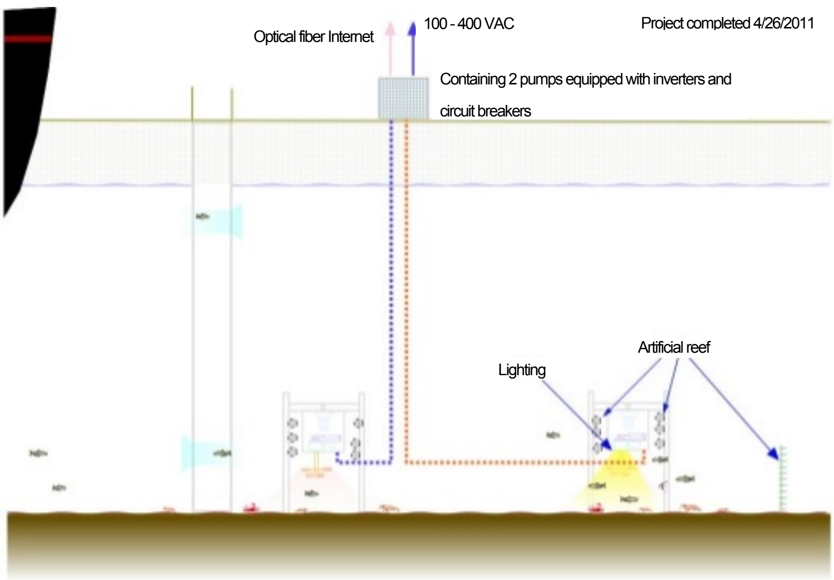
Example of water quality improvement at Hakkeijima Island by introduction of micro nanobubble generator employing ultrafine pores

1. Introduction

Although ultrafine bubbles have come to be used in various fields for some time now, there has not been enough discussion concerning enlarging the scale ultrafine bubble generating equipment and making it more energy efficient. This is particularly an important theme for purification of seas, lakes and rivers. The possibility of employing our unique technologies for enlarging scale of and making such equipment more energy efficient for improving marine environments is now being considered.

We are currently involved in various initiatives to improve the environment of closed bodies of water. We are conducting continuous micro nanobubble generation projects using natural solar energy exclusively (24 hours a day for a period of 3 months) and online seabed monitoring by live camera (maximum depth of 10 meters). These projects have revealed the fact that evaluation of water quality alone does not accurately reflect the actual state of massive quantities of water coming and going through aquatic environments such as marine areas, lakes and marshes. This report concerns the results of a project to improve the aquatic environment of Hakkeijima, in the city of Yokohama, as an example of a closed aquatic environment, using our own microbubble generating equipment primarily affecting benthic organisms.

Fig. 1: Operation of equipment by solar energy (Lake Hyoko, Niigata Prefecture)



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2. Micro nanobubble generator employing ultrafine pores

Our micro nanobubble generator produces bubbles by pushing gas through material perforated with ultrafine pores. The surface of the material features extremely small contact angle, thus enabling microbubbles to be produced efficiently by applying minimal water flow. This enables the generator to gently produce bubbles using a minimal amount of energy. The gas supply pressure required to produce bubbles must be approximately 0.1 Mpa different from the liquid phase; liquid phase relative flow rate of approximately 1 m/sec is sufficient. When compared to other equipment based on electrical power demand in cooperative research with a certain university, whereas the amount of electrical energy required to dissolve the same amount of gas in water for our equipment was approximately 1/200 that of conventional aeration, it was 1/20 for microbubble generators that worked by swirling liquid. Also, in a study based on amount of oxygen added, we obtained data that suggested that our equipment was able to accomplish the same task as other equipment using 1/5 to 1/20 less energy than the other equipment.

Bubble size distribution of microbubbles generated in 100 litre tap water using an all-in-one generator developed for usage at research institutions was measured. As shown in Fig. 3, water in an acrylic tank gradually became cloudy. Bubble particle size at this time was distributed as shown in Fig. 4. Distribution of particle size near Gaussian distribution which consisted of particles approximately 30μm in diameter was observed. When compared with other generators, we found our equipment to be inferior to none. Because water flow is gentle, it offers a significant advantage for cultivation of organisms and so on. The surface area of the ceramic material used was $12.5cm^2$.

