Bull. Korean Fish. Soc. 20(6), 561~568, 1987 韓水誌 20(6), 561~568, 1987

The Ammonia Removal Capacity of a Few Kinds of Filter Media in a Water Reuse Aquaculture System*

In-Bae KIM, Pyong-Kih KIM**, and Young-Ok CHEE***
Fish Culture Experiment Station, National Fiseries University of Pusan, Nam-gu, Pusan, 608 Korea
**Marine Biotechnology Laboratory, Korea Ocean Research & Development Institute, Sa-dong, Ansan, Kyonggi-do, 171-14 Korea
***432 Kwejong-dong 3, Saha-gu, Pusan, 600-02 Korea
(Received September 17, 1987; Accepted November 7, 1987)

The purpose of this study was to find out the removal capacity of harmful ammonia by different filter media in the submerged biological filters in a given space of chamber.

Four materials, pile cloth, corrugated skylight roofing plate, embossed plastic plate, and gravel, were used as the experimental filter media. Each filter medium was placed in two aquariums, each aquarium measuring 90 *cm* × 60 *cm* × 60 *cm* (depth).

Under the normal operating condition, the average of mean ammonia removal rates during the first and second functioning periods by each filter material which occupied the space in the filter chamber (aquarium) was as follows:

1. Pile cloth: 8.381 $g.m^{-3}$. day^{-1}
2. Corrugated skylight roofing plate: 7.834 $g.m^{-3}$. day^{-1}
3. Embossed plastic plate: 7.797 $g.m^{-3}$. day^{-1}
4. Gravel: 7.051 $g.m^{-3}$. day^{-1}

Thus, there were no significant differences between the media, but at the time of practical application of these materials, some other factors such as investment cost, easiness for the removal of excess detritus accumulated in the interstices of filter media, etc. should be taken into consideration. When large units are required, in particular, removal of excess detritus from the gravel bed is extremely difficult, and in case of pile cloth filters the installation work is much complicated and a problem in supporting the structure when drained also exists.

In these respects, corrugated skylight roofing plate and embossed plastic plate seem to be more optimal, but again in practice the local situation for the availability and the price of the materials should be rechecked and the fitness of the materials in the particular filter chambers under use or under consideration for construction must be taken into account.

Introduction

Fish culture in Korea has been developing year by year in recent years, but suitable sites together with greatly adverse climatic conditions are limiting factors. Some major production facilities are cages installed in large dammed lakes, but they are also becoming limited. Most lakes used for cage

* 本 研究는 月海學術振興會의 支援에 依하여 施行되었음.

aquaculture are located up-rivers aiming primarily at the storage of water for multiple purposes including human drinking. Therefore, the number of fish rearing units must be reasonably restricted not to polute the water resources. The pond system may be used for seed fish production, but this system may not be practical for the mass production of food fish because of highly restricted area of cultivable land in Korea. By these reasons, the future development of food fish culture should depend on other systems such as closed system which requires very little amout of land area as well as limited amount of water.

On the other hand present level of development in the closed system is not well advanced, being still in its primitive stage, though this system is probably the only potential for the future expansion of edible fish culture in the inland area of Korea. Especially not only because of limited land area available to fish culture, but also because of short growing season in a year owing to prolonged unfavourable low temperature, this closed system fish culture seems to be much more desirable than outdoor pond culture. Closed system controls all water parameters including water temperature, thus allowing the fish under rearing to grow nearly year-round.

The efforts to develop effective closed fish culture system have been paid in many countries around the globe. There are several types of filter system which can be employed in the closed water system (Naegel, 1980). In early days submerged gravel filters were mainly employed with different fish species both in the laboratory and pilot experiments (Saeki 1958, 1965; Saeki and Aoe 1962, 1963) but other types such as revolving plate type (Lewis and buynak 1976) and activated sludge filter (Meske 1979) have been tested. Liao and Mayo (1974) reported on the efficiency of several types of semiclosed systems for practical salmonid hatcheries. Of these types, the submerged filter is the simplest to install and easiest to manage, and also very good performance has been shown in rearing fish (Broussard and Simco 1976) and Kim (1980) showed some promissing results in his pilot scale fish production experiment. Especially in the case of a large commercial production units it will be particularly important to build cost-effective system. But there are still many problems which must be overcome including modification and improvement of system structures, management of the system in operation, and so on. Among them, the filter section, so called the pivotal part of the system, requires much more work to be carried out in structure and management before full swing practices are realized for fish culture industry development.

