Dryden Aqua

Air Diffuser

Instructions for use

Typical applications

- Activated sludge, wastewater
- Landfill leachate waste water
- Extended diffused aeration systems
- Destratification of lakes or reservoirs
- Industrial wastewater treatment
- Reduction of THMs by air stripping
- Agricultural waste water
- Wetland water treatment systems
- Aquaculture for fish & shrimps

Specifications

- Highly efficient oxygen transfer, up to 5kg/kw/hr
- Self-ballast, simply dropped into tanks or lagoons
- Very easy installation and retrofits
- Very easy to maintain, no need to drain tank
- Less than 2 psi differential pressure
- Built in non-return valve
- Stainless steel and plastic construction
- 10 year average life cycle
- Can be used with Air, N_2, CO_2

CONTENTS

1. Introduction

Product order codes & oxygen transfer data

Product code	Description Length of diffusers m	Diffuser Weight kg	Air Flow m^3/hr (+/- 20 %)	Oxygen Transfer kg of O_2/day per diffuser at different depths at 20 °C and 50% O_2 saturation		
				2m depth	3m depth	4m depth
70000	0.33 m	0.5 kg	1	2 kg O_2	2.5 kg O_2	3 kg O_2
70001	0.66 m	1.0 kg	2	4 kg O_2	5 kg O_2	6 kg O_2
70002	1.00 m	1.5 kg	3	6 kg O_2	7.5 kg O_2	9 kg O_2
70003	1.33 m	2.0 kg	4	8 kg O_2	10 kg O_2	12 kg O_2
70004	1.66 m	2.5 kg	5	12 kg O_2	12 kg O_2	15 kg O_2
70005	2.0 m	3.0 kg	6	14 kg O_2	15 kg O_2	18 kg O_2
70006	2.33 m	3.5 kg	7	16 kg O_2	17 kg O_2	21 kg O_2
70007	2.66 m	4.0 kg	8	18 kg O_2	20 kg O_2	24 kg O_2
70008	3.0 m	4.5 kg	9	20 kg O_2	22 kg O_2	27 kg O_2

Unique product features and benefits

Dryden Aqua air diffusers are of semi-flexible construction of 32 mm in diameter and of variable length up to 3 metres depending on the air, oxygen or carbon dioxide throughput required. The diffusers have their own internal ballast and will stay on the bottom of the aeration tank without the requirement to secure them to the base. This makes our diffusers easy and quick to install. The diffusers can also be maintained while the tank is full of water, and even while the air blowers are running,

The Dryden Aqua Air Diffusers are among the most robust, versatile and efficient fine bubble diffusers. Fine bubble diffusion is inherently more effective than coarse bubble diffusion in providing a greater mixing action and gas transfer efficiency (up to 5 times more efficient). The diffuser has been independently verified to have 40% higher performance than equivalent fine bubble membrane diffusers manufactured in Japan and the USA

Installation

The diffusers are ideally suited for clay or plastic lined lagoons, but they are also perfect for steel and concrete tanks, lakes and aeration ditches. Installation in a lagoon or tank is very simple; fit an air ring main pipe (usually in HDPE or steel) around the perimeter of the lagoon, fit a ½" hose on to the air ring main using saddle clamps, cut the hose to a length that will take it to the base of the lagoon, fit one diffuser on the end of the hose and throw it into the lagoon. An Installation with 100 diffusers to cater for a PE (Population Equivalent) of 10,000 can be completed in 5 days.

Maintenance

The air diffusers require virtually no maintenance. DA air diffusers are used to treat landfill leachate and compost/ anaerobic wastewater digesters. The COD can be over 10,000mg/l with an alkalinity of 2000 mg/l. Under these conditions, some degree of scaling can occur. However, because the diffusers are semi flexible, a simple flexing of the diffuser will crack off any rigid scale deposits.

