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The Closed Recycling System for Combined fish Culture and Hydroponic Vegetable Production

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ABSTRACT

The constructed closed recycling system discussed in this technical report will be economically viable in future for the production of fish and vegetable in earth, space station and space colony, further, it will contribute a lot in the prevention of pollution in the world's ecological system.

To make combined system, water management (Nitrification) is required, and it took 45 days to breed microorganism which facilitates this process. After this period, the recycle was confirmed to be working. Using derived equations, the expected nutrient characteristics of waste water were determined and it was found that the resulting nutrient balance was almost same as that in hydroponic solution when KOH was added to maintain pH level. Reverse osmosis (RO) system could solve the problem of the low nutrient concentration. It was found that plants grow well in fish waste water which was produced using RO system. RO system could combine fish and plant production through the advantageous use of separated high concentration water for plant and permeated water for fish in integrated combined system.

Key Word: CELSS, Fish culture, Hydroculture, Nitrification, Reverse osmosis (RO)

INTRODUCTION

Aquaculture which is a new technology of fish breeding is rapidly growing but there are problems which hinder growth in this sector. Two of major problems hindering growth are lack of sufficient water, and the disposal of waste water from ponds. It has been estimated that the industry requires 10 % of the total available amount of water, which is quite high considering the fact that water is also needed in many other fields in the country. Waste water from breeding is also hazardous to the environment.

Hydroculture which is a soilless method for growing plant is not expanding due to high investment cost. In order to alleviate this high cost, then it would be proper to cut down on the operation cost which consists mainly of fresh water input and fertilizers.

From the above cases, it seems that combined aquaculture and hydroculture systems could be put into better use through recycling system to save water and nutrients. This subject is also related CELSS (Closed Ecological Life Support Systems) which is to be considered in constructing the closed environment for sustaining the life in space station and space colony. Therefore, combined aquaculture and plant production system is developed and investigated in this study.

MATERIALS AND METHODS

Basic data required to develop a combined fish and plant production system were determined from an experimental system (Fig. 1) consisting of a fish tank (160cm * 160cm * 60cm depth, under the ground), hydroponic bed (91cm * 135cm * 20 cm depth, each line has three beds) , water management section (biofilter:two 200 ℓ tanks) and reverse osmosis (RO) section in a greenhouse (width 5.4m * height 2.8m * length 16m). To make a habitat for bacteria, the ceramic ball (about 1 cm diameter) made of SiO_2 and Al_2O_3 were filled up to a 50 ℓ volume for each biofilter. The one year old frog (Xenopus Leavis) was used as fish specimen , it was about 5 cm size and weighed 20 to 30 g.

The water flow system consisted of 3 parts, the first flow was waste water management (nitrification) through biofilter from fish tank. The second flow was waste water separation using reverse osmosis system after finishing nitrification section. The third flow was cycling for hydroculture system for plant.

Five kinds of membrane (FT-40, NTR-7250, SCL-100, SC-3100 and SU-710) were tested in prototype RO system.

RESULTS AND DISCUSSION

Water recycling system in the fish sector was as shown in Fig. 2, and it mainly consisted of feed for fish, nitrification of waste water, alkali for maintaining pH level and dentrification, all which effect components of fish water . The water content at which fish could not survive easily was analyzed and it was found to contain NH_4^+-N 40 ppm and NO_2^--N 18 ppm which is above normal for fish growth. Nitrification (the oxidation of NH_4^+ to NO_2^- and NO_3^-) is required for fish growth to save and recycle water. Nitrification's (bacteria's activity) process is as follows:

$$2NH_4^+ + 3O_2 \rightarrow 2NO_2^- + 4H^+ + 2H_2O \quad \cdots\cdots (1)$$

$$2NO_2^- + O_2 \rightarrow 2NO_3^- \quad \cdots\cdots (2)$$

From the above reaction, when process (1) is in progress, the pH of water is lowered due to the reaction of H^+ ion and to OH^- ion in water. Fig. 3 shows that pH gradually decreased when process (1) was in progress and it took 45 days to breed microorganism which facilitated this process. After this period, the recycle was confirmed to be working satisfactorily since only NO_3^- could be detected. Hence, for the water management, linear regression equations could be given in terms of the elements (Y:ppm) in water and the number of days (X:days) as follows.

T-N : $Y = 0.741 X - 0.429$ ($r = 0.998$)

PO_4^{3-}-P : $Y = 0.230 X - 2.610$ ($r = 0.970$)

K^+ : $Ya = 0.386 X + 11.755$ ($r = 0.928$)

K^+ : $Yb = 0.993 X + 13.566$ ($r = 0.996$)

Ca^{2+} : $Y = 0.441 X + 19.066$ ($r = 0.974$)

Mg^{2+} : $Y = 0.771 X + 6.077$ ($r = 0.777$)

To maintain pH level for water NaOH and KOH is used in line with the equations Ya and Yb respectively for K^+ component. The original water contained dissolved K^+ 13 ppm, Ca^{2+} 20 ppm and Mg^{2+} 5 ppm.