The impacts of filter media in the filter section are of special importance both in material and management, therefore present study concerns several kinds of filter media which are commonly used or are under consideration for use in the submerged filter bed in the future in Korea. The filtering capacity of these materials was evaluated based on chemical determinations, and management practices are also discussed.

Materials and Methods

The experimental biofilters were set up with four kinds of materials, pile cloth, corrugated skylight roofing plate, embossed plastic (polyvinyl chloride) plate, and gravels, as the experimental filter media which were installed in glass aquarium tanks in duplicate. The aquarium measured: 90 *cm* × 60 *cm* × 60 *cm* (depth). Table 1 shows the volumes of the filter chamber and the space occupied by each filter material, and Fig. 1, the schematic diagram of the setting. The filter materials were laminar-

Table 1. The volumes of filter chamber and the spece occupied by filter material in the filter chamber

(unit in m^3)

Material	Volume of filter chamber	Space occupied by filter material
Pile cloth	0.324	0.147
Corrugated skylight roofing plate	0.324	0.134
Embossed plate	0.324	0.142
Gravel	0.324	0.129

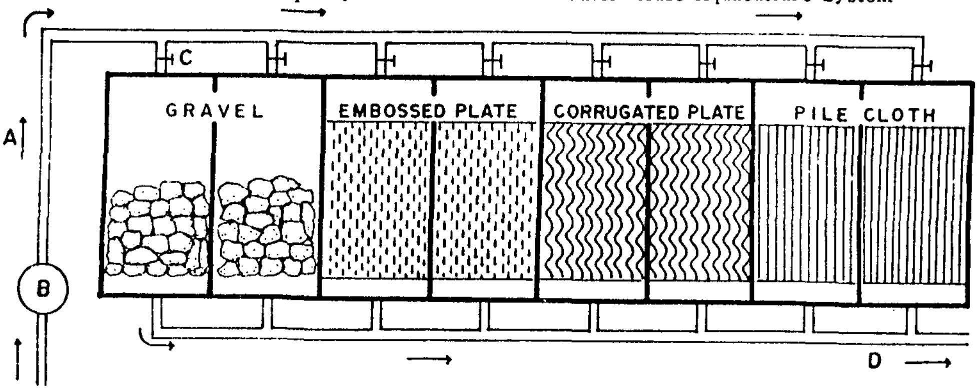

Fig. 1. Schematic diagram of the experimental filters employed.
A. Influent line; B. Pump; C. Flow rate control valve to each filter; D. Effluent line

ly arranged in the aquarium chamber spaced adequately except gravels which were just filled in. A total of 16 sheets of the pile cloth, each measuring 61 *cm* × 50 *cm*, were first placed in a framework, spaced 3 *cm* between sheets. This framework was then placed in each aquarium of a duplicate. In case of corrugated skylight roofing plate, 33 sheets, each measuring 64 *cm* × 42 *cm* were likewise placed in the filter chamber, spaced 1.8 *cm* between plates. In the filter chamber of embossed plastic plates, a total of 33 plates each measuring 60 *cm* × 41 *cm* were arranged in the same manner as the previous ones. The gravels, 5 to 7 *cm* in diameter, were filled with a space between the chamber bottom and filter media. The dimensions of the gravel filter medium were 89 *cm* × 58 *cm* × 25 *cm* (depth) (Table 1).

The water to be treated in the experimental filter was pumped from the effluent of the main fish rearing chambers of the pilot scale closed system fish culture unit of the university. The water pumped was diverted to each experimental filter, and the flow rate was regulated by a valve for each filter.

