WITH FINE BUBBLE **400L/min OK Nozzle**

CHILE・STRAIT OF MAGELLAN SEABED PURIFICATION EXPERIMENT

---Strait of Magellan Seabed Pollution Purification Project--- 20.8.2020

Summary: **OK Engineering Co., Ltd.** **https://oK nozzle.com/**
CEO. Takeshi Matsunaga
Experiment: **Kran, Chile**
Jaime de la Cruz, CEO **https://kran-nanobubble.com/**
Enrique Perez, Director of Development
Mauricio Bueno, Head of Aquaculture

1. INTRODUCTION

As part of the Strait of Magellan sea purification experiment, Kran (https://kran-nanobubble.com/) is currently conducting a seabed purification project at the Strait of Magellan. The result has been great. In this experiment, they are injecting nanobubbles (ultra fine bubble - ufb) at the seabed using 400L/min OK Nozzle.

As for the purpose of the purification experiment, Jaime de la Cruz, CEO of Kran, indicated that: “There is salmon farming activity at Strait of Magellan. Some effect of this activity is that fish feed and organic compounds accumulate at the bottom of the sea, which in time generate an anoxic surface. After the salmon is harvested, in order to start a new production cycle, the farming site needs to obtain an environmental permit from Chile’s authorities. The conditions include, among others, a minimum level of dissolved oxygen in the sea water and the absence of specific bacteria that is considered to be part of an anoxic environment.

Environmental regulations are getting tougher every year around the world, and Chile is no exception to this trend. Kran’s project intends to help salmon farmers give back to the environment what has been taken from it, so as to allow to recreate conditions for life to reclaim these seabeds, and farming activity to resume. The long-term goal is to be able to prevent the damage, by injecting nanobubbles (ufb) throughout the farming life cycle, and thus prevent the formation of the anoxic layer at the seabed.”

All over the world, fish farming is held at the bay of the sea, and they have similar problems to Chile’s one to a greater or a lesser degree. I think the experiment results made by Kran will spread all over the world.

Here, I will summarize the contents of exchanged emails with Jaime about the experiment Kran is conducting. I will also make some proposals myself about the purification method of the seabed of 300 depth.

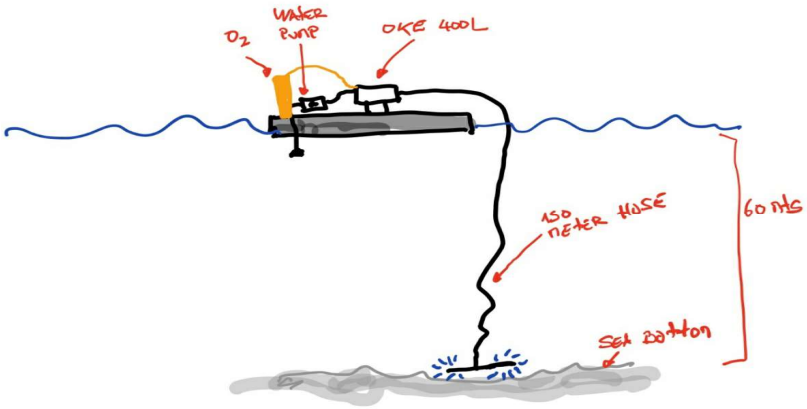

2. SEABED PURIFICATION EXPERIMENT

(1) EXPERIMENT CONDITION

Current experiment condition is below.

① At the entrance of the nozzle, the water pressure is 6 bar (0.6Mpa)
② At the exit of the nozzle, the water pressure is 4.5 bar (0.45MPa)
③ In order to make fine bubbles reach the seabed, the nozzle is connected to 150m hose
④ Oxygen supply amount is 6L/min
⑤ Pipe diameter is 2 inches

(2) OUTLINE OF FB GENERATION APPARATUS



(3) ANSWER FOR QUESTION

"We have been developing a solution to remediate the seabed of the Strait of Magellan at the very south of Chile since two years ago. We need to purify the seabed so that it will be possible to produce salmon again in this area after the salmon is harvested. As we need to operate fine bubbles at the depth of 100m, we apply 6 bar(0.6MPa) pressure to 400L/min OK Nozzle and then the flow rate increases to approx. 520L/min. I would like to ask you if this is ok and what kind of effect would happen. Also, we would like to understand more about how it affects the nanobubbles generating process.
Thank you for attaching information about the freshwater clam in Shinji Lake."
(Document attached as an appendix)

Q 1 When 400L/min nozzle is used for this experiment, the flow rate becomes approx. 520L/min but does it have effect on generating nanobubbles?