It is very easy to clean the diffusers, just pull on the ½" hose to recover the diffuser, give it a quick shake and brush, and then throw back into the water. Cleaning of 100 diffusers takes about 4 hours. Frequency of cleaning depends upon the quality and temperature of the water, but it is usually between once very 4 weeks to every 6 months. The diffusers can be maintained while the air blowers are running and whilst the lagoon or tanks are full of water**.**

Landfill leachate treatment
Scotland

Oxygen transfer rate

The performance of an air diffuser is related to bubble size, oxygen transfer coefficient and energy consumed. The Dryden Aqua fine bubble air diffuser efficiency has been measured at 5kg of O_2 transfer per kw. One diffuser and 10 m^3/hr of air will provide sufficient mixing and oxygen for 50 to 100 PE people in a municipal treatment plant. This equates to 1 to 2 kg of oxygen transfer per hour per diffuser.

The Dryden Aqua diffusers are usually twice as efficient as any other diffuser on the market and up to 4 times more efficient than surface aerators.

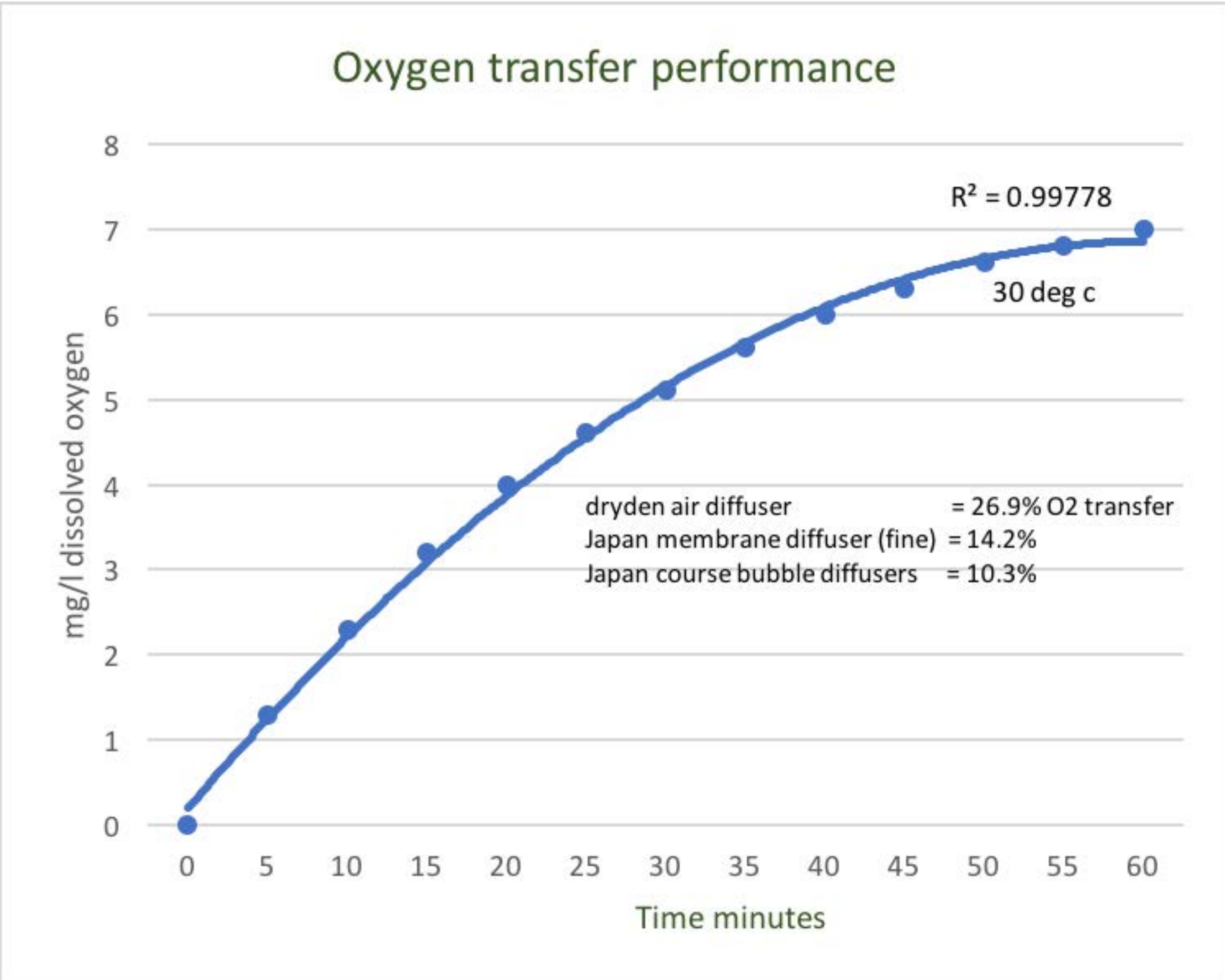
Independent verification of diffuser performance

