OXYGENATION OF LAKES WITH PACIFIC NANOBUBBLE SYSTEMS

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ENVIRONMENTAL ISSUES IN LAKES

Lakes with high trophic level index are affected by severe cyanobacteria blooms because of seasonal stratification of the lake and by their anatomical and physiological attributes.

Seasonal algae bloom in such lakes are mainly caused by –

1) Nutrient release from sediments at the bottom of the lake under hypoxic/anoxic conditions.

2) Ongoing sediment and nutrient loading – from high rate of soil erosion, run off from farms and urban areas, aerial topdressing, effluent discharge from factories etc.

3) Lake topography and stratification due to elevated temperatures in the summer

Anoxia of the hypolimnion occurs when the microorganisms use the dissolved oxygen to biodegrade the algae biomass that has sunk to the bottom of the lake. Thermal stratification prevents addition of oxygen in the oxygen depleted hypolimnion. An anoxic hypolimnion results in the reduction of oxidized compounds, and the subsequent release of soluble reactive phosphorus from the sediment, in to the hypolimnion.

Longer periods of anoxia result in more significant deterioration of water quality as soluble reactive phosphorus continue to diffuse out of the sediment and enter the hypolimnion.

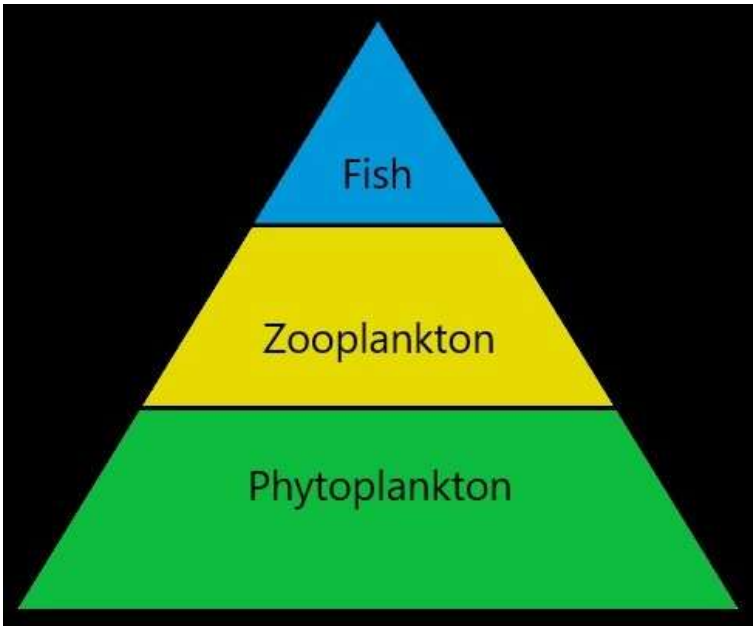
Phosphorus and nitrogen enhance the growth of phytoplankton, breaking the balance with zooplankton.

The resolution of this problem is by RESTORATION and PREVENTION –

RESTORATION – Supplying sufficient oxygen for growth of Zooplankton and other aquatic organisms that feed on the phytoplankton (algae) without disturbing the “natural” Lake environment.

PREVENTION – Maintaining oxic conditions at the hypolimnion prevents nutrient release from the sediments.