Results and Discussion

Overall Functioning During the Experiment

All data monitored and calculated during the experimental period are shown in Table 3. In the table some factors such as temperature, pH, and dissolved oxygen level (DO), which seem to affect the ammonia removal rate are presented in addition to the rate of ammonia removal (AR). After examining the table, the whole period was arbitrarily divided into : conditioning period, 1st functioning period, senile period, cleaning and reconditioning period, 2nd functioning period, senile period (2nd), and so on. Table 2 shows the overall ranges of major water parameters during the experiment, and Fig. 2 shows the amount of ammonia nitrified by each filter medium.

Conditioning

Each filter required several weeks before full functioning. After the start, ammonia removal rates were gradually increased and the highest

Table 2. Overall ranges of water parameters during the experiment

		Effluent			
	Influent	Cloth	Skylight pls.	Embossed pls.	Gravel
Flow rate(*l/cm³/day*)		0.064～0.093	0.071～0.111	0.067～0.093	0.072～0.105
Ammonia level(*mg/l*)	0.635～1.020	0.547～0.945	0.582～0.965	0.582～0.959	0.608～0.967
D.O. (*mg/l*)	2.0～3.5	0.7～2.3	0.8～2.2	0.7～2.1	0.6～1.8

pH: 6.85～7.05; Water temperature: 20.1～29.3°C

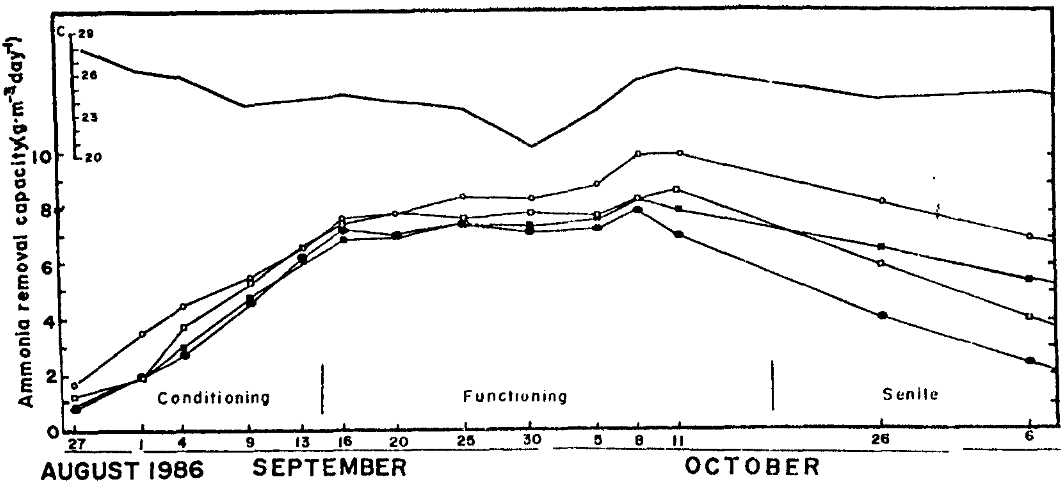

Fig. 2-1. The rates of ammonia nitrified by each filter during the first functioning period (Unit in g/m^3/day).