A 1 There is no problem. It is natural the flow rate becomes 520L/min as you applied 6 bar (0.6MPa) water pressure to OK Nozzle. I presume the result would be good for generating fine bubbles.

Q 2 What is the ratio of microbubbles (MB) and nanobubbles (NB) and do they change significantly with the 400L/min flow rate?

A 2 I do not know exactly but I think the number of generated bubbles per unit volume will not change much. The reason is that even though you applied 6 bar (0.6MPa) water pressure to 400L/min OK Nozzle, the discharge rate of the OK Nozzle was as low as 520L/min because of the backpressure and the resistance inside the tube and so on.

As the discharge increased approx.120L/min by applying high pressure, fine bubbles (FB) amount increases approx. 30%.

Microbubble (MB) is defined to be over 1μm bubble diameter by ISO. When there is 0.6MPa water pressure, microbubbles under 5μm become nanobubbles. Therefore, there will be more nanobubbles (UFB)to that extent I presume.

As the water pressure is approx.0.6MPa at the seabed of 60m depth, and also as the water pressure inside the pipe leading to the seabed is over 0.4MPa, there would be more dissolved oxygen although it does depend on the oxygen supply amount. This is the principle of pressurization dissolution.

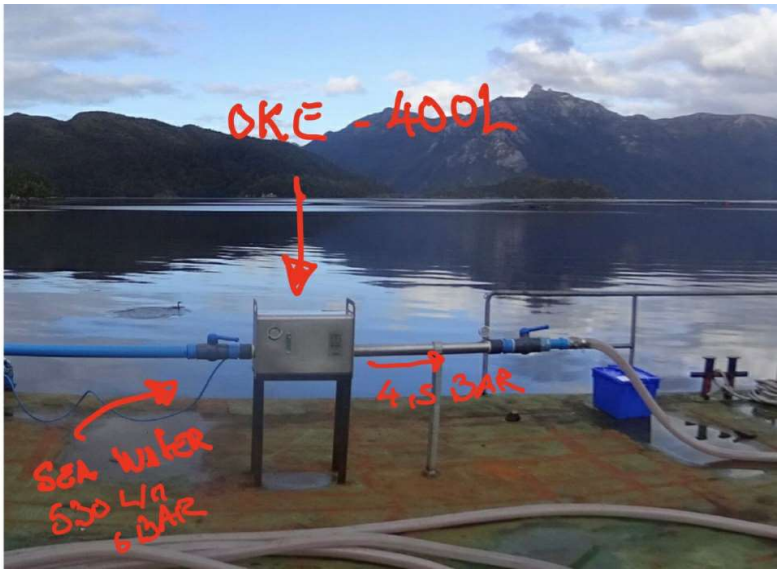
It is presumable from the example of flatfish farm in Jeju Island that the DO level becomes higher. In the present situation, you mentioned DO level has become 330% by supplying 6L/min oxygen to OK Nozzle. If you supply 10L/min oxygen to the nozzle, DO level will go up to nearly 400%. The water pressure of 60m seabed is approx. 0.6MPa, so approx. 600% DO level will be the saturation. To stabilize nanobubbles for a long time, I presume it will be better to make DO value close to the oxygen saturated state at the seabed.

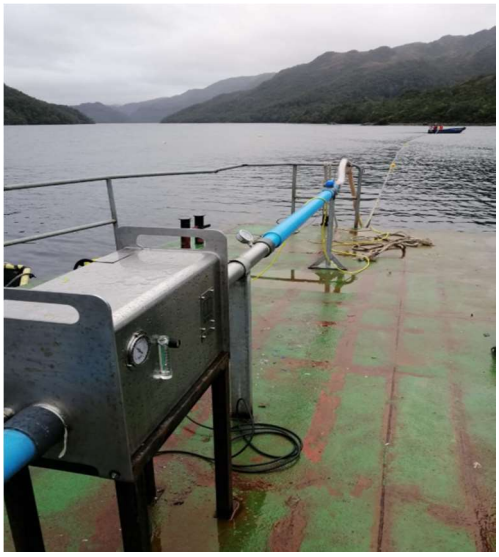
Therefore, I recommend that you increase the oxygen supply to 10-15L/min and let DO level be 400-500%.