A comparative analysis of air diffuser performance was conducted in 2016 by;

Dr. Shigetaka Wada
Chulalongkorn University, Thailand

Test Procedure

1. Water tank: diameter 1.0m, height 4.0m, water depth 3.5m.
2. Coarse diffuser tested for comparison (943-made in Japan, 013-made in USA, 0225 &0226- made in Japan)
3. Membrane diffuser tested for comparison (836, 046-ceramic diffuser, made in Japan)
4. Oxygen content is dropped to nearly zero by adding $CoCl_2 6H_2O$ as a catalyser and Na_2SO_3 as an oxygen absorber.
5. Air is blown in through the aerator in the bottom of the tank and the oxygen content measured until near 100% oxygen saturation is reached.



2. Sizing a system for different applications

The size of an aeration system depends on a number of variables and the objectives of the system, for most applications it will be the provision of oxygen, however the diffusers are also sized on their ability to move and mix water very efficiently.

The size of a system is also a function of the physical conditions, including the size and depth of water in the tank / lagoon to be aerated. The temperature of the water as well as the chemistry will also impact on oxygen transfer and oxygen solubility.

Solubility of Oxygen in water

The solubility of oxygen in water in equilibrium with air at 760mm Hg pressure and 100% relative humidity Units:mg/l.
The data gives the mg/l of oxygen in solution that is equivalent to 100% saturation at the specified temperature.

T ºC	**0.0**	**0.1**	**0.2**	**0.3**	**0.4**	**0.5**	**0.6**	**0.7**	**0.8**	0.9
0	14.60	14.65	14.52	14.48	14.44	14.40	14.36	14.33	14.29	14.25
1	14.21	14.17	14.13	14.09	14.05	14.02	13.98	13.94	13.90	13.87
2	13.83	13.79	13.75	13.72	13.68	13.64	13.61	13.57	13.54	13.50
3	13.46	13.43	13.39	13.36	13.32	13.29	13.25	13.22	13.18	13.15
4	13.11	13.08	13.04	13.01	12.98	12.94	12.91	12.88	12.84	12.81
5	12.78	12.74	12.71	12.68	12.64	12.61	12.58	12.55	12.52	12.48
6	12.45	12.45	12.39	12.36	12.33	12.29	12.26	12.23	12.20	12.17
7	12.14	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.90	11.87
8	11.84	11.81	11.78	11.76	11.73	11.70	11.67	11.64	11.61	11.58
9	11.56	11.53	11.50	11.47	11.44	11.42	11.39	11.36	11.34	11.31
10	11.28	11.25	11.23	11.20	11.17	11.15	11.12	11.10	11.07	11.04
11	11.02	10.99	10.97	10.94	10.91	10.89	10.86	10.84	10.81	10.79
12	10.76	10.74	10.72	10.69	10.67	10.64	10.62	10.59	10.57	10.55
13	10.54	10.50	10.47	10.45	10.43	10.40	10.38	10.36	10.34	10.31
14	10.29	10.27	10.24	10.22	10.20	10.18	10.15	10.13	10.11	10.09
15	10.07	10.04	10.02	10.00	9.98	9.96	9.94	9.92	9.89	9.87
16	9.85	9.83	9.81	9.79	9.77	9.75	9.73	9.71	9.69	9.67
17	9.65	9.63	9.61	9.59	9.57	9.55	9.53	9.51	9.49	9.47
18	9.45	9.43	9.41	9.39	9.37	9.36	9.34	9.32	9.30	9.28
19	9.26	9.24	9.23	9.21	9.19	9.17	9.15	9.13	9.12	9.10
20	9.08	9.06	9.05	9.03	9.01	8.99	8.89	8.96	8.94	8.92
21	8.91	8.89	8.87	8.86	8.84	8.82	8.81	8.79	8.77	8.76
22	8.74	8.72	8.71	8.69	8.67	8.66	8.64	8.63	8.61	8.59
23	8.58	8.56	8.55	8.53	8.51	8.50	8.48	8.47	8.45	8.44
24	8.42	8.41	8.39	8.38	8.36	8.35	8.33	8.32	8.30	8.29
25	8.27	8.26	8.24	8.23	8.21	8.20	8.18	8.17	8.16	8.14
26	8.13	8.11	8.10	8.08	8.07	8.06	8.04	8.03	8.01	8.00
27	7.99	7.97	7.96	7.94	7.93	7.92	7.90	7.89	7.88	7.86
28	7.85	7.84	7.82	7.81	7.80	7.78	7.77	7.76	7.74	7.73
29	7.72	7.70	7.69	7.68	7.66	7.65	7.64	7.63	7.61	7.60
30	7.59	7.57	7.56	7.55	7.54	7.52	7.51	7.50	7.49	7.47