Resolution of Environmental Pollution - RESTORATION



Balanced Biological Pyramid

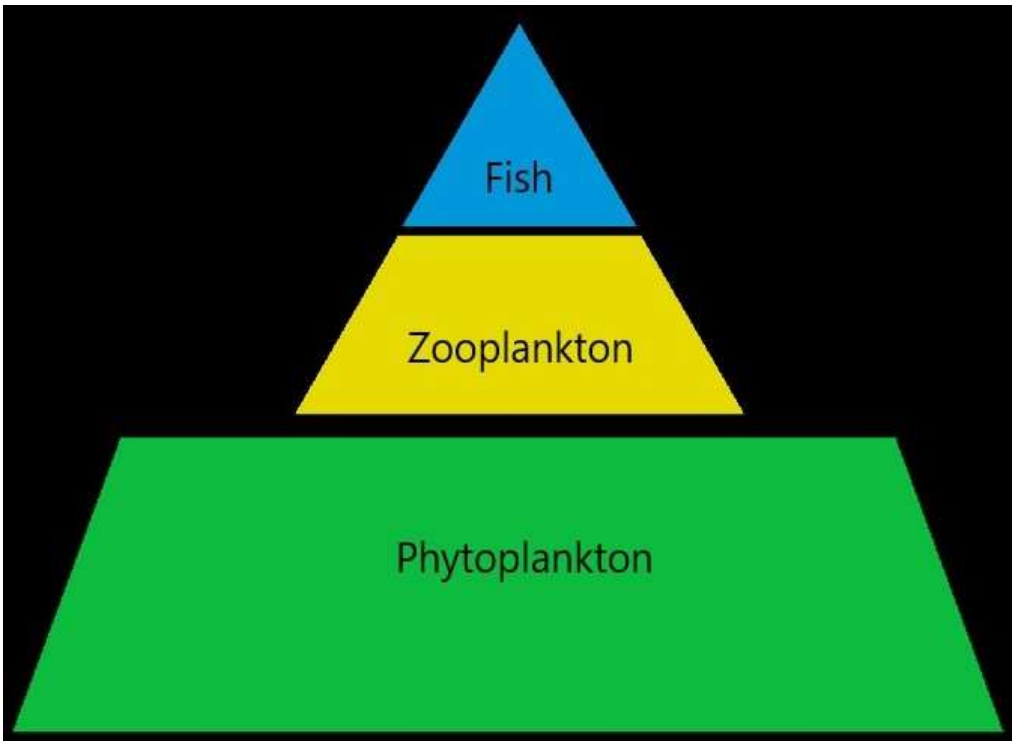
Excess nutrient salt deposits are absorbed most efficiently by Phytoplankton which quickly spreads, further reducing the oxygen supply to the water, needed by Zooplankton.

This results in an imbalance to the Biological Pyramid (below).

One of the effective way of removing nutrient salt, is to increase the number of Zooplankton that feed on the Phytoplankton.

More Zooplankton leads to an increase in the number of fish which eat it.

Fishing removes fish from the lake which completes the purification of water cycle.



Imbalanced Biological pyramid during algae bloom

How to increase the number of aquatic animals?

Increasing the number of fish, shell fish, crustaceans and birds in wildlife, requires vast amount of Zooplankton. There are plenty of Phytoplankton which become the food of Zooplankton.

Zooplankton becomes revitalised, by supplying plenty of Oxygen.

How do we deliver enough Oxygen to reach the Zooplankton at the bottom of the lake?

One of the most cost-effective and practical solutions is Nanobubble technology. Nanobubbles are nano-sized bubbles that remain in the water for a long time.

They deliver Oxygen effectively to the bottom of the lake. The increase in the number of Zooplankton leads to the growth of more invertebrates and results in the increase in the number of water animals.

ZOOPLANKTON INCREASE

OXYGEN NANOBUBBLES

CRUSTACEAN INCREASE

FISH INCREASE

FISH REMOVED BY FISHING

Resolution of Environmental Pollution – PREVENTION

Maintaining oxic conditions at the Hypolimnion prevents nutrient release from sediments.

There are three traditional ways to solve hypolimnetic anoxia –

1) Artificial Destratification

Compressed air is injected through perforated pipes or diffusers that are located at the bottom of the lake.

Rising air bubbles produces vertical mixing, thereby breaking stratification. It also increases bottom DO by redistributing photosynthetically produced oxygen from surface to bottom water.

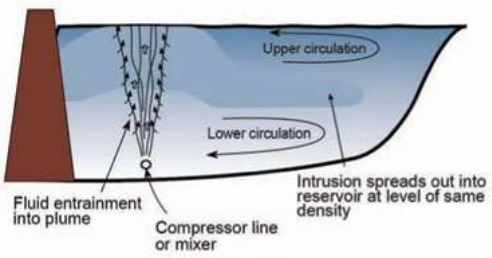


Figure 3
Typical circulation pattern set-up by artificial destratification (Sherman, 2000)

Drawbacks –

a) Stirs up the sediments, releasing more nutrients, hence increasing sediment oxygen demand. The circulation currents may transport nutrients to the photic zone and stimulate phytoplankton production.
b) Increased temperature of hypolimnion due to mixing degrades the cold-water fishery habitat.
c) Short term solution that could create other negative effects to the natural Lake environment.