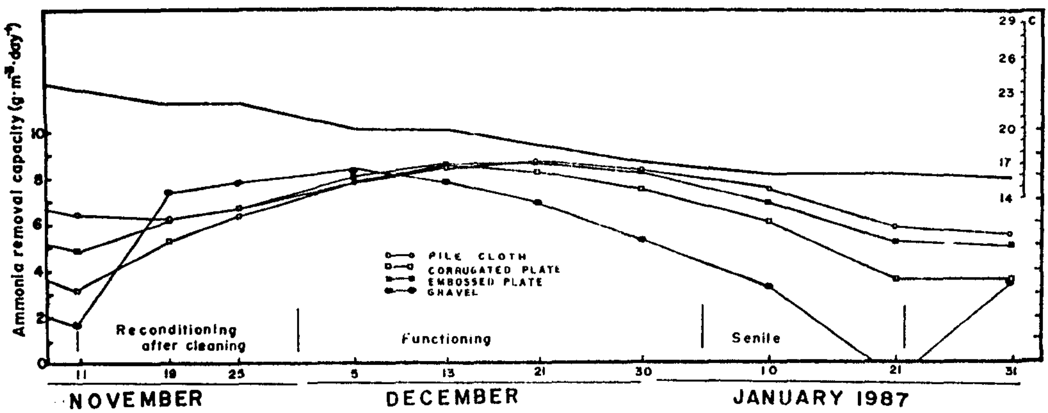

Fig. 2-2. The rates of ammonia nitrified by each filter during the second functioning period (Unit in g/m^3/day).

rates were reached in one month or so when new filters were installed and operated. From the results of present study, it was found out that pile cloth medium was conditioned most rapidly after new installation, but after cleaning (back-washing) the gravel filter showed the fastest pick-up, while the other three showed slightly slower but almost the same pattern.

Functioning and Senile Period

After conditioning the pile cloth filter showed the highest ammonia removal rate for more than one month, the average value of 7 measurements being 8.6 *g* per cubic meter of filter medium space occupancy per day, followed by skylight corrugated roofing plate 7.8 *g*, embossed plate 7.4 *g*, and gravel 7.1 *g*. These values could mean that there are no considerable differences in the capacity of ammonia removal rate among the four materials tested during the main functioning period. But a great difference was shown in the lengths of high functioning period. Even in the senile period designated according to overall trends of the filter functioning in this study, the pile cloth filter showed very active ammonia removal activity. In