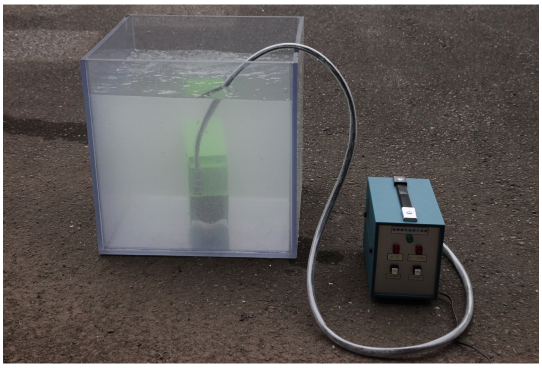


Fig. 3: Microbubble generation

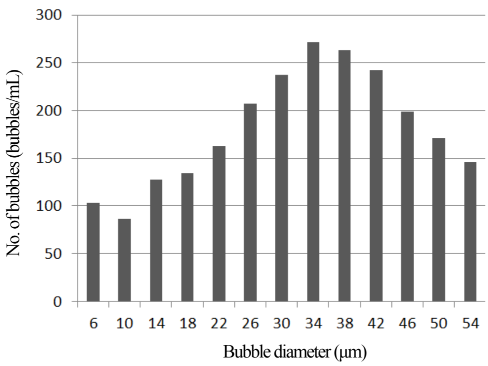
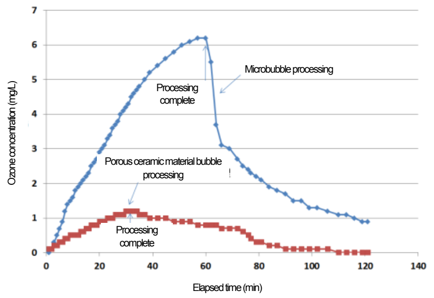
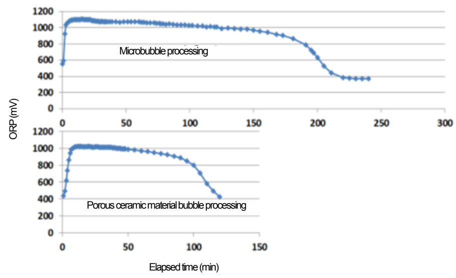


Fig. 4: Particle size distribution of bubbles (measured by the National Institute of Advanced Industrial Science and Technology)

The system by which bubbles are generated of our equipment is made of ceramic material and offers excellent resistance to ozone. Fig. 5 shows an experiment comparing our bubble generation element with one made of porous ceramic material. Fig. 8 shows a comparison of change in ORP as time elapses. The ceramic material used in our equipment was continuously able to offer approximately 3 times higher ozone concentration and close to double the ORP variation than conventional ceramic material under the same start conditions.



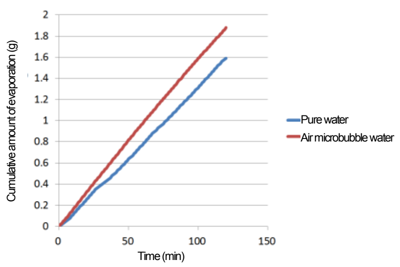
Comparison of ozone concentration elapsed time variation in due to difference in ozone microbubble processing and porous ceramic material bubble processing



Comparison of ORP elapsed time variation due to difference in ozone microbubble processing and porous ceramic material bubble processing

Fig. 7 Fig. 8

Evaporation promoting effect when micro nanobubbles are used is as shown in Fig. 9. Because we can anticipate gasification promotion of approximately 20%, the equipment can be applied to enhance efficiency of cooling tower and desalination of seawater (patent pending).



Comparison of evaporation speed of air microbubble water and pure water

Fig. 9

3. Example of application in Hakkeijima

This section provides a brief description of initiatives to improve the aquatic environment of Hakkeijima Sea Paradise / Central Bay of Yokohama city as an example of application of the device (see Fig. 10).

