nitrogen and phosphorus in plants in December, in spite of the cold temperature. Therefore it is expected to use this weed even in late fall in the southern part of Japan.

CONTENT OF NITROGEN AND PHOSPHORUS IN PLANTS: As a result of N and P analyses of aquatic weeds, it was observed that the tissue concentrations of both N and P were much higher in *Oenanthe, Elodea, Hydrocharis, Phalaris and Eichhornia.* These values did not change with season, but *Iris, Scirpus, Juncus* and *Typha* did. Values were generally higher in floating and submerged weeds than in emergent weeds (Table 3).

BIOMASS PRODUCTION: Aquatic weed populations were allowed to establish themselves by natural succession after an initial planting in each trench, as a result, in the second year of operation, all aquatic weeds showed seasonal variation in producing biomass. *Cyperus iria, Polygonum thunbergii* were disappeared by insect damage or unsuitable environment. The growth of *Acorus gramineus* were also inhibited throughout operation. The highest standing crop

Table 1 Influent and effluent loading levels for wastewater treatment system.

Date		COD (mg/l)	BOD (mg/l)	SS (mg/l)	T-N (mg/l)	T-P (mg/l)
Sept. 12 1990	Influent	18.0	19.0	23.0	10.0	1.57
	Effluent	10.0	3.0	3.0	5.6	1.25
	Removal rate(%)	44.4	84.2	87.0	44.0	20.40
Nov. 26 1990	Influent	18.0	26.0	62.0	9.4	1.30
	Effluent	6.8	2.6	<1.0	8.1	0.89
	Removal rate(%)	62.2	90.0	98.4	13.8	31.50
Dec. 21 1990	Influent	32.0	45.0	97.0	17.0	1.70
	Effluent	6.5	2.7	4.8	7.3	0.84
	Removal rate(%)	79.7	94.0	95.1	57.1	50.60
March 6 1991	Influent	77.0	107.0	162.0	23.5	7.22
	Effluent	10.0	5.2	<1.0	9.9	1.42
	Removal rate(%)	87.0	95.1	99.4	58.1	80.30
Jyly 23 1991	Influent	160.0	680.0	740.0	25.0	31.00
	Effluent	10.0	3.0	<1.0	4.3	2.40
	Removal rate(%)	93.8	99.6	99.9	82.8	92.30
Nov. 15 1991	Influent	56.0	30.0	600.0	9.5	3.6
	Effluent	7.2	2.4	<1.0	6.3	1.1
	Removal rate(%)	87.1	92.0	99.9	33.7	69.4

Table 2 Standing crop and plant height of *Eichhornia crassipes* populations cultured in a stabilization trench, and their nitrogen and phosphorus removal performance.

Date	Standing crop* (kg FW/m²)	Plant height* (cm)	Contents in dried plants(%) N	Contents in dried plants(%) P	Accumulation (g/m²) N	Accumulation (g/m²) P
1990 Aug. 28	2.67 ± 0.00	15.25 ± 3.48	2.80	0.72	3.60	0.93
Sept. 23	15.24 ± 0.28	42.23 ± 4.29	2.57	0.64	19.35	4.82
Oct. 24	21.72 ± 0.30	49.42 ± 6.53	3.62	0.97	33.50	8.51
Nov. 14	29.24 ± 0.33	46.07 ± 4.54	3.77	1.13	49.94	14.97
Dec. 14	33.88 ± 0.41	42.37 ± 4.80	3.59	1.00	69.09	19.24
1991 May 17	5.60 ± 0.50	16.85 ± 5.24	4.77	0.89	13.52	2.52
Sept. 12	40.04 ± 0.22	73.85 ± 6.81	4.05	0.72	82.05	14.59