The solubility of oxygen in water decreases as the water temperature increases. Aeration systems are sized based on the oxygen demand, often referred to as the BOD (Biochemical or Bacterial Oxygen Demand). The warmer the water, the more active the bacteria. Starting at a temperature of 5ºC, for every additional 5ºC, biochemical activity will increase by 100%, up to a temperature of 36ºC, then it starts to slow down.

Examples of applications & sizing of a system

	Number of diffusers code 70008	Air flow, m³/hr	Diffuser depth m	Capacity of system to deliver oxygen kg/day	Water flow m³/day	COD mg/l	COD loading per kg/day	Water minimum residence time days	
Municipal waste water	1	10	2 to 3m	20	15	400	6	1-5	50- 100 people
Industrial waste water	1	10	3 to 5m	27	4	4500	18	3 to 15	
Textile waste water								3-5	
Pharma waste								30 to 60	
Agriculture, cows	1	10						5-50	10 cattle
Agriculture, swine	1	10						5 - 50	20 swine
Degassing application THMs drinking water	1	10	3 to 5m	n/a	240 to 480	n/a	n/a	60 minutes	3000 people

Notes.

- COD = refers to the Chemical Oxidation demand of the water. COD is always higher than the BOD, however BOD laboratory analysis always gives an underestimate. We therefore recommend that sizing is based on COD.
- Application factor = a factor of 1.5 should be applied, COD loading per day x 1.5 = capacity of system to deliver oxygen. The system may be over-sized, but under-sizing should be avoided.
- Capacity of system to deliver oxygen is just an estimate, this figure could vary depending upon water chemistry and physical conditions, it should therefore only be considered as a guideline.

3. Sizing a system based on COD (BOD) & ammonium (all waste water applications)

- All activated sludge system
- Municipal waste water
- Industrial process waste water
- Agricultural waste water
- Extended diffused aeration system

The aeration activated sludge systems are sized on the basis of the COD and ammonium concentration with application factor of 1.5. If you do not know the COD and only have BOD, then substitute BOD for COD and apply an application factor of 2.5. To size an installation for wastewater treatment, determine the COD loading in kg/day. For example, if the water flow is 100m^3/hr at 300mg/l of COD,