2) Hypolimnetic Aeration

This method is used for maintaining DO levels in the hypolimnion without disturbing the thermal stratification.

The oxygen is transferred to the water due to the mixing of compressed air, which is injected at the bottom of the inner tube, and water as they travel up the tube. The oxygenated water then flows down through the annulus back into the hypolimnion.

Drawbacks –

a) Low oxygen transfer efficiency – 12% to 50%.
b) Moderate induced oxygen demand and low oxygen transfer efficiency = Low DO levels in Hypolimnion
c) Large systems in large lakes can cause accidental destratification and high rate of stirring of sediments.

3) Hypolimnetic Oxygenation

This is similar to Hypolimnetic Aeration, but pure oxygen gas (compressed) is used instead of compressed air. The added advantage is:

a) High oxygen transfer efficiency 60% to 85%
b) Low sediment stirring – hence low induced oxygen demand

Resolution of Environmental Pollution – PREVENTION with NANOBUBBLES

Oxygenating the hypolimnion, without creating turbulence to stir up the sediments is the best attempt in preventing algae bloom in eutrophic lakes. Improving water quality and preserving habitats in the lake is the main aim with this technology.

There is a novel way of transferring oxygen to water, at any desired layer, by using NANOBUBBLES.

Nanobubbles are extremely small gas bubbles, few nanometres in diameter, and are not buoyant. They slowly sink to the bottom of the lake, thereby increasing the DO at the hypolimnion where it is needed the most. Small size of the bubble = large surface area = excellent solubility in water.

The gas transfer efficiency of our nanobubble system is >90%.

COMPARISON BETWEEN TECHNOLOGIES USED FOR LAKE RESTORATION

Operational Feature	Artificial Destratification	Hypolimnion Aeration	Hypolimnion Oxygenation	Nanobubble Technology
First Installation	1919	1940's	1973	2011
Gas used	Air	Air	Oxygen	Oxygen/Air
Objective towards water quality	Maintain	Maintain	Maintain	Improve
Destratification /Mixing	High	Moderate	Low	Lowest
Hypolimnetic heating	High	Moderate	Low	Lowest
Induced oxygen demand	High	Moderate	Low	Lowest
Efficiency of O_2 transfer	Irrelevant	Low (12-50%)	Medium (avg. 75%)	High (>90%)
Engineering of equipment	Custom	Custom	Custom	Generic
Reusability in other lakes	Hard	Very Hard	Very Hard	Easy
Maintenance	Hard	Very Hard	Very Hard	Easy
Warm water fishery	Yes	Yes	Yes	Yes
Cold water fishery	No	Yes	Yes	Yes
Requirement of Heavy Machinery	Yes	Yes	Yes	No
Safety of swimmers while in operation	Required	No	No	No

Artificial Destratification/Mixing for Lakes

In an artificially mixed system, the phytoplankton often increases partly due to an increase in nutrients entrained from the hypolimnion or resuspended from the sediments.

Studies from past experiments show that if phytoplankton is entrained in the turbulent flow and redistributed vertically over the entire depth, green algae and diatoms win the competition over (colonial) cyanobacteria due to higher growth rate and reduced sedimentation losses. So there is a possibility that the algal biomass might not decrease significantly or at all and might increase depending on the dominant algae.

On the basis of artificial mixing experiments in enclosures, Reynolds et al. (1983) distinguished four groups of phytoplankton that each responded differently to deep mixing:

A) Phytoplankton favoured by mixing –
Staurastrum (Green algae), Oscillatoria (Cyanobacteria), Asterionella, Fragilaria,

B) Phytoplankton favoured by stability and/or reduced optical depth but whose increase stimulates cropping by zooplankton, and in turn enhances loss rates by grazing -*Cryptomonas, Rhodomonas, Ankyra*

C) Phytoplankton whose growth rate is merely arrested by episodes of deep-column mixing -
Anabaena (Cyanobacteria), Ceratium, Volvox, Microcystis (Cyanobacteria)