Using the equations, the expected nutrient characteristics of waste water after 85 days were determined and it was found that the resulting nutrient balance was almost the same as that in hydroponic solution when KOH was added to maintain the pH level as shown in Fig. 4. However, the resulting concentration of nutrient was quite low for plant production. This problem was solved by using reverse osmosis (RO) system which is used for separation for sea water to get water, whereby the low nutrient concentration of waste water was made higher by separation. The advantage of using RO system are as follows:

1) It has low energy cost compared to distillation and cooling method.

2) The equipment of RO system is quite small, simple and maintenance is quite easy.
3) It does not affect composition of water components since there is no heating.

The prototype RO system mainly consisted of RO filter, high pressure circulating pump, pressure gauge, flow meter, waste water and permeated water tank as shown in Fig. 5. After testing five separation membranes using RO system, the component removable rates (EC removable rate) of water from waste water were 85% to 95% in SC-3100 and SU-710 membranes as shown in Fig. 6. From linear regression equations, the permeated water rate of SU-710 was larger than SC-3100, hence it was found that SU-710 membrane was the best among this five membranes for waste fish water.

By using reverse osmosis four levels of concentration (Table 1) were produced from fish waste water and hydroculture water (control) in plant growth experiment. It was found that plants in EC 1.6 and EC 2.2 sectors had good enough growth when compared with control.

CONCLUSIONS

The constructed closed recycling system discussed in this technical report will be economically viable in future for the production of fish and vegetables in earth, space station and space colony. It is anticipated that waste water from fish culture could be put into better use through recycling system and save water and nutrient, further, it will contribute a lot in the prevention of pollution in the world's ecological system.

The following results were obtained:

1) Nitrification was required to maintain water quality for fish and it took 45 days in this process.
2) The water recycle system was confirmed to be work satisfactorily after the breeding of bacteria, and the expected nutrient characteristics of waste water were determined using some equations.
3) It was found that the resulting nutrient balance was almost the same as that in hydroponic solution when KOH was added to maintain pH level.
4) RO system could combine fish and plant production through the advantageous use of separated high concentration water for plant and permeated water for fish in the integrated combined system.

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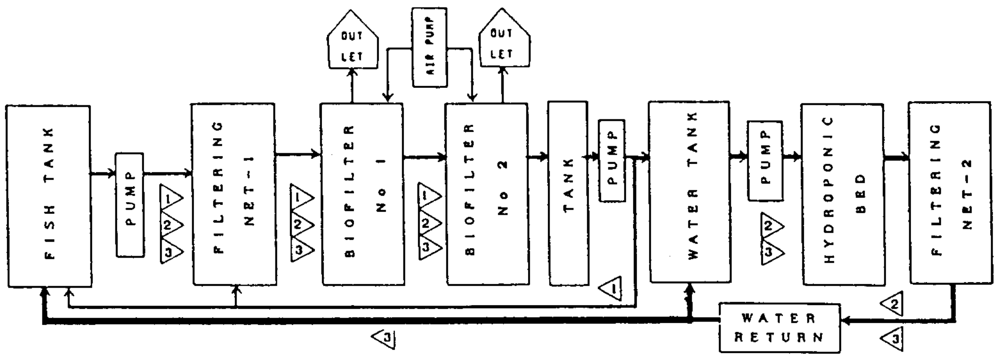

Fig. 1 The closed recycling system for combined fish and hydroponic vegetable production.

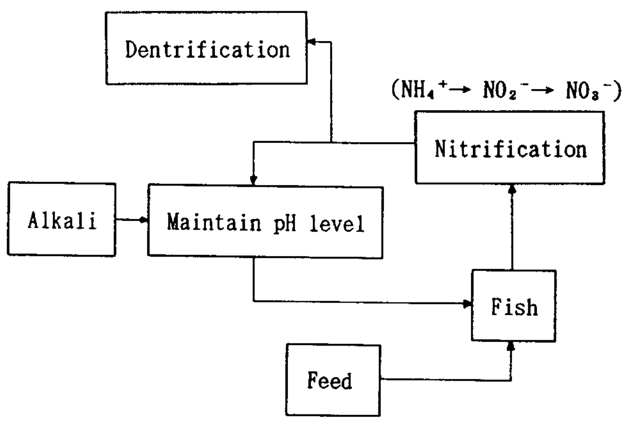

Fig. 2 Components of water recycling system in the fish sector.

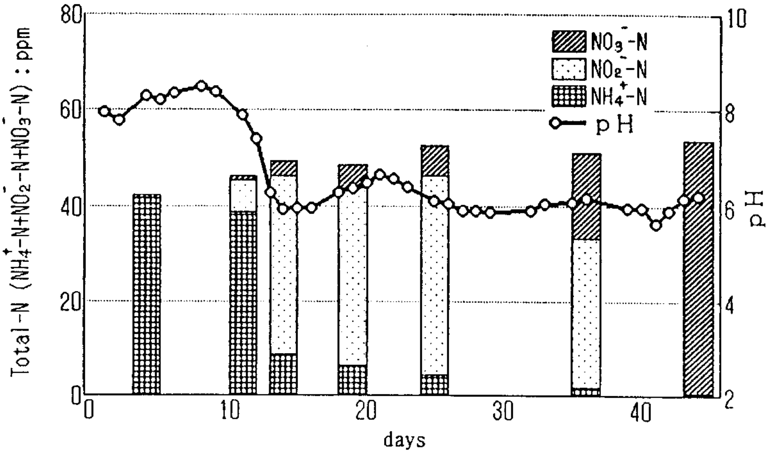

Fig. 3 Changes of nitrogen movement and pH during breeding microorganism in biofilter.