Hakkeijima Sea Paradise is located slightly west of the center of Tokyo Bay. Tokyo Bay is a marine area that is not entirely sealed off but is similar in many ways to a closed body of water. The environment id highly susceptible to contamination because of the organic materials that flow in and the high nutrient salt concentration. There is notable oxygen deficiency at the bottom layer due to formation of thermocline and decomposition of organic matter in the sediment, particularly in the summer. Although the Hakkeijima marine area rarely becomes deprived of oxygen like deep in the bay, by there appears a wide range of oxygen deficient water whereby dissolved oxygen concentration falls below 2.5mg/L. Appearance of such oxygen deficient water and absence of oxygen at the bottom layer is connected with destruction of the ecosystem, and generates red tide and blue tide, as well as foul oder. Supplying oxygen to the bottom layer of the sea is the most effective way to improve the environment of such closed bodies of water. Simply supplying air by aeration has downsides such as being inefficient and producing a useless ascending current. While microbubbles have attracted attention as an efficient way of suppling oxygen to the bottom layer of such aquatic environments, the method produces a strong current and stirs up sediment, which pose engineering problems. Our system, on the other hand, is capable of generating a massive quantity of micro nanobubbles with a gentle current, and is therefore applicable for improving the environment of the concerned area. It has also become possible to run the equipment with minimal electrical power consumption by machining the material into the shape of a propeller and rotating it gently near the seabed. Fig. 11 shows the setup. Location of the study and the items included in the study are shown in Fig. 12.

The equipment began operating at the beginning of June. The jet direction was changed in the middle of August, and was stopped at the end of August. The population of benthic organisms increased dramatically from June through August, and masses of fish and crustaceans were also visually observed (see Fig. 13).

Studies were conduct in February prior to equipment operation, June, end of July and end of August while the equipment was operating, as well as at the end of September and October. An explosive increase from June to July was confirmed by comparison of populations; the decrease in August is thought to be owing to the facts that the method of spraying bubbles horizontally from a pipe run along the seabed was altered by changing the direction of the nozzles to spray somewhat upward. More than 20 symbionts such as gobies and snapping shrimp were confirmed in 30 × 40 cm of water in the area in the middle of August.

Daring to alter the bubble jet direction upward to establish an efficient nanobubble atomization method resulted in a slight decrease in organisms at point NB. (* Because there was no accurate data in the middle of August, a clear decrease was confirmed at point A.) Horizontal diffusion of nanobubbles was confirmed necessary for wide-area purification (see Fig. 14).

(For details, visit our website at http://anzaimcs.com/)

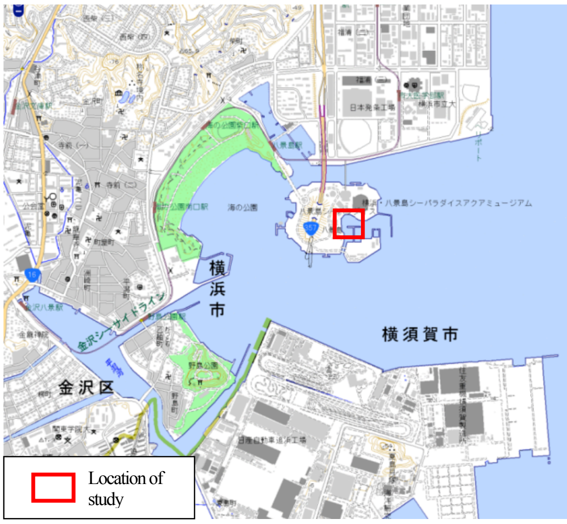


Fig. 10: Sea where study was conducted (Hakkeijima Sea Paradise, Yokohama city)