D) Phytoplankton whose growth rate is reversed –
Spaerocystis, Eudorina

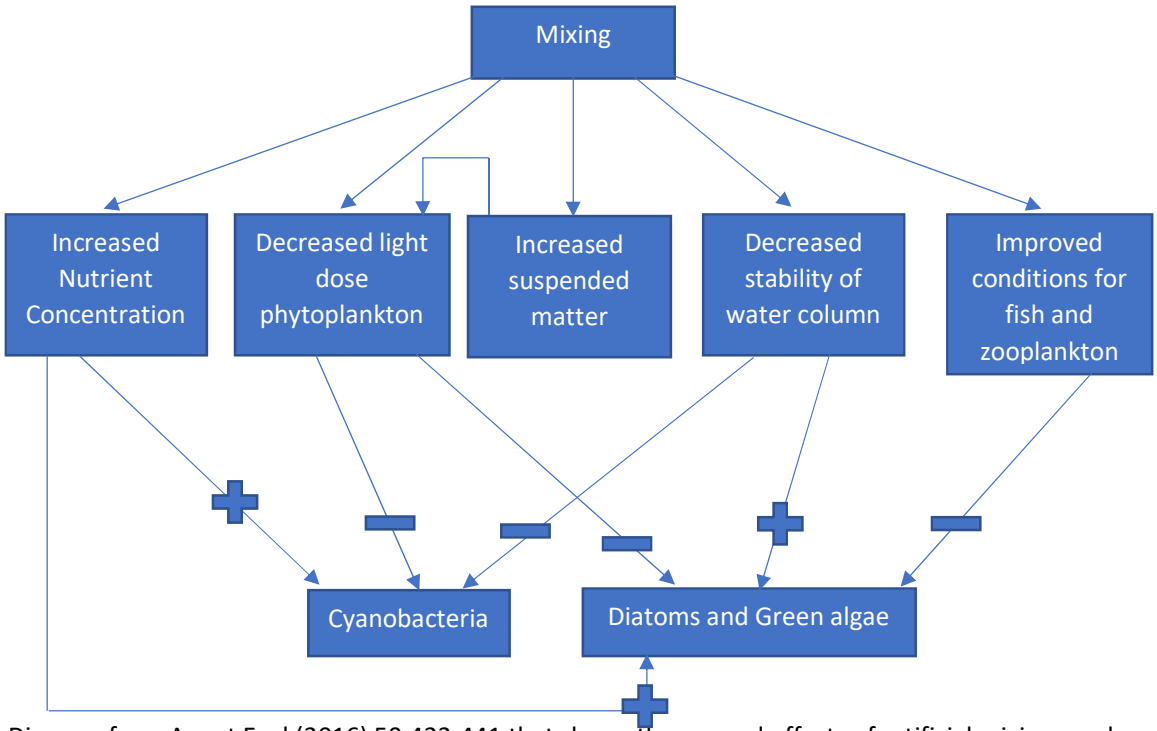


Diagram from Aquat Ecol (2016) 50:423-441 that shows the general effects of artificial mixing on algae and cyanobacteria.

Pacific Nanobubble System (PNS)

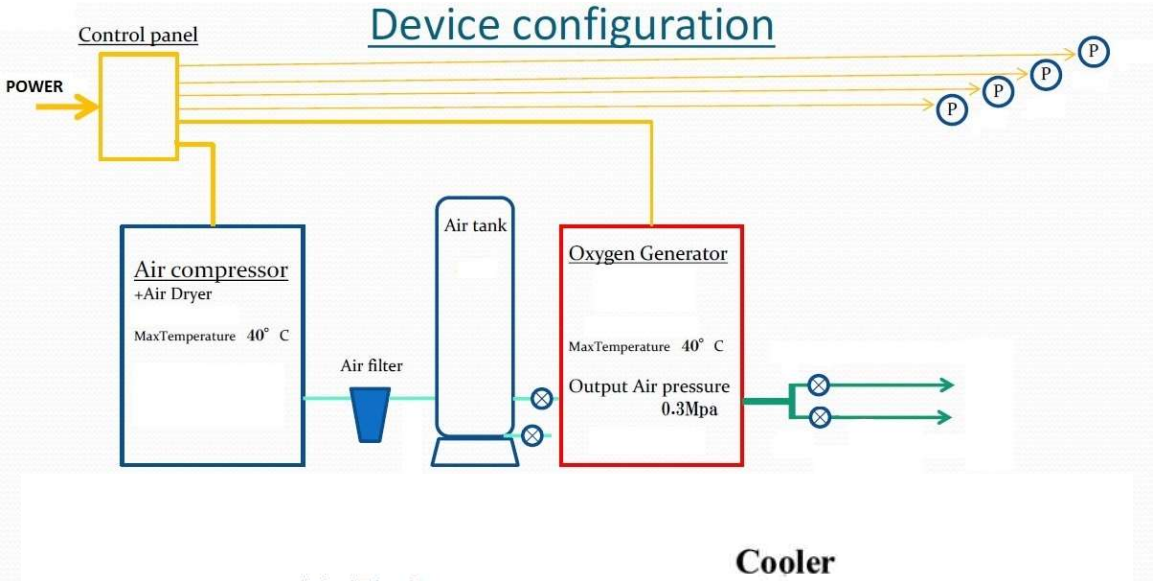
The PNS comes complete as a land based container and a floating pontoon. The PNS can be - Grid, Integral generator and or Solar powered.