Table 3. Water parameters determined and the amount of ammonia removed

Date (month/day)	pH	Temp	Influent		Effluent															
					Pile cloth				Skylight plate				Embossed plate				Gravel			
			DO	AL	DO	AL	FR	AR	DO	AL	FR	AR	DO	AL	FR	AR	DO	AL	FR	AR
Starting and Conditioning Period*																				
8/27	6.9	27.9	3.1	.638	1.7	.619	85	1.615	1.6	.623	84	1.260	1.5	.628	87	.870	1.7	.629	86	.774
9/1	7.0	25.8	2.3	.800	1.5	.758	83	3.486	1.3	.774	71	1.846	1.6	.777	79	1.817	1.2	.781	99	1.881
9/4	7.0	25.5	2.5	.970	1.5	.911	75	4.425	1.3	.925	82	3.690	1.3	.934	81	2.916	1.2	.938	84	2.688
9/9	7.0	23.2	2.0	1.020	1.0	.945	73	5.475	1.2	.965	95	5.225	1.4	.959	78	4.758	1.0	.967	86	4.558
9/13	6.9	23.6	2.6	.960	1.1	.868	70	6.440	1.1	.893	98	6.566	1.2	.892	88	5.984	1.0	.882	79	6.162
(average ammonia removal rate)								4.288				3.717				3.269				3.213
1st Functioning Period*																				
9/16	6.9	24.0	3.3	.936	2.3	.855	93	7.533	2.2	.857	93	7.347	2.1	.863	93	6.789	1.8	.848	81	7.128
9/20	7.0	23.5	2.6	.926	1.2	.812	68	7.752	1.1	.832	82	7.708	1.0	.844	84	6.888	0.9	.829	72	6.984
9/25	7.0	22.9	2.0	.905	0.7	.774	64	8.384	0.8	.824	93	7.533	0.7	.813	80	7.360	0.6	.835	105	7.350
9/30	7.0	20.1	2.9	.933	1.8	.839	88	8.232	1.7	.857	102	7.752	1.7	.825	67	7.236	1.0	.845	80	7.040
10/5	7.0	22.8	2.8	.885	1.2	.781	84	8.736	1.2	.816	111	7.659	1.1	.802	90	7.470	0.8	.809	94	7.144
10/8	7.0	25.1	2.9	.878	1.1	.758	82	9.840	1.1	.795	100	8.300	1.0	.778	83	8.300	0.7	.793	92	7.820
10/11	6.9	25.7	3.2	.755	1.2	.634	81	9.801	1.2	.660	90	8.550	1.1	.670	92	7.820	0.9	.670	80	6.800
(average ammonia removal rate)								8.611				7.836				7.409				7.181
Senile Period*																				
10/26	6.8	23.5	3.4	.670	1.7	.564	76	8.062	1.7	.599	81	5.756	1.3	.591	80	6.318	1.2	.626	88	3.887
11/6	6.6	24.1	3.5	.635	1.6	.547	77	6.797	1.2	.582	73	3.852	1.7	.582	98	5.184	1.3	.608	83	2.257
(average ammonia removal rate)								7.430				4.804				5.751				3.072
11/11 Lightly cleaned and Reconditioning Qeriod*																				
11/19	6.6	21.9	5.7	.620	3.9	.534	70	6.020	3.8	.554	77	5.082	3.9	.540	74	5.920	3.7	.550	102	7.140
11/25	6.8	22.1	4.6	.700	2.6	.588	58	6.496	2.3	.607	66	6.138	2.6	.613	74	6.438	2.4	.587	68	7.684
(average ammonia removal rate)								6.258				5.610				6.179				7.112
2nd Functioning Period*																				
12/5	6.7	19.9	3.2	.880	2.5	.772	71	7.668	2.5	.785	80	7.600	2.5	.783	81	7.857	2.3	.770	74	8.140
12/13	6.7	19.8	2.8	.752	1.5	.631	68	8.228	1.6	.650	82	8.364	1.6	.644	78	8.424	1.6	.674	98	7.644
12/21	6.8	18.5	3.5	.765	2.7	.666	86	8.514	2.6	.668	83	8.051	2.6	.648	72	8.424	2.5	.688	88	6.776
12/30	6.8	17.0	4.3	.740	3.2	.635	78	8.190	3.1	.656	87	7.308	3.2	.637	78	8.034	2.7	.679	84	5.124
(average ammonia removal rate)								8.150				7.831				8.185				6.921
Senile Period*																				
1/10	6.8	16.0	3.8	.725	2.8	.631	78	7.332	2.8	.649	78	5.928	2.8	.645	84	6.720	2.7	.689	87	3.132
1/21	6.8	16.1	4.5	.750	3.5	.693	100	5.700	3.5	.709	84	3.444	3.5	.670	63	5.040	3.3	.758	88	-.704
(average ammonia removal rate)								6.516				4.686				5.880				1.192
1/21 Light Cleaning*																				
1/31	6.8	15.8	3.3	.740	2.5	.668	75	5.400	2.6	.703	94	3.478	2.5	.661	62	4.898	2.4	.699	86	3.526

Note: DO, dissolved oxygen level in *mg/l*
AL, ammonia level determined in *mg/l*
FR, flow rate in *ml/m³/day* through filter medium
AR, ammonia removal rate in *g/m³/day*
*The designation of the stages of functioning was arbitrarily set up for convenience.

this period, the average of two measurements for the pile cloth filter on October 26 and November 6, was 7.4 g/m^3 filter space per day while 4.8 g for the skylight plate, 5.7 g for embossed plate, and 3.0 g for gravel. This trend was also manifested during the second functioning period, this time with much more pronounced expression, and the gravel filter showed even a negative value on January 21.

The quick start-up and also quick senile phenomena in the gravel filter can be explained by the easier accumulation of the nitrifying organisms as well as the decomposing waste detritus on the flat upper surfaces and interstices of the gravels. This explanation based on the results of present experiment well agrees with the fact that many fish farmers have experienced that the gravel filters had worked only for the first one or two months, and thereafter they not only did not work but also showed much worse results than other types of fish culture. We actually have found out that even after the cleaning of excess detritus by strong flushing from the surface of the gravel filter bed, there still remained much decaying un-cleaned waste materials in the gravel filter bed when examined by removing the gravels.