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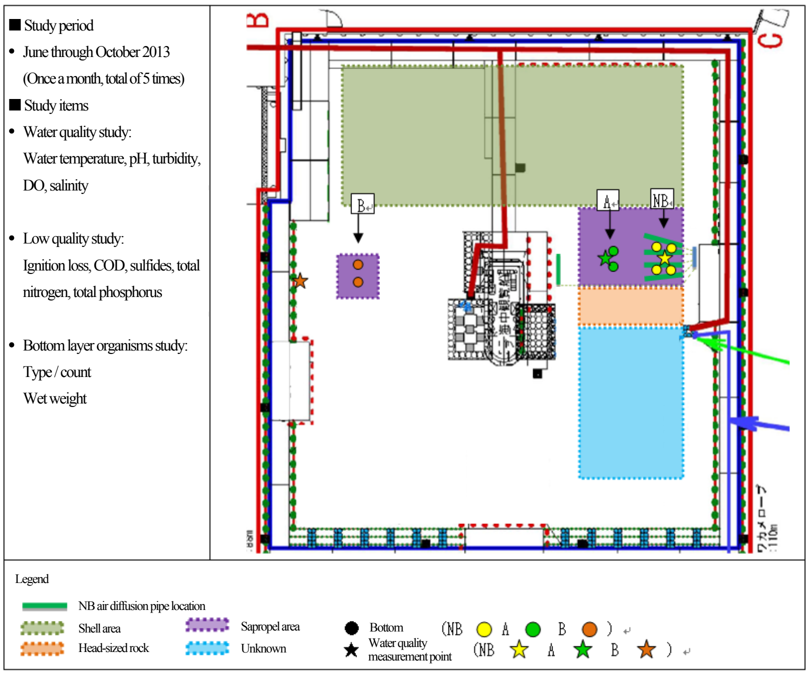

Fig. 12: Setup details and study items

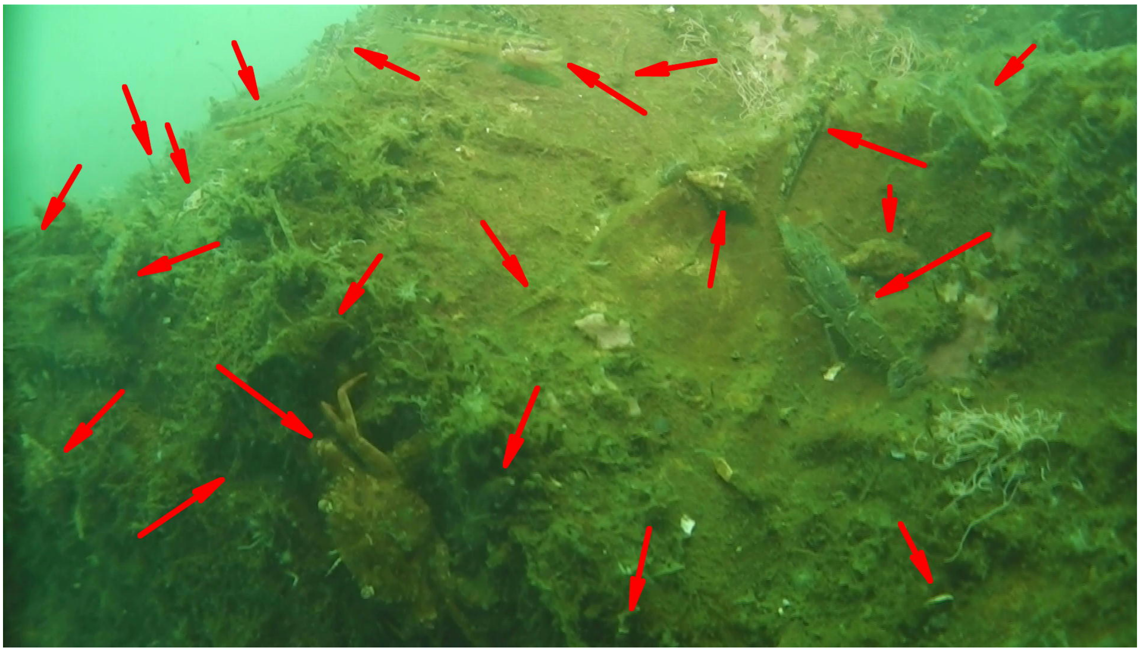

Fig. 13: Seabed condition at point NB at the middle of August (arrows indicate organisms such as fish and crabs)

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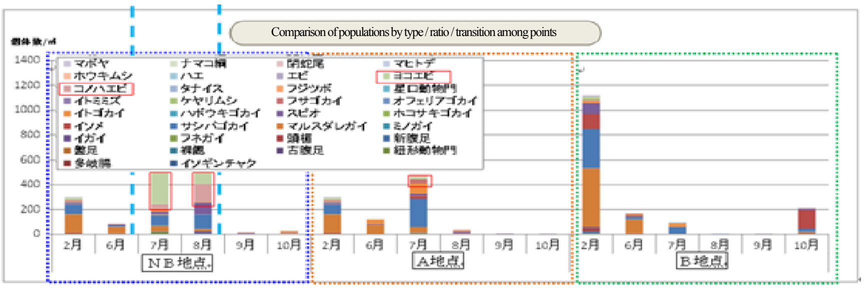

Note 1) Graph of various points by month shows average of number of samples taken.
Note 2) Number of species and number of individuals per 1m2 is at each point is converted to this figure.