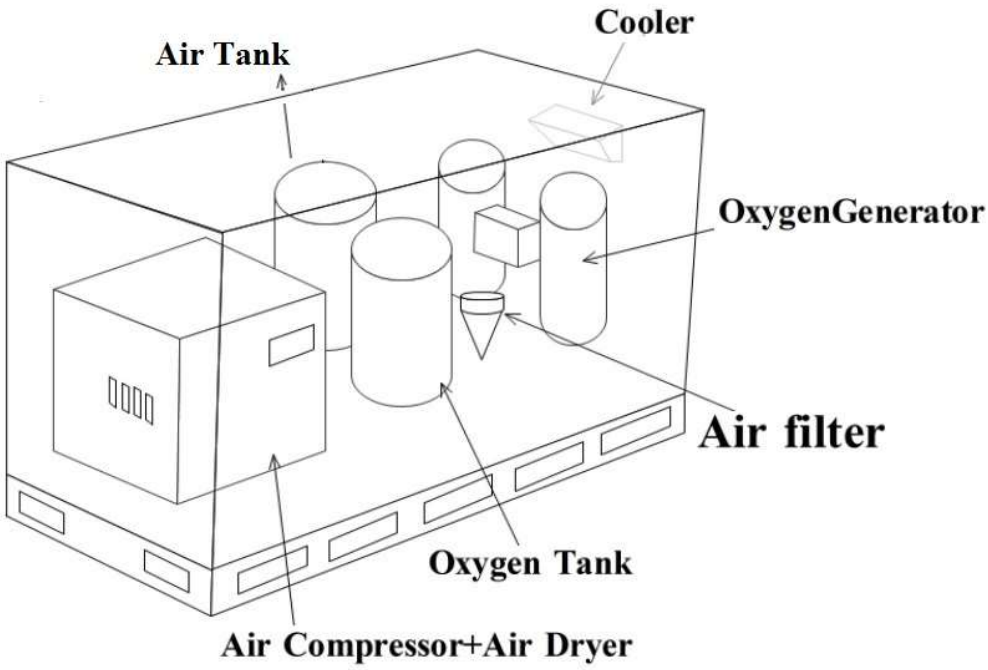
The PN system consists of two main components:

1) **Oxygen Generator Container System**
2) **Nanobubble Generator**

Oxygen Generator System

The Oxygen Generator Container System provides continuous oxygen supply to the Nanobubble generators.
It consists of – a) Air compressor, b) Filters + dryers, c) Air tank, d) Oxygen Generator.