Please try some experiments with this condition.

3. PHOTO OF EXPERIMENTAL LANDSCAPE

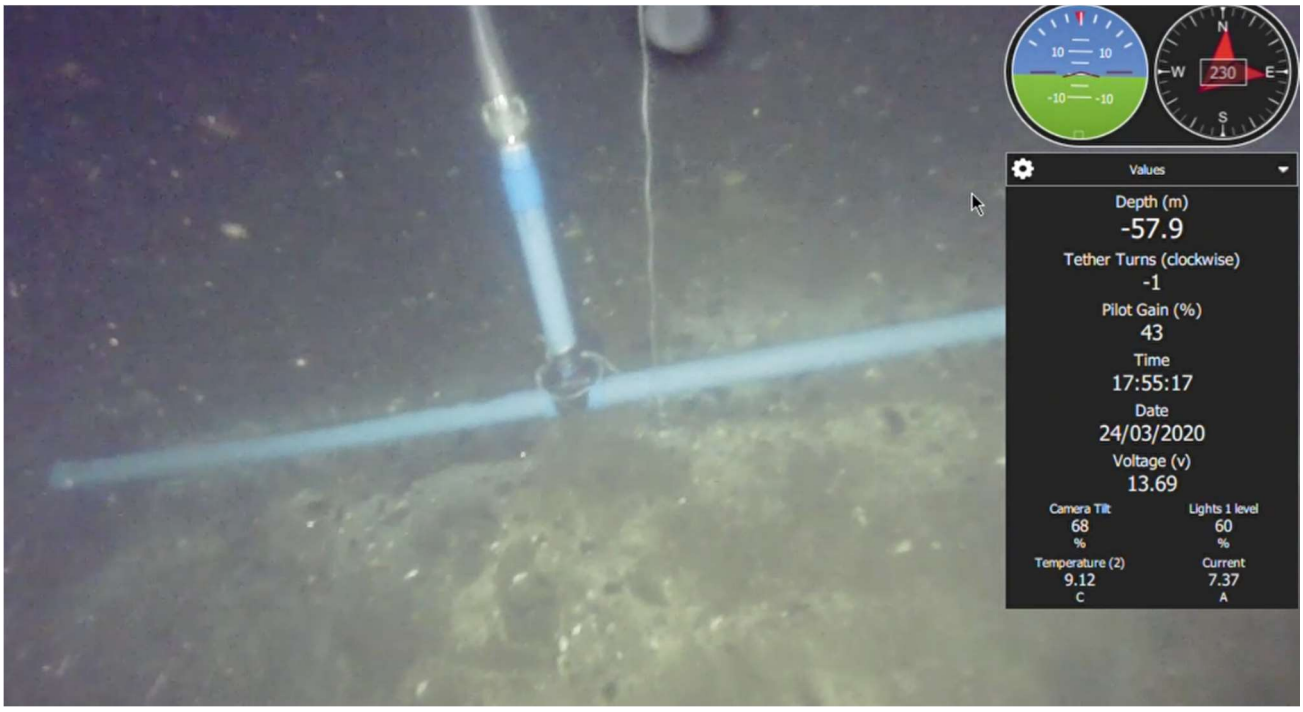
CHILE: BAY OF THE STRAIT OF MAGELLAN





KRAN FB GENARATION APPARATUS WITH OK NOZZLE

INSIDE THE SEA



JETTING OXYGEN FINEBUBBLE FROM T-SHAPED JET NOZZLE AT SEABED
taken by a ROV (remote operated vehicle).

4. ABOUT EXPERIMENT RESULT

(1) Oxygenation of the seawater at the seabed as the main purpose of the experiment is resulting in good status. By supplying 6L/min oxygen to 400L/min OK Nozzle and jetting oxygen fine bubble water from T-shaped jet nozzle at the seabed, DO level of the vicinity of the seabed became 300%.