Fig. 14: Transition in populations of benthic organisms

No.	門	綱	目	科	学 名	和 名	A-1		A-2		B-1		B-2		Nb-1		Nb-2		Nb-3		Nb-4	
							個体数	湿重量	個体数	湿重量	個体数	湿重量	個体数	湿重量	個体数	湿重量	個体数	湿重量	個体数	湿重量	個体数	湿重量
1	刺胞動物	花虫	イソギンチャク	−	Actiniaria	イソギンチャク目											6	0.13				
2	扁形動物	渦虫	多岐腸	−	Polycladida	多岐腸目															1	+
3	軟体動物	二枚貝	イガイ	イガイ	*Musculista senhousia*	ホトトギスガイ									1	0.02	1	+	1	+	3	0.02
4			マルスダレガイ	ツキガイ	Lucinidae	ツキガイ科			1	0.05												
5				ニッコウガイ	*Macoma incongrua*	ヒメシラトリガイ									1	0.97					1	0.59
6					*Nitidotellina nitidula*	サクラガイ											1	0.06				
7				イワホリガイ	*Petricola sp. cf. lithophaga*	ウスカラシオツガイ											4	0.02			1	+
8	環形動物	ゴカイ	サシバゴカイ	サシバゴカイ	Phyllodocidae	サシバゴカイ科															1	+
9				チロリ	*Glycera* sp.														1	0.10		
10				オトヒメゴカイ	Hesionidae	オトヒメゴカイ科									1	+	1	+				
11				カギゴカイ	*Sigambra* sp.				1	+	1	+			17	0.07			1	+		
12				ゴカイ	*Neanthes caudata*	ヒメゴカイ													1	0.02	1	+
13					*Neanthes succinea*	アシナガゴカイ											1	+				
14					*Nectoneanthes latipoda*	オウギゴカイ											2	0.14			8	0.87
15					*Nectoneanthes* sp.										8	0.03	9	0.07	4	0.01		
16			イソメ	コイソメ	*Schistomeringos rudolphi*	ルドルフイソメ			1	+												
17			スピオ	スピオ	*Aonides oxycephala*	ケンサキスピオ															1	+
18					*Paraprionospio patiens*	シノブハネエラスピオ											1	+			9	0.08
19					*Polydora* sp.														1	+		
20					*Prionospio pulchra*	イトエラスピオ	2	+	1	+					23	0.01			9	+	3	+
21				ツバサゴカイ	*Spiochaetopterus* sp.																1	0.05
22			イトゴカイ	イトゴカイ	*Capitella* sp.		2	+							2	+	1	+				
23	節足動物	軟甲	コノハエビ	コノハエビ	*Nebalia* sp.		1	+									1	+	53	0.22	13	0.03
24			ヨコエビ	ユンボソコエビ	*Aoroides* sp.										1	+	1	+				
25					*Grandidierella japonica*	ニッポンドロソコエビ									2	+	20	0.05	6	0.01	14	0.03
26	棘皮動物	ヒトデ	マヒトデ	マヒトデ	*Asterias amurensis*	マヒトデ													1	1.94		
						合 計	5	0.00	4	0.05	1	+	0	0.00	56	1.10	49	0.47	78	2.30	57	1.67
						種 類 数	3		4		1		0		9		13		10		13	