COD = 100 x 0.3 = 30 kg/hr = 30kg of oxygen per hour = 720 kg per day.
If the water depth is 3m, then from the performance table;
1 x diffuser code 70008 will deliver 27kg/day.
Number of diffusers required = 720 /27 x application factor 1.5 = 40 diffusers and an air flow of 400 m^3/hr
Ammonium will exert an autotrophic nitrification BOD on the system, which is not measured as COD.
1 kg of ammonium = 5 kg of oxygen demand or (COD equivalent)
If the ammonium concentration is 40mg/l in 100m^3/hr water flow, then mass of ammonium = 4kg/hr = 96kg/day.
If 1 kg of ammonium = 5 kg of COD, then the COD equivalent = 96 x 5 = 480kg
480kg / 27 x 1.5 = 27 diffusers. This figure assumes that the ammonium reduction is by nitrification which will not be the case if there is organic matter in the water.

Heterotrophic bacterial metabolism requires 1 kg of ammonium nitrogen per 10kg of organic matter, if the COD is 10 times the ammonium concentration, then all the ammonium will be assimilated as heterotrophic bacterium respiration. If the COD is at a lower concentration, then extra oxygen may be required to provide sufficient oxygen to complete the autotrophic bacterial nitrification metabolism of the system.

Example to determine the ammonium, COD equivalent factor

Ammonium = 40mg/l
COD = 300mg/l
Water flow = 100m^3/hr

Mass of ammonium kg/day = 0.04 x 100 x 24 = 96kg
Mass of COD kg/day = 0.3 x 100 x 24 = 720kg
Equation = (Ammonium - (COD / 10)) x 5 = COD factor
(96 – (720/10)) x 5 = 120 as COD factor

If the COD component is 720 kg day, and the ammonium contributes 120kg, the total number is 840 kg/day The number of diffusers = 840/27 x 1.5 = 47 diffusers and 470 m^3/hr of air.

4. Air Diffuser Installation

Detailed instructions

Installation of aeration systems

Dryden Aqua air diffusers are suited for installation in tanks, plastic lined lagoons, lakes or reservoirs of virtually any size or configuration. There is no limit to the size of the aeration system.

The systems comprise 4 basic components.

- Air blower
- Air ring main
- Air delivery hose / fittings
- Air diffusers

Typical roots blower specification

- 1 bar discharge pressure
- fitted with an acoustic environmental enclosure
- no load valve
- pressure relief valve
- temperature transmitter alarmed for over temperature
- filter restriction indicator and switch for connection to alarm system
- pressure transmitter connected to alarm system

Air blower installation

The air blower should be a 100% oil free positive displacement blower; for small systems, up to 150m^3/hr of air, rotary sliding vane compressors are the most economic and appropriate. For greater air flowrates, progress on to rotary lobe / roots type air blowers for air flows up to 2000m^3/hr. The blower should be able to deliver air at 1 bar pressure for installations where the diffusers are located at a depth up to 5m.

The blowers should be sized to deliver air at 1 bar discharge pressure, even if the water depth is only 3m. The blowers will always deliver the same air flow. If the pressure is lower however, then the work done by the blower and power absorbed will be reduced.

If the diffusers are located at a water depth greater than 5 metres, a rotary vane or roots type blower will be required that can deliver air of up to 1.5 bar pressure to compensate for the increased hydrostatic head and to make sure that the blower is relaxed and not running at its upper limit.