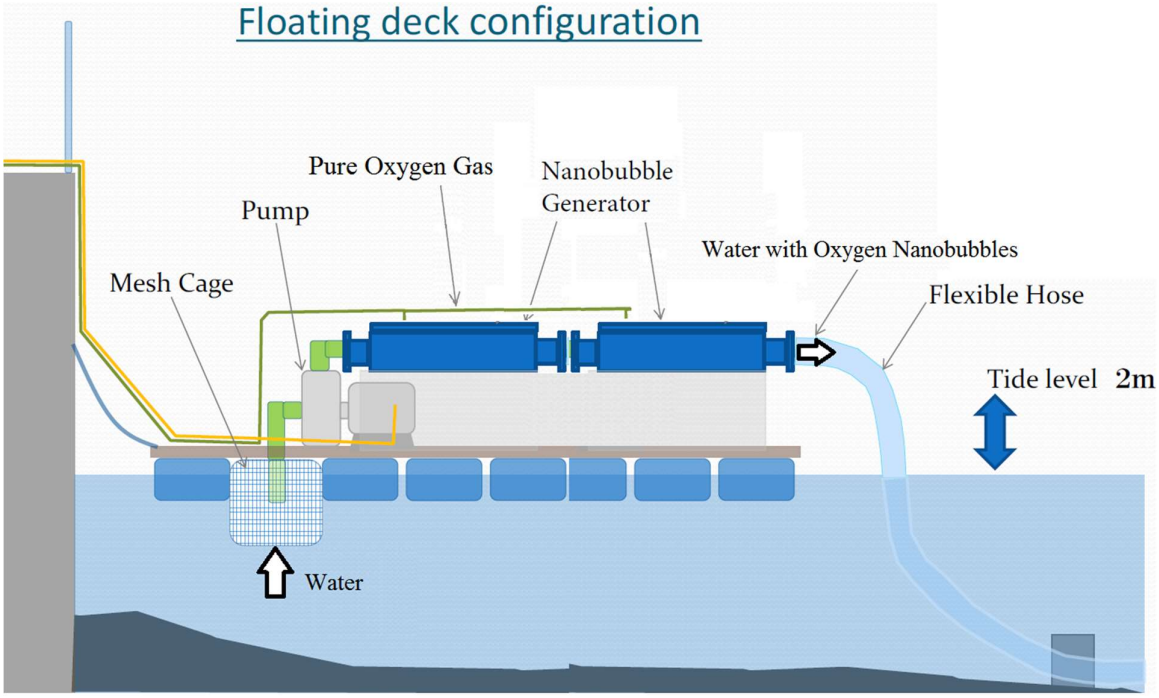


Nanobubble Generator System

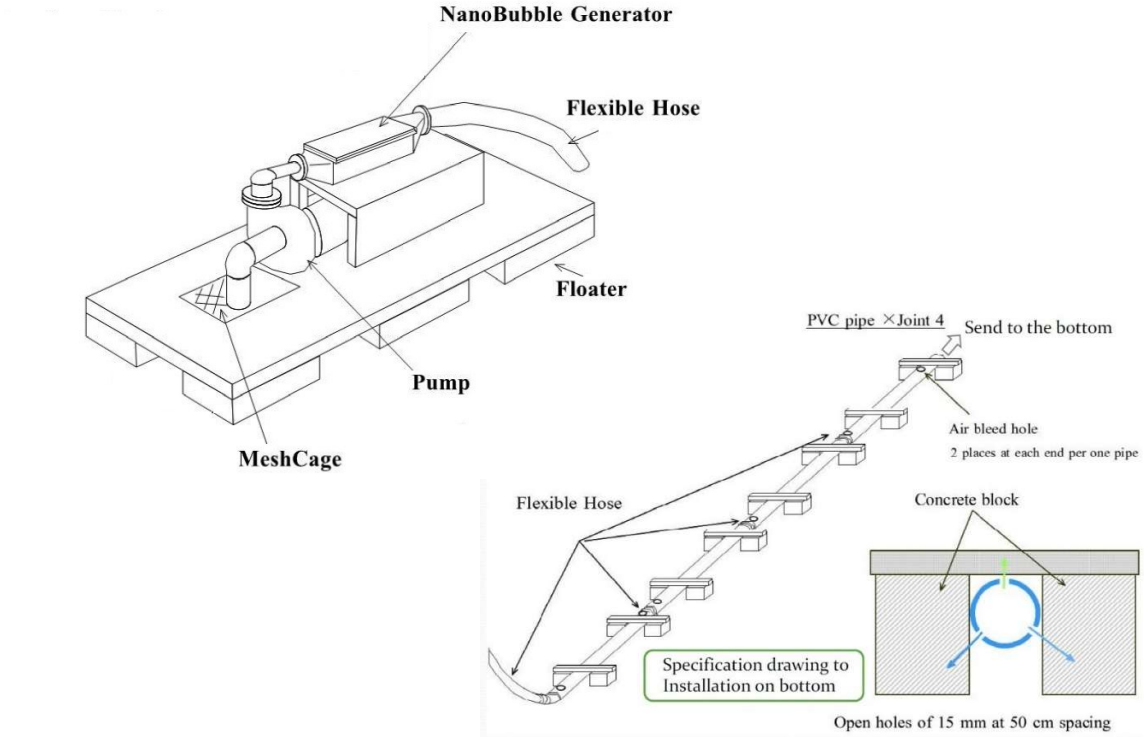
One PNS generator Package consists of –

a) One submersible pump
b) Two Nanobubble Generators
c) One Pontoon approx. 6m x 2.5m

Following basic arrangements – TBC.