(2) Seabed accumulation which is the source of the pollution became extremely less and it has been gradually purified. The result has been good. There has not been for the analysis result of the noxious bacteria and algae yet.

(3) The experiment has been decided to be continued with additional two 500L/min OK Nozzles. (Shipped two 500L/min OK Nozzles to Chile on 11.8.20)
Furthermore, to purify the seabed of 300m depth, we are planning to introduce 2000L/min OK Nozzle with 30 bar(3.0MPa) pressure resistant.

5. DISCUSSION

(1) It became clear that the countermeasure for poor oxygenation is achieved through increasing DO level highly effectively by supplying oxygen to OK Nozzle and jetting oxygen fine bubble water to the seabed.
Supplied oxygen is mostly dissolved and the remain is considered as fine bubbles. As for the example of flatfish farming in Jeju Island, it is known that DO level increases in proportion to the amount of oxygen supplied in OK Nozzle.

When you dissolve oxygen into sea water under an atmospheric pressure, the maximum DO level will be around 450%. This kind of data was also measured in Kran's oxygen dissolve experiment under an atmospheric pressure. They had sent me an email: "As per the results from our experience, this was unfortunately not the case. When we increased from 6 L/min O2 (330%, 34.5 mg/L) to 12 L/min O2, DO increased to 430%, 44 mg/L, which leads to assume that the oxygenation process is non-linear."

Certainly, their point may be correct when under an atmospheric pressure but this experiment is about the seabed of 60m depth and the water pressure at the seabed is approx. 6bar (0.6MPa). Under the 0.6MPa water pressure, the maximum of DO level becomes higher than when it is under the atmospheric pressure.

In this experiment, DO level has become 330% by supplying 6L/min oxygen to OK Nozzle, so I presume DO level becomes higher than 400% by supplying 10L/min oxygen.
Because the water pressure at the seabed of 60m depth is approx. 0.6MPa, I presume approx. 600% DO level will be the saturation on the basis of Henry's law: "the amount of dissolved gas in a liquid is proportional to its partial pressure above the liquid". It is considered it will be better to make the sea water around the seabed close to the oxygen saturation state in order

to extend the life expectancy of ultra-fine-bubbles (UFB). Therefore, if you increase oxygen supply to 10-15L/min and make DO level around 400-600%, purification treatment capacity of the seabed pollution will be greatly enhanced. It is worth conducting the experiment with this amount of oxygen supply. Please measure the DO level of the sea water actually spouting in the seabed of 60m depth. What is the maximum % of the DO meter Kran uses? The measurement experiment over 500% DO level can be conducted in an atmospheric pressure too. It can be done by applying high back pressure to the discharge side of OK Nozzle. Please give it a try.
It is possible to conduct the measurement experiment over 500% DO level in an atmospheric pressure too. It can be carried out by applying a high back pressure to the discharge side of OK Nozzle. Please give it a try.

When the seabed pollution treatment is almost finished, you need to monitor the oxygen supply amount. The reason for this is when the DO level of the seabed is too high, it is possible that the seabed ecosystem would be modified comparing to natural levels. It is necessary to give attention to this.

(2) As the apparatus takes-in the sea water near the sea surface, it is considered the aerobic bacteria near the sea surface is treating the pollutant at the seabed. It can be imagined the treatment capacity is increasing as ultra-fine-bubbles are activating the bacteria and letting them grow. Also, possibly the growth of the aerobic bacteria is exterminating the harmful bacteria. It is also possible that the oxygen fine bubbles are oxidizing and sterilizing them.