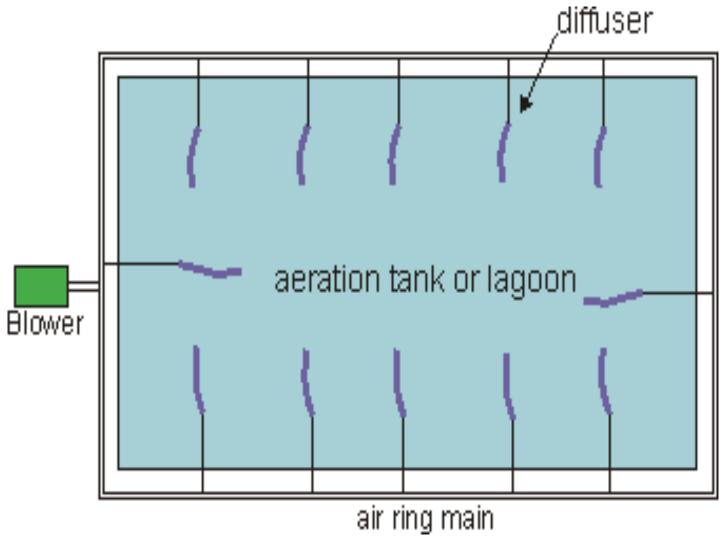
If water depth is greater than 10m, the pressure will need to be increased even further and rotary screw compressors will be better suited.

Blower location

The blowers must be located away from any air pollution, such as a diesel generator or source of any atmospheric contamination from dust, fines or solvents. The air blowers should be fitted inside an acoustic enclosure or installed under cover and protected from the elements. Ensure that the blower location is well ventilated to avoid the equipment over-heating. If the blower is located under cover in a room, then it is essential that the room has forced fan ventilation, otherwise the cooling air will be recycled in the room and the blowers will overheat.

The blowers must be located above the water level in the aeration system to avoid back siphoning of water through the pipework.

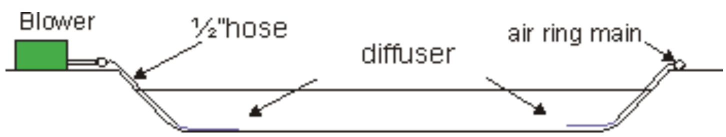
Air ring main



Locate the blower on a concrete pad and fit at least 6m of metal discharge pipe. When air is compressed the temperature increases, the metal pipe will help to dissipate some of the heat energy to protect the plastic pipework.

In tropical or hot climates, or if the water depth is over 3m, the discharge pipe from the blowers and the full ring main should be in metal pipe.

When air is compressed it gets hot, for every 0.1 bar, the air temperature will increase by 10°C. The maximum upper temperature for plastic pipe is 90°C. If the temperature is likely to exceed 80°C then metal pipe is recommended.



Example

Air temperature 30°C
Running pressure 0.8 bar = 8 x 10 = 80°C increase
Blower discharge temperature = 80 + 30 = 110°C
The diameter of the air ring main is a function of the air flow and perimeter of the lagoon. As a guide,

100 to 150m³/hr of air	90mm diameter pipe
150 to 200m³/hr of air	125mm diameter pipe
200 to 500m³/hr of air	150mm diameter pipe
500 to 1000m³/hr of air	250mm diameter pipe
1000 to 1500m³/hr of air	300mm diameter pipe

Condensate

The air in the air ring main will cool down as it progresses around the network. As the air cools a water condensate will collect in the pipe. The accumulation of water can be very rapid. If the outlet connection for the air is connected to the side of the pipe, then the air ring main pipe may half fill with water over the first few weeks of operation. It is therefore important to fit water vents around the air ring main.

Noise

Occasionally a resonant frequency may be achieved between the blower and the pipework. To attenuate the sound and prevent a resonant frequency, metal clamps with an elastomer lining should be used to absorb pipe vibration.

Delivery hose and fittings

A high quality ½" flexible hose connects the air ring main to the air diffuser. Urethane reinforced braided hose is recommended. The mechanism by which hoses are connected to the air ring main will depend if it is plastic or metal pipe.

If plastic pipe is used then HDPE (high density polyethylene) is recommended, if metal pipe is used then stainless steel is recommended. If mild steel pipe is used, it should be hot dipped galvanised to help with corrosion.