注）湿重量欄の"+"は、湿重量が0.01g未満であることを示す。

Fig. 15: Population of benthic organisms in August

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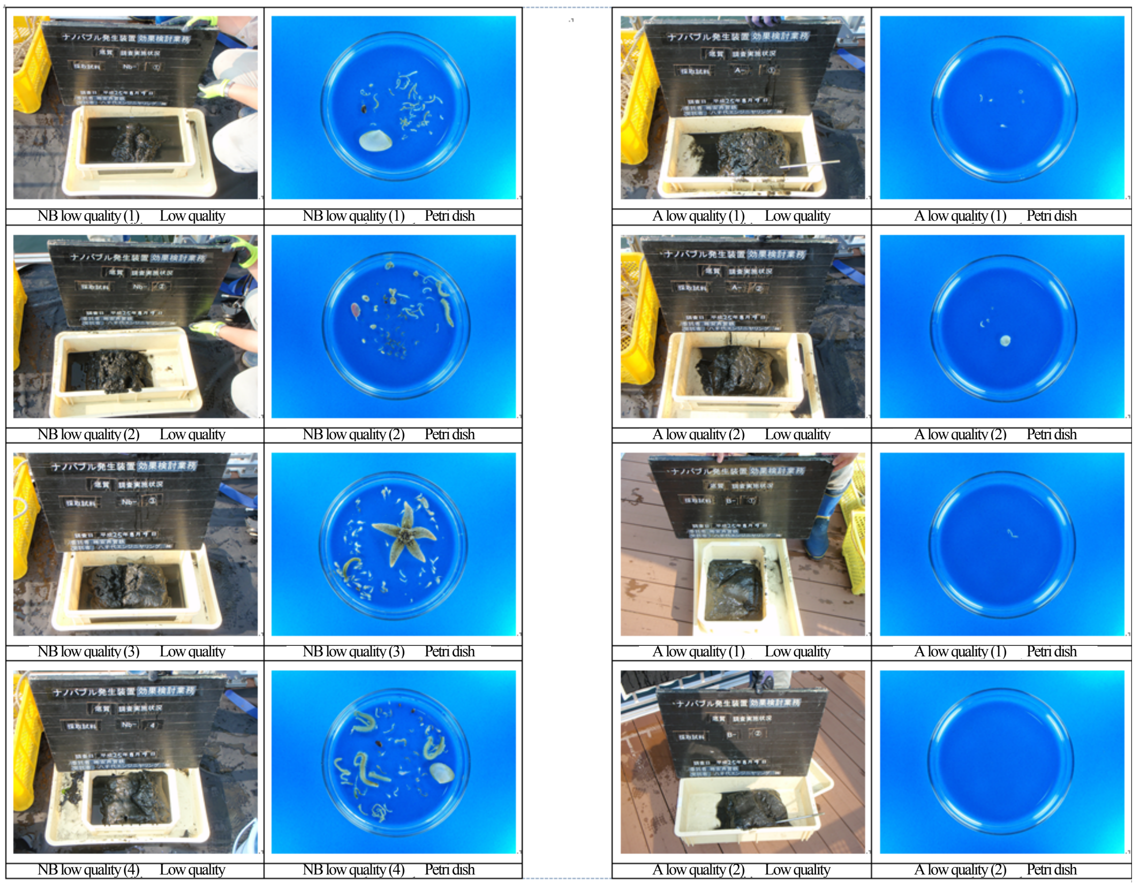