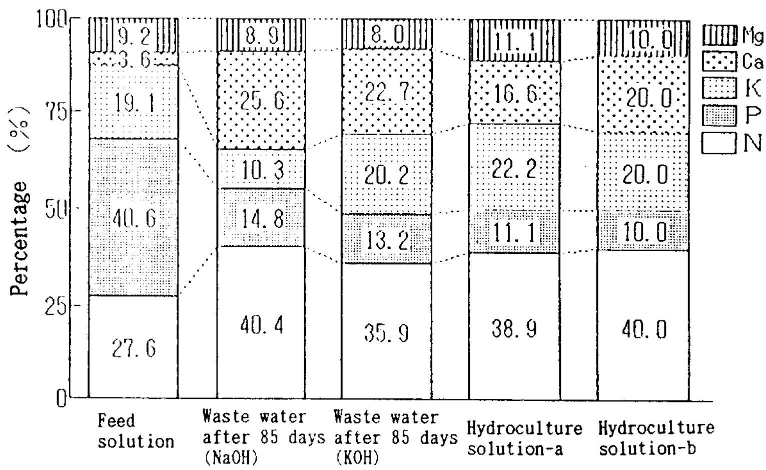

Fig. 4 The component characteristics of fish waste water.

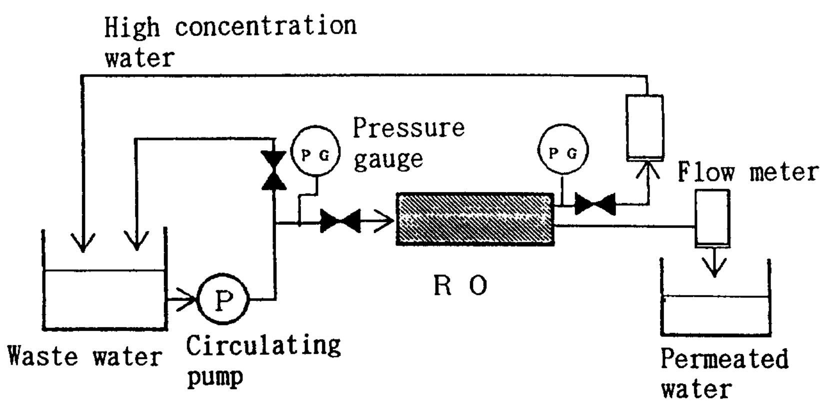

Fig. 5 The system of prototype reverse osmosis.

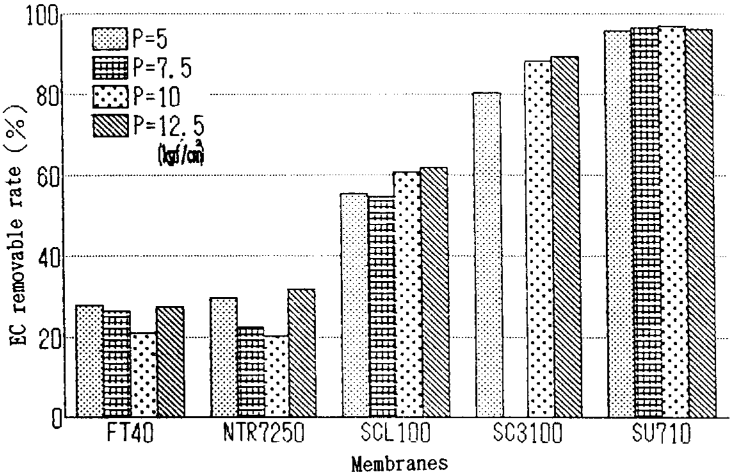

Fig. 6 The EC removable rate of fish waste water in each membrane.

Table 1. The component of solution which were produced by using reverse osmosis for plant growth.

EC (mS/cm), components (ppm)

	EC	pH	NH_4^+-N	NO_3^--N	PO_4^{3-}-P	K^+	Ca^{2+}	Mg^{2+}
EC 0.6	0.66	6.3	0	45	8	93	46	6
EC 1.1	1.21	6.2	0	82	17	159	75	12
EC 1.6	1.69	6.1	0	133	36	215	103	19
EC 2.2	2.40	6.0	0	163	43	298	143	30
H.C	2.32	6.0	27	191	49	318	141	53

	S^{2-}	Fe^{2+}	Cl^-	Mn^{2+}	Na^+
EC 0.6	12	0.1	15	0.1	25
EC 1.1	22	0.1	28	0.2	49
EC 1.6	42	0.1	53	0.2	70
EC 2.2	52	0.1	65	0.3	103
H.C	54	1.6	3	1.4	17

EC: fish waste water
H.C: hydroculture solution