Special Features in the Present Experiment

The experimental filter system was set up at a corner of a totally closed system fish rearing facility, and a fraction of the effluent water from the fish rearing chambers was pumped into the experimental filter system. The experiment was first carried out in the open air but as the temperature declined down to 20 C the whole system was covered with vinyl film sheet in early October and the water temperature regained upto 25 C in early October, then again it began to gradually decrease and was maintained below 20 C during the second functioning period in December. Another matter should be mentioned is that total ammonia level all through the experimental period was maintained at relatively high concentrations, ranging from 0.6 to 1.0 mg/l, but the fish maintained in the rearing chambers were healthy and kept normal growth. The species reared includes common carp, *Cyprinus carpio*; goldfish, *Carassius auratus*; tilapia hybrid; channel catfish, *Ictalurus punctatus*; and some grass carp, *Ctenopharyngodon idellus*. On the other hand the pH was maintained at 7 or slightly less. Oxygen levels were also very low, the values staying at around 3 mg/l with fluctuations in the influent to the filter and at around 1 to 2 mg/l in the effluent. Though the oxygen levels dropped considerably, they generally ranged well above 0.6~0.7 mg/l, the critical level suggested by Forster (1974) in his study on a marine filter, except for only a few cases which showed 0.6~0.7 mg/l at the effluent. Even so, the oxygen levels inside the filter must have been maintained well above this detrimental level.

Management Recommendations

Through this experiment on the efficiency of the filter materials, filter beds must be periodically cleaned to remove excessive detritus accumulated in the filter system. The data shown in Table 3 show that sometimes the cleaning further decreases the nitrifying capacity, i.e., after the cleaning on November 11 of pile cloth filter, the ammonia removal capacity decreased from 6.797 g/m^3/day (on November 6) to 6.020 g/m^3/day (on November 19). This is considered to have resulted from an over-removal of microflora together with accumulated detritus. In practice it may be rather difficult to determine the proper cleaning extent, but in case of suspended filter media the detritus covering the bottom of filter chamber only should be flushed out trying not to touch any significant amount of microflora attached on the surfaces of filter materials. In case of the gravel filter, the situation becomes a little different. An important amount of detritus accumulates in the interstices of gravels, and the most on the upper surfaces of each gravel. To remove the wastes, a strong flushing through the whole filter bed becomes compulsory. Even doing so, it was found out that the excessive detritus was very hard to remove where the depth of the gravel bed is great. In the present study, though the size of gravels was 5 to 7 *cm* in diameter and the depth of the filter was only 25 *cm*, yet the excessive detritus was quite hard to remove. Even after a cleaning with quite a strong flushing, it appeared that there has been left quite a bit of detritus remaining in the interstices of gravels which certainly contains a large portion of active nitrifying microflora, thus leading to direct recovery of the ammonia removing activity. Instead, the detritus quickly accumulates and the system becomes senile very early, thus shortening the functioning time span. Therefore, when gravels are used as filter medium, rather frequent cleaning should be carried out, but if a big or huge filter unit is required, the use of gravel filter is not recommended, because the removal of excessive detritus becomes extremely difficult especially when the filter needs a deep bed. Not necessarily to mention, if the particle size of the gravel is small the thickness of the filter bed should be smaller in accordance with the decreasing gravel particle size.

Economic Consideration

Though the functioning capacity is the greatest in the pile cloth filter, not only the cost of the cloth is relatively high, but also the installation work is quite time consuming, and especially when large size systems are required the framework must be very sturdy to prevent collaps during draining for cleaning. The capacity of ammonia removal of skylight plate and embossed plate filters is slightly inferior to that of pile cloth, but the materials cost much less and the intallation work is much simpler. The materials are also quite sturdy therefore they can stand well even when the water is drained.