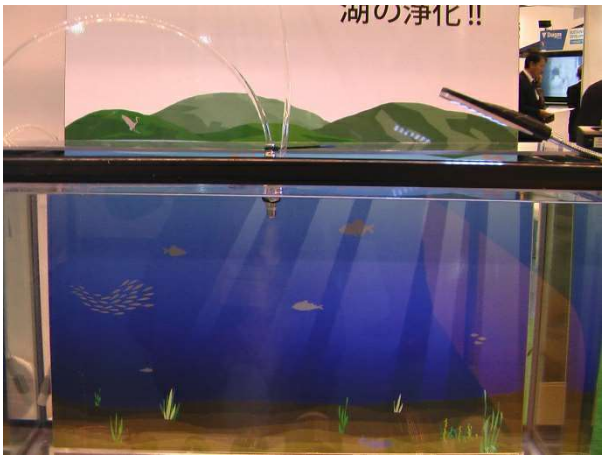
(3) By applying fine bubbles to the sea water even during salmon farming to purify not only the seabed but also the whole farm, it is presumed it will result in producing better quality salmon as the chemical use decreases to a great extent accordingly.

(4) Kran's team is the very first to conduct salmon farm seabed purification using fine bubbles. The success of this project will spread all over the world.
This project will not only supply good quality salmon but also will let the sea recover from the pollution and preserve beautiful and safe sea.
This is the spirit of SDGs itself which United Nations (UN) has been advocating.

6. PROPOSAL FOR 300m DEPTH SEABED PURIFICATION METHOD

(1) FINE-BUBBLES SPREAD ALONG THE BOTTOM

I have been thinking continuously over purification method of deep sea and lakes, especially oxygenation method of Biwako Lake.
One time, I came up with an idea of easy method of the lake bottom purification. The hint was in the small-sized OK Nozzle performance testing which was held on a daily basis.



When testing the performance of small-sized OK Nozzle under 1L/min, water flow is generated towards the bottom as we inject fine bubbles vertically to the bottom of the tank from the water surface. In the daily testing, I have been witnessing that the fine bubbles descend along with the flow and when they reach the bottom they spread along the bottom surface. Also, I have known that visible but small-diameter microbubbles are carried along with the water flow.
I noticed that this phenomenon would be the simplest method for poor oxygen countermeasure of lake bottom.
I named it “Vertical Convection Purification method”.

(2) EXHIBITING “VERTICAL CONVECTION PURIFICATION METHOD”

When I heard from Kran about the depth of 300m seabed purification of the Strait of Magellan, I was convinced the vertical convention method mentioned above could be applied realistically for purification method of deep seabed.
In Oct.2019, we exhibited it at “Biwako Environmental Business Exhibition (Enviro-Shiga)”. We exhibited the “Vertical Convection Purification method” visually.

*Later, we had an email from Kran as follows:
“This 300m depth is actually from another project in the Puyuhuapi Fjord, at the Strait of Magellan the depth we are working with is 100m.”

(3) ABOUT 300M DEPTH SEA BOTTOM PURIFICATION METHOD

There are two methods to purify deep seabed. One is “T-shaped Jet Nozzle Method” applied for the 60m seabed purification, and the other is the new proposal “Vertical Convection Purification Method”. There are no clear criteria for which method to choose. As criteria for determination, those would be the depth of the seabed, condition of the geographical feature of the seabed and the flow of the current, among others.

(1) METHOD 1 T-SHAPED JET NOZZLE METHOD (SHINJI-LAKE METHOD)

There is a method to jet fine bubbles at the seabed using T-shaped jet nozzle. However, when it comes to the depth of 300m seabed, there will be some difficult issues.

< ADVANTAGES >
- For seabed of about 50m depth, treatment speed is fast as the seabed can be cultivated by jet injection of T-shaped jet nozzle.
- Purified place can be clearly identified.
- Possible to purify at a pin point.

< DISADVANTAGES >
- When it comes to the depth of 300m, operability of T-shaped jet nozzle becomes inconvenient.
- Stable design for fixed T-shaped jet nozzle is required.
- 30 bar (3MPa) pump and 3MPa pressure resistant OK Nozzle are required.
- The hose will be the length of 400m.

(2) METHOD 2 "VERTICAL CONVECTION PURIFICATION METHOD"

The principle of this method is described above.
It is presumed the position to sink the jet orifice can be around 1/3 of the depth of the sea. The reason is the pressure loss of the OK Nozzle itself is so small as around 0.01-0.02MPa that the discharge pressure of the sea water will be almost kept, and strong downward convection will be generated.