Fig. 16: Photograph of benthic organisms （スペースと照らし合わせて代表図を選定）

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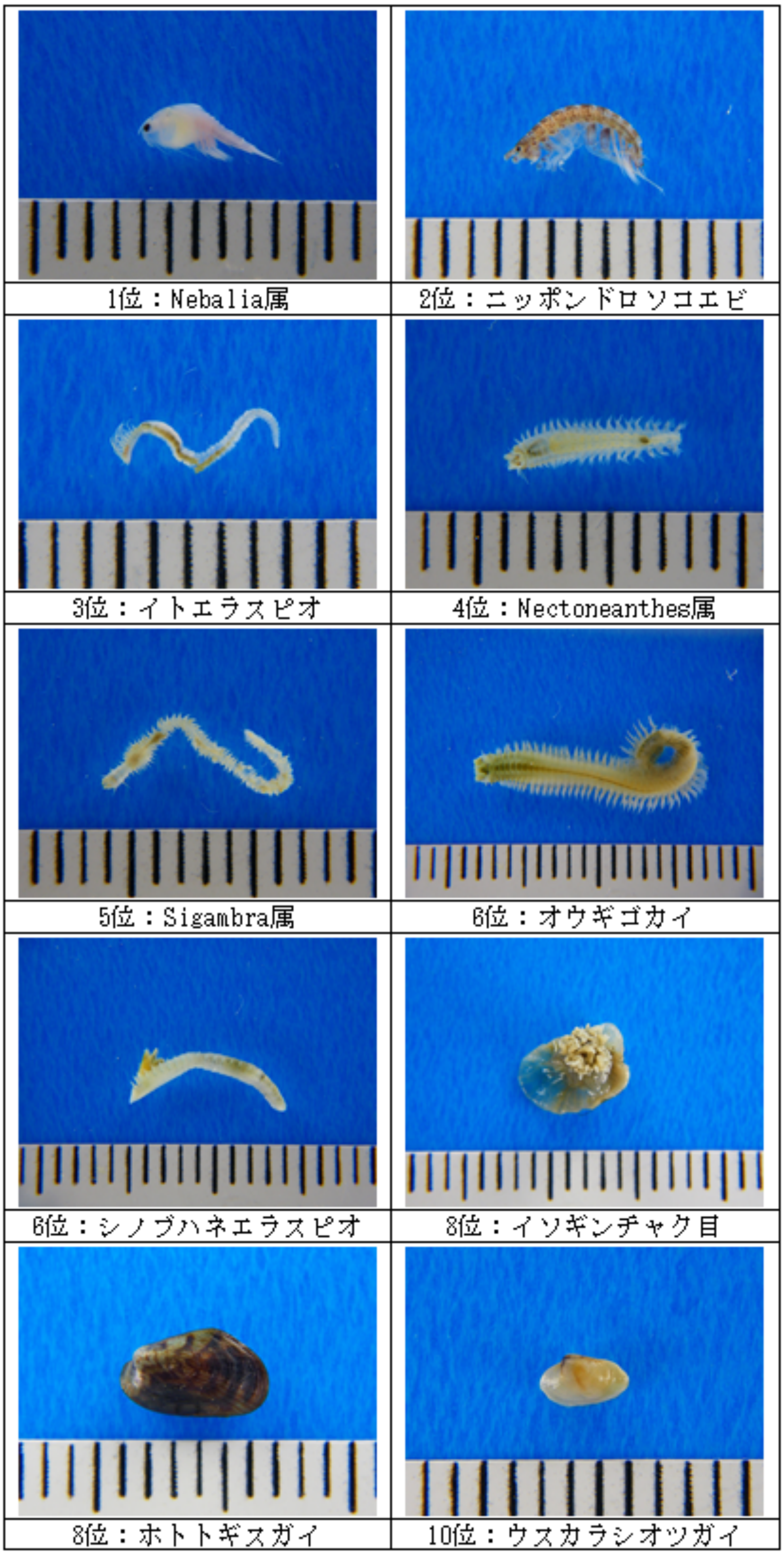

Fig. 17: Photograph of benthic organisms （スペースと照らし合わせて代表図を選択　もしくは16か１７のいずれかをカット）

4. Conclusion

Although many ways to use micro nanobubbles have been proposed, we would like to take advantage of our experience in fields required for "widening the range of liquids that can be used even if contaminated, facilitating the expansion of scale, and consuming minimal energy for achieving objectives" that this product excels in. Purification of seawater is a matter of urgency for densely populated areas around the world. Purification of seawater and treatment of wastewater use a similar process. Our nanobubble generation method holds great promise for these fields. In the proving test conducted at Hakkeijima, a striking difference was observed between the NB introduction point and control point (point B). As sludge (organic compost) continues to accumulate, Tokyo Bay has become an environment where organisms cannot survive; through use of micro nanobubbles from June through October, living creatures began to thrive among the masses of organic sediment.

We have already applied for a number of patents for our products, which are overwhelmingly superior to those of the competition in terms of many aspects such as energy required to operate. We aim for realization of a sustainable global society where people can coexist and prosper, and hope to develop new technologies in cooperation with many other technicians and researchers.

References

Dr. Katsuhiko Nakamuro, Setsunan University, Department of Life Science, Faculty of Science and Engineering: "What are Microbubbles?" (2012)

Yachiyo Engineering Co., Ltd.: Review Report on Effect of Nanobubble Generator (2013).

Latest NTS of Ultrafine Bubbles (2006)

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