1. Fit the saddle clamp around the HDPE air ring main pipe with the 3/4* female BSP threaded fitting pointing toward the tank or lagoon. If metal pipe is installed, then a clamp may be used or a ¾" female BSP threaded socket welded onto the pipe. If the pipe is installed over the water, the air connection should be on the under-side of the pipe.
2. Through the ¾" BSP threaded fitting drill a ½" hole into the air ring main pipe
3. Screw into the ¾" female connection, a ¾" valve with a ½" female BSP socket, screw into the socket a ½" male threaded x ½" fluted hose tail
4. Cut the flexible ½" hose to a length that will take it to the base of the tank, make sure the diffuser is not hanging from the hose. For lagoons cut the hose at a point 0.5m above the base of the lagoon.
5. Push fit the hose onto the valve hose tail and secure with a screw clip.
6. Fit the diffuser on to the other end of the hose and drop the diffuser into the tank.
7. Repeat this process for all the air diffusers.

Extra ballast

If the tank or lagoon has a water depth over 5m, with diffusers spaced less than 5m apart, then there may be a tendency for the diffusers to lift. Under these conditions, we can provide additional ballast for the diffusers. The ballast fits onto the end of the hose, and the diffuser screws onto the ballast.

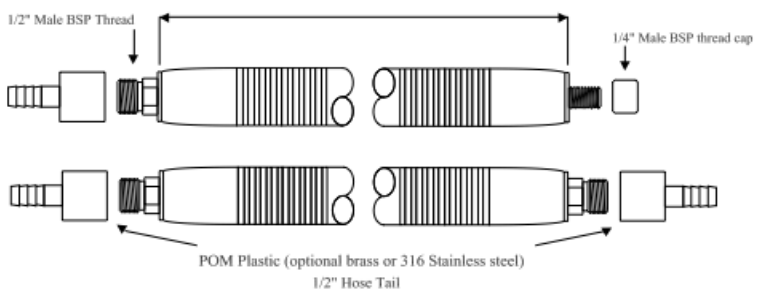
The ballast is manufactured in 316L grade stainless steel and measures 75mm x 75mm x 75mm. Ballasts are available with an air connection on the top with either 1 or 4 diffuser outlets, one on each side.

Diffuser Construction

The diffusers are manufactured from a very heavy-duty polyester fabric tube, a nylon distributor hose runs down the centre of the tube. Between the nylon hose and polyester tube there is a ballast comprising spherical glass beads.

The diffuser is banded using 316 stainless steel compressed on to the nylon inner tube with a nitrile rubber bush.

The metal end fittings are 316L grade stainless steel. As standard, each diffuser is fitted with a ½" acetyl plastic hose tail for connection of the diffuser to a ½" flexible hose. The plastic hose tail is screwed into the stainless-steel fitting on the end of diffuser.



5. Air Diffuser Maintenance

Solid diffusers are more efficient than membrane diffusers, however they experience problems due to carbonate and iron deposition which blocks the diffusers. For this reason, the water industry has moved to membrane type diffusers.

Membrane or elastomer diffusers do not block; however, they must be installed on frames or modules and secured to the base of the tanks. This makes them unsuitable for lagoons and makes them difficult to service. The modules must either be recovered using a crane, or the tank must be emptied every 1 to 5 years to repair or replace the diffusers. Typically, on any installation with 10 aeration lanes, one will be decommissioned for servicing at any one time.

The Dryden Aqua fine bubble, self-ballasted air diffuser will also experience both mineral and biofouling. They are however very easy and quick process to clean and, by using Dryden Aqua diffusers, the aeration lanes will never be out of service. A second major advantage is the very high performance of Dryden Aqua diffusers, 26.9% Oxygen Transfer Efficiency against only 14.2% for membrane type diffusers. This means that the blowers are much smaller with Dryden diffusers and 30% less energy is consumed. The waste water industry in Europe uses 2% of all power generated, and most of this energy is expended on driving the aeration systems.

The Dryden Aqua diffuser is a hybrid unit. Because it is semi flexible, carbonates and metal oxide precipitates simply crack and fall off the flexible surface, and biofilm comes off with an occasional brush. Also, because the diffuser has its own internal ballast, it does not need to be anchored to the base of the tank. When cleaning or, if maintenance is required, the diffuser is simple pulled out of the tank using the air hose. The tank can be full of water and the air blowers running when diffusers are removed. This makes the diffusers very easy and efficient to maintain.