References

Broussard, Jr., M.C. and B.A. Simco. 1976. High density culture of channel catfish in a recirculating system. Progr. Fish-culturist 38(3), 138—141.

Forster, J.R.M. 1974. Studies on nitrification in marine biological filters. Aquaculture 4, 387—397.

Kim, I.B. 1980. Pilot scale fish production in water recycling system. Bull. Korean Fish. Soc. 13(4), 195—206.

Lewis, W.M. and G.L. Buynak. 1976. Evaluation of a revolving plate type biofilter for use in recirculated fish production and holding units. Trans. Am. Fish. Soc. 105(6), 704—708.

Liao, P.B. and R.D. Mayo. 1974. Intensified fish culture combining water reconditioning with polution abatement. Aquaculture 3, 61—85.

Meske, Ch. 1979. Fish culture in a recirculating system with water treatment by activated sludge. In Advances in Aquaculture. ed. by T.V.R. Pillay and Wm. A. Dill. 527—531. Fishing News Books Ltd.

Naegel, L. 1980. Water-reuse system in aquaculture. Animal Res. & Dev. 11, 12—31.

Saeki, A. 1958. Rearing of eels in recirculating aquarium. Aquiculture 6(1), 36—42 (Issued in Japan).

Saeki, 1965. Studies on fish culture in filtered closed circulating aquaria-2. On the carp culture experiments in the systems. Bull. Jap. Soc. Sci. Fish. 31(11), 916—923.

Saeki, A. and H. Aoe. 1963. Rearing (recirculat ing) system for the production of 5 ton carp and a rearing example in the system. Aquiculture 11(4), 217—228 (Issued in Japan).

Saeki, A. and M. Aoe. 1962. Rearing (recirculating) system for the production of 1 ton carp and a rearing example in the system. Aquiculture (Special issue) No. 1, 13-27 (Issued in Japan).

순환 여과식 양식 시설에 이용된 수종의 여과 재료의 효능에 관한 연구

김 인 배 · 김 병 기* · 지 영 옥**
부산수산대학, *해양연구소 생물응용실, **부산시 사하구 괴정3동 432

순환 여과식 양식에 있어서 사육수에 축적되는 암모니아를 여과 재료별로 그 제거 능력을 알아보고, 실제 산업에의 적용에 관한 문제를 검토하였다. 여과 재료는 첨모직(pile cloth), 스카이 라이트 골판(corrugated skylight roofing plate), 요철 플라스틱판(embossed plastic plate), 및 자갈의 4종류를 사용, 90 *cm* × 60 *cm* × 60 *cm*(깊이)의 수조에 각각 2개씩 같은 재료를 넣어서 모두 8개를 설치하였다. 주입수는 부산수산대학 순환여과식 양식 시설의 어류사육 탱크에서 나오는 물을 사용하여 그 속에 함유된 암모니아 제거능력을 측정하였다.

정상적 기능을 발휘하는 두 기간의 여과 재료별 1일 1 m^3의 여과재 설치 용적당 평균 암모니아 제거 능력은 다음과 같았다.

1) 첨모직 8.381 *g*
2) 스카이 라이트 골판 7.834 *g*
3) 요철 플라스틱판 7.797 *g*
4) 자갈 7.051 *g*

이와 같이 주기능 발휘 기간동안에는 재료별 차이가 별로 없었지만 그 기간의 길이 차이, 청소의 난이도, 설치 비용 등을 고려해야 한다. 특히 대형 여과조의 경우, 자갈 여과조를 청소하는 일은 대단히 어렵고, 첨모직 여과조는 그 설치 작업이 까다롭고, 배수시 그 구조를 유지하는 데 어려운 문제가 따른다.

이러한 관점에서 볼 때 스카이 라이트 골판과 요철 플라스틱판이 가장 적당하다고 생각된다. 그러나, 실제 설치시는 재료의 입수 가능성, 가격은 물론, 사용중 또는 계획중의 여과 탱크에의 적합 여부도 고려되어야 한다.