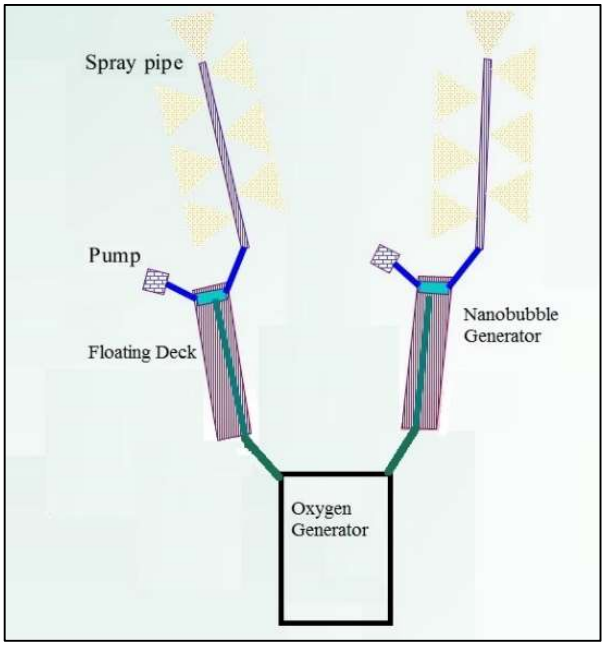


Nanobubble Generator Floating configuration – 2D (above) and 3D (below)



Installation Figure Reference

One Oxygen Generator Skid System will be connected to two Nanobubble Generator. The arrangement is shown in the figure below. This arrangement is not definite and can change depending on the oxygen requirement, surface area and depth of the lake.



Purification Plan

Nanobubbles are the only way to supply oxygen to the bottom of the lagoon gently, effectively and without turbulence to stir up the sediments or to change the quality of the sludge dramatically.

Oxygen transfer in the lake will be designed based on the requirement.

It will take a minimum of one month, to visually see some impact. The evaluation method can vary but would usually involve both a short term (six months) and long term (two years) evaluation to establish the ongoing required number of PNS on Lake as conditions improve over time.

Short term evaluation includes –

1. Changes in the number, types and size of microbes.
2. Natural looseness of deposits.

Long term evaluation includes –

1. Changes in the population of various type fish.
2. Total nutrient salt quantity.
3. Water clarity.
4. Changes in the characteristic and measurement of deposits.

The sampling of data should be taken every 2 weeks, but ideally weekly.

REUSABILITY IN OTHER LAKES - REDUCE FUTURE CAPITAL COSTS

Using nanobubble technology, the hypolimnetic oxygen demand is expected to decrease with each following year, while excluding external factors.