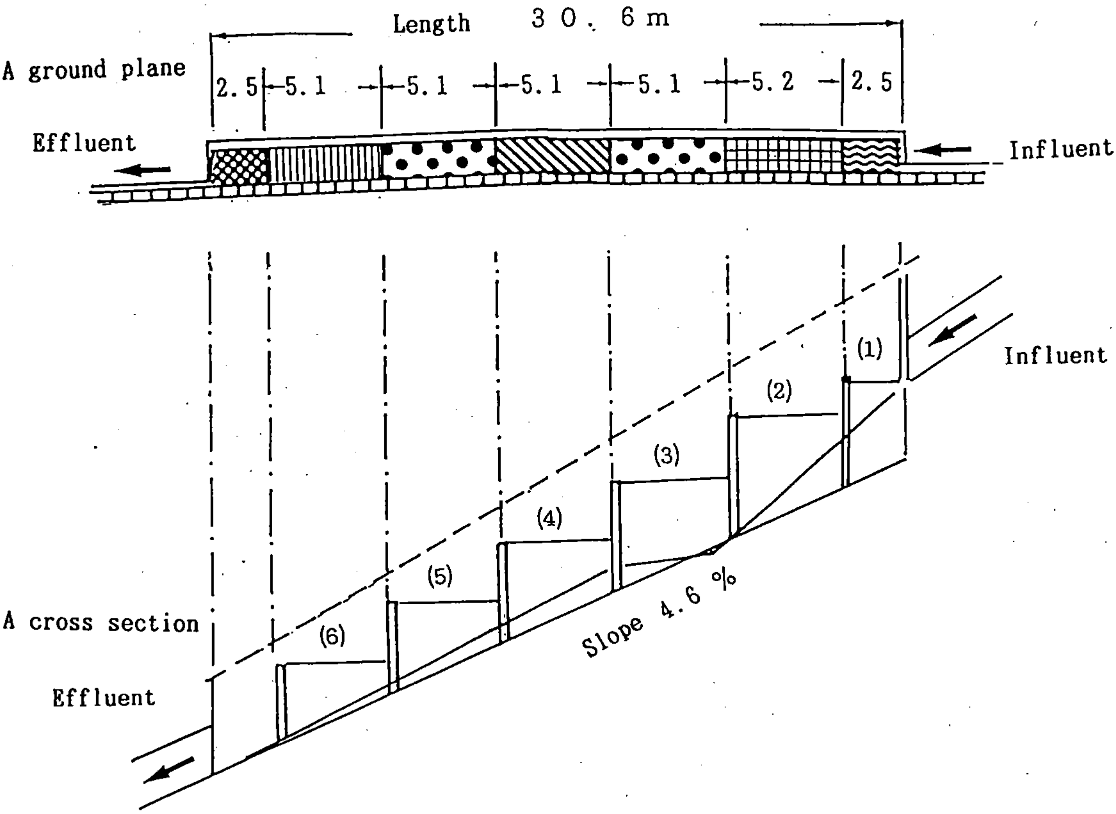
*: Values represent Mean ± S.D

Table 3 Content of nitrogen and phosphorus (% dry weight) in the tops of aquatic weeds.

Weed species	Date of investigation					
	Nov.14,1990		May 17,1991		Sept.12,1991	
	N	P	N	P	N	P
Aquatic weeds trench I						(%)
Iris pseudacorus	3.09	0.280	1.53	0.303	1.79	0.390
Scirpus fluviatilis	1.13	0.180	2.30	0.430	2.19	0.301
Pharagmites japonica	2.45	0.170	3.70	0.316	2.68	0.168
Phalaris arundinacea	3.07	0.540	3.42	0.374	4.75	0.443
Typha angustifolia	0.64	0.120	1.87	0.240	1.70	0.271
Aquatic weeds trench II						
Coix lacryma-jobi	2.51	0.510	2.39	0.498	2.59	0.525
Juncus effusus	1.50	0.248	2.26	0.288	1.68	0.253
Hydrocharis dubia	-	-	3.41	0.790	3.73	0.933
Oenanthe javanica	4.74	0.970	3.50	0.786	3.10	0.992
Elodea nuttallii	4.48	1.510	3.80	1.515	4.44	1.217

Table 4 Seasonal change in standing crop of the tops of aquatic weeds populations for each trench.

Weed species	Date of investigation				
	May 17,1991	June 27	July 19	Sept.12	Dec.1
Aquatic weeds trench I					(g DW/trench)
Iris pseudacorus	1,381	3,625	5,928	19,087	17,016
Scirpus fluviatilis	108	372	779	591	261
Pharagmites japonica	413	1,982	2,949	724	384
Phalaris arundinacea	309	1,481	2,642	1,367	1,216
Typha angustifolia	153	544	712	2,332	2,713
Elodea nuttallii	418	485	571	734	521
Aquatic weeds trench II					
Coix lacryma-jobi	65	7,554	10,090	86	69
Juncus effusus	1,126	1,257	1,416	1,883	1,801
Hydrocharis dubia	67	123	270	684	0
Oenanthe javanica	1,276	122	1	2	741
Elodea nuttallii	626	728	856	1,102	782



(1) A stabilization trench covered with *Eichhornia crassipes*.

(2) A catalytic oxidation trench filled up oyster shells.

(3) Aquatic weeds trench I
(*Iris pseudacorus, Scirpus fluviatilis, Pharagmites japonica, Phalaris arundinacea, Cyperus iria, Typha angustifolia, Elodea nuttallii*)

(4) A catalytic oxidation trench filled up fishing nets.

(5) Aquatic weeds trench II
(*Coix lacryma-jobi, Juncus effusus, Hydrocharis dubia, Polygonum thunbergii, Oenanthe javanica, Acorus gramineus, Elodea nuttallii*)

(6) A catalytic oxidation trench filled up bricks.

Fig. 1. Design of the wastewater treatment facility using aquatic weeds.