< ADVANTAGES >
- The length of the hose to sink inside the sea can be as short as approx. 100m and the operability is simple.
  For the hose end, just install jet orifice which will also prevent the hose from swinging.
  When there is a sea current, you only need to consider the flow.
- Fine bubbles spread widely at the seabed and purify the water extensively.
- No need for the fine bubble generation nozzle resistant to 30 bar (3.0MPa) pressure.
- Pump with about 13 bar (1.3MPa) water pressure is fine.

7. PROPOSAL OF BYPASS CIRCUIT METHOD

(1) EFFECTIVE USE OF OK NOZZLE WITH OXYGEN AND BYPASS CIRCUIT

When supplying oxygen to OK Nozzle, there will be a great effect if you install bypass incorporated

with OK Nozzle in addition to the main pipe.
The photo on the right shows 300L/min OK nozzle incorporated to the bypass circuit for sandy bottom flatfish farm in Jeju Island.
100% DO level sea water is supplied to ten culture ponds 80m ahead.
Oxygen supply amount is approx. 10L/min.
If you increase the supply amount, DO level increases in proportion and it is effective for sea water.

(2) SECURE 20000L/MIN of DO 100% SEA WATER using 500L/MIN OK NOZZLE

With sea water, DO level can increase up to nearly 500% by supplying oxygen using independent circuit for OK Nozzle. Therefore, if you want 100% DO level water, you can secure four or five times more water discharge using bypass circuit incorporated with OK Nozzle even if it is a small-sized nozzle. The condition also is that there should be moderate back pressure to the OK Nozzle installed tothe bypass circuit at the middle of the pipe.
For example, if you use 500L/min OK Nozzle and if you let 1500L/min sea water flow in the main pipe, you can secure 20000L/min 100% DO level sea water. Of course, the oxygen supply amount needs to be as large as being capable of making the oxygen amount of 500L/min into 400%.

---Concluded---

APPENDIX

①Shinji Lake Freshwater Clam Culture

WITH FINE BUBBLE Using 100L/min and 500L/min OK Nozzle

LAKE BOTTOM PURIFICATION AT SHINJI LAKE

[APPLICATION EXAMPLE ③]

REPORT FROM FRESHWATER CLAM MEASURE AT SHINJI LAKE

in Shimane Prefecture

① **In July 2012, 100L OK Nozzle was installed.**
② **About after a year, the freshwater clam catch was increased.**
③ **In August 2014, Shinji Lake fishermen's cooperative installed 500L OK Nozzle.**

(1) MOUTH OF HIIKAWA RIVER & FRESHWATER CLAM BOAT MOORAGE

Good quality iron sand is collected at the headstream of this river. The sand after collecting iron sand is used for the freshwater clam measure.

(2) FRESHWATER CLAM MEASURE RESULTING SUCCESSFULLY by Collaboration of Fine Bubbles and Jet Injection

① **Sprinkle the sand to the lake bottom after the iron sand is collected as the freshwater clam measure.**
② **Cultivate the lake bottom with jet water using the injection device in the photo below.**
③ **During the spawning season of freshwater clam, keep salinity concentration steady by stirring up the water with fire pump.**
④ **In July 2012, Mr. Hara installs 100L OK Nozzle.**
⑤ **Cultivate the lake bottom by jetting fine bubbles using the injection device in the photo below for two hours each day, rotating with the fishermen companions after the fishing.**
⑥ **As a result, gradually freshwater clam increased.**

< Why is this Result Produced? >
It is considered the collaboration of fine-bubbles and injection device worked effectively.

(3) LAKE BOTTOM AGITATION INJECTION APPARATUS -- LARGE SIZE In August 2015, Installed 500L/min OK Nozzle

① **Since there was an effective result using 100L/min OK Nozzle, this time Shinji Lake fishermen's cooperative purchased 500L/min Nozzle.**

② **We went to observe the first trial operation also for collecting some data. It turned out the discharge amount from the injection device was too small for 500L/min OK Nozzle. We suggested them to make the injection port thicker.**

(4) WITH 500L/min OK NOZZLE

●Using Fire Pump, Supply Pressured Water to OK Nozzle

Mouth of Hiikawa River

FIRE PUMP

Jet-Nozzle

Used 500L/min OK nozzle

Fire pump