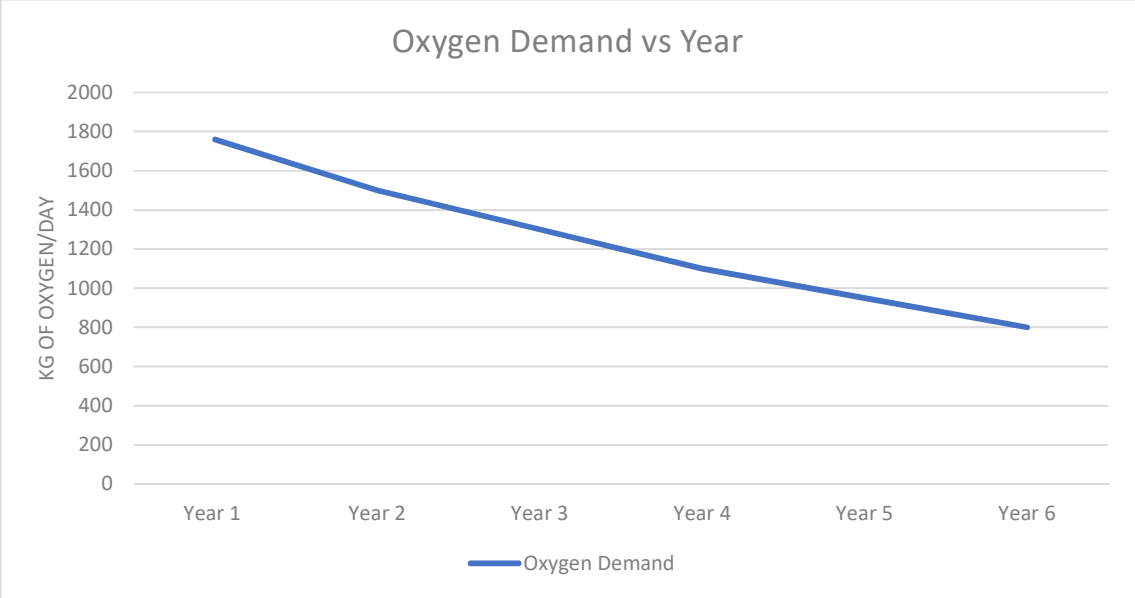


Chart is indicative only.

Once the lake has been cleaned to the satisfactory level, we can use reduce the number of nanobubble generators proportionally, to compensate for the ongoing nutrient loading.

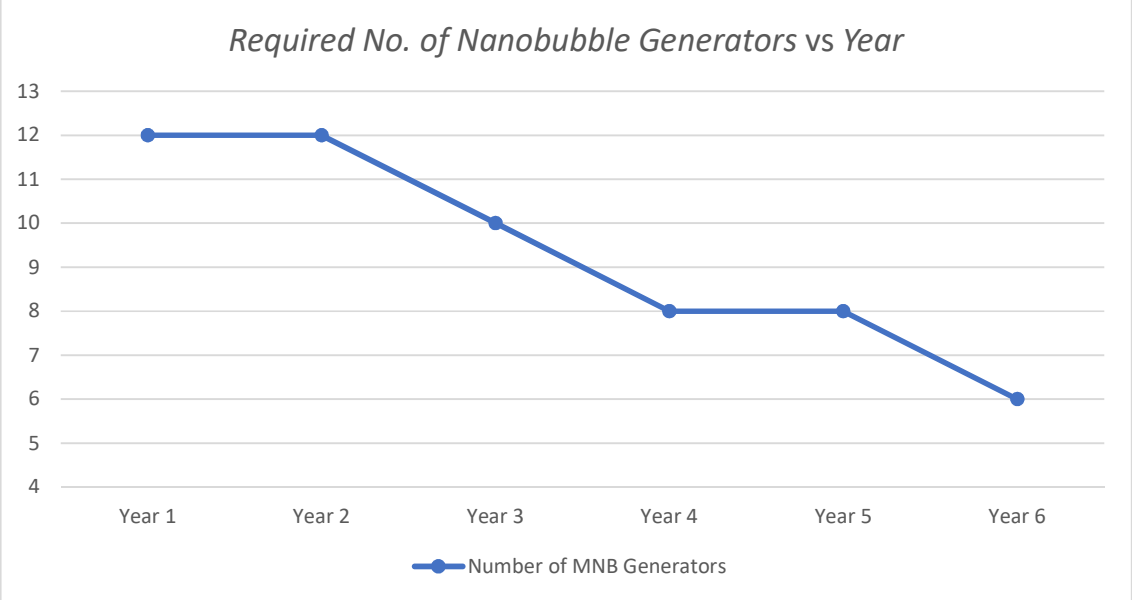


Chart is indicative only

The MNB generators that are no longer required can be used for clean-up in other lakes. This decreases the capital cost for future lake/water reservoir clean-up projects.

Trial option

A trial could be undertaken in a small lake or in one part of large lake to study the movement of nanobubbles and the oxygen transfer efficiency of the system. The trial will help to understand the capabilities of the system and the resulting benefits.

The PNS model #700 Includes:
Oxygen Generator Container System x 1 – land based.
Nanobubble Generator x 1 – on 1 x pontoon.

The total power requirement of the PNS system is 6.1 KW.
Power options: Grid or PNS supply.

Oxygen transfer rate per day – approx. **16.67 kg O_2/day.**

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