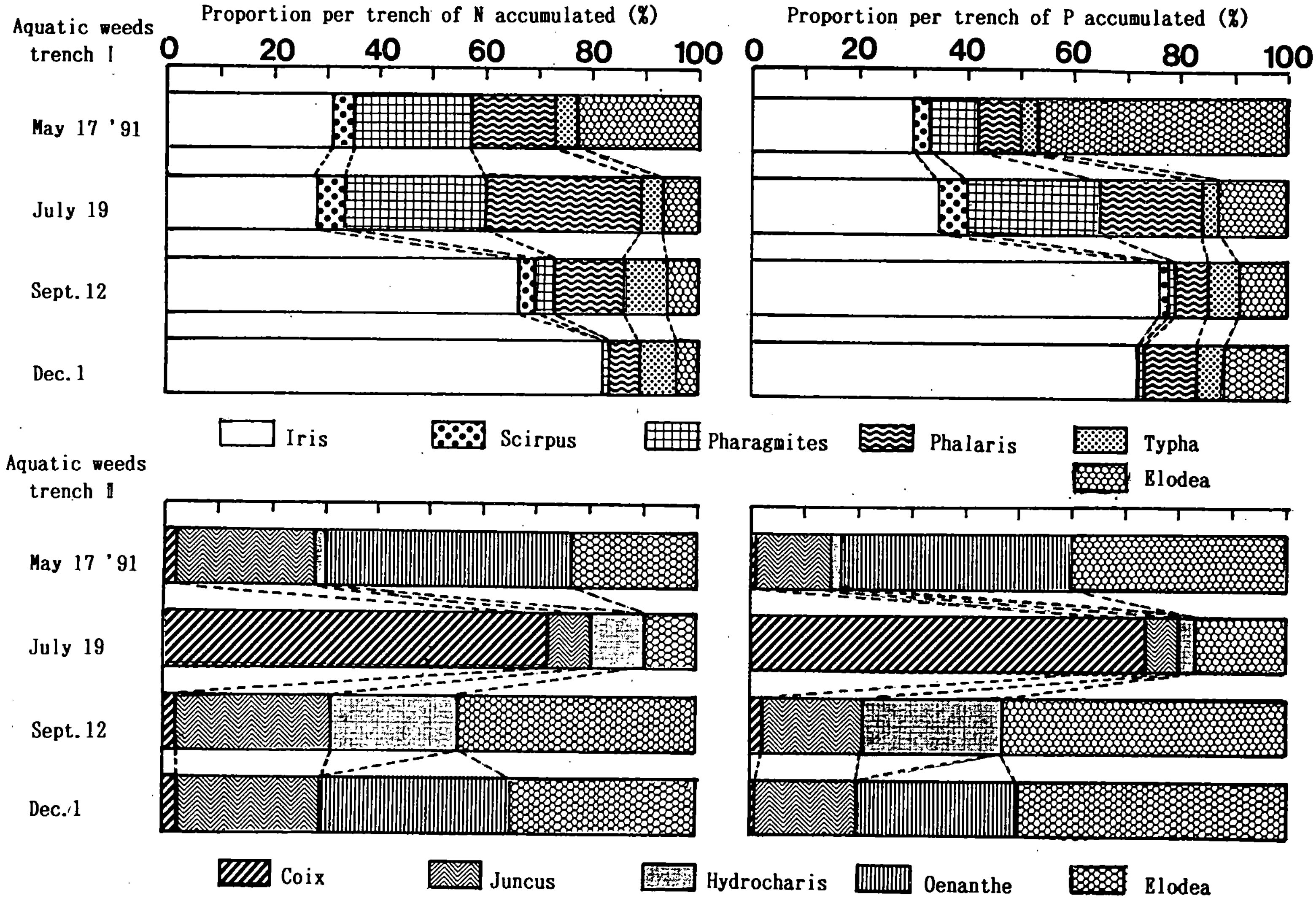


Fig. 2. Seasonal change in proportion per trench of nitrogen and phosphorus accumulated by the top of each aquatic weed populations.

of the tops of *Iris, Typha, Hydrocharis and Elodea* appeared to be in September, while *Pharagmites, Phalaris* and *Coix* did in June and July. *Oenanthe* produced large standing crop during the cooler season of the year. Continual growth all the year was observed in *Juncus* (Table 4).

ACCUMULATION BY AQUATIC WEED POPULATIONS: Generally the increase in accumulation of N and P by weed populations was closely related to the increase in their standing crop (Oki et al., 1981). In trench 1, *Iris* appears to show promise in highest accumulation of N and P, while in trench II *Juncus* and *Elodea* took part in the higher accumulation of N and P constantly all the year except summer. Also accumulation by *Oenanthe* was higher during cooler season (Fig. 2).

These results demonstrated that satisfactory removal of nutrient and organic matter in this trench system with emergent weeds was obtained throughout the observation period. And it was evident that there was significant removal, occurring even in winter because of polyculture which combined several emergent with submerged species. There, however, remains further research related to management technique and more detailed removal mechanism. In this study, the regular harvest system was not performed. However, emergent plant biomass require harvesting, or cutback is proposed as a management technique (Bavor et al., 1987). On the other hand, in addition to plant uptake, nutrient removal in aquatic weeds-based wastewater treatment systems is affected by a number of biological, physical and chemical processes functioning in the water, sediment and bed substrate (Reddy and DeBusk, 1987). Therefore research of more detailed nutrient removal mechanism is needed.

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