The frequency of cleaning depends upon the quality of the water. Usually, the cleaning frequency will be once every 4 weeks to 6 months. If the diffuser starts to become fouled, the air blower pressure will start to increase. If the discharge pressure increases by any more than 2 psi (0.15 Bar), then it is recommended that the diffusers are cleaned. Normal static pressure loss, without taking account of water depth, will be 3 psi (0.2 Bar).

Standard cleaning procedure

1. Remove the diffuser for the tank or lagoon using the ½" flexible hose to recover the diffuser
2. Wearing a pair of strong gloves, simply pull the diffuser through your clenched hand, give it a shake and then drop back in the tank

The above basic cleaning process is all that is required. Once every 1 to 6 months however, they may require a more aggressive chemical clean once a year, especially during the first year of operation, or if the water has a high alkalinity and hardness.

Chemical Cleaning of the diffusers

Any surface in contact with biologically active water, will develop a biofilm. If the water has a high calcium and carbonate concentration, then there may also be scale formation.

Most of the scale formation will take place during the first 12 months. During this period, the diffusers will be working hard to reduce the concentration of organics in the water and any sludge in the system. It also takes around 6 months for the bacterial cell biomass to develop.

If scale forms on the diffuser this will happen very slowly, because it is difficult for scale to form on a flexible air diffuser. However, if the water is very hard then scale is a possibility. To remove the scale, make up a solution of 30% phosphoric acid, diluted with 5 parts water. Soak the diffuser in the solution for 10 minutes or until it stops fizzing. Do not soak for more than 20 minutes. After acid treatment wash with freshwater and immediately connect back onto the air ring main and throw back into the water.

The acid will be consumed during the cleaning process, so if cleaning multiple diffusers some fresh acid solution will be required. Any waste acid solution may be added to the aeration system. If the diffusers are cleaned and looked after, they can be expected to give up to 10 years of useful life.

6. System Performance

Extended diffused aeration system and system performance

Wastewater, extended aeration systems can be operated as serial tanks or SBR Sequencing Batch Reactors. SBR performance is usually superior to serial-based systems but they are technically more complex and require more space. If the residence time of waste water in the system is under 10 days then we recommend serial flow systems, if more than 10 days then SBR is better.

The systems should be as large as possible, the greater the volume of water in the lagoons/tanks, the longer the waste water residence time. Most heterotrophic bacteria that digest organic matter grow very quickly, they may have a doubling time as short as 15 minutes. However, if the organics are hard for the bacteria to oxidise, then the time required may be substantially longer and extend into days. Bacterial activity follows the 80:20 rule, it is easy for a bacterium to metabolise the first 80% to 90% of the organics, it is the remaining 10% to 20% that is difficult. If systems are aiming to achieve the best possible discharge standards, or even zero discharge, then use of extended diffused aeration, activated sludge systems as part of the main process is the perfect choice.

Natural selection

If a system is stable, then through a process of natural selection bacteria will develop that will be able to oxidise most organics, even toxic PCBs can eventually be metabolised or removed. If the organic load is low, then autotrophic bacteria will predominate in the system, especially towards the end of the process. Heterotrophic bacteria and COD/BOD reduction will often take place at the beginning of the system, and as the organics are reduced in concentration, autotrophic bacteria start to colonise the latter parts of the aeration system.

Autotrophic bacteria such as the nitrifiers Nitrosomonas and Nitrobacter are responsible for oxidising ammonium to nitrite and nitrate and can take up to 30 days to double in biomass at a temperature of 10ºC. Long residence time and/ or fluidised bed bioreactors or fixed film systems should be used to optimise the process.

Caution must be exercised when running systems close to 36ºC because this is the temperature of human blood, and as such there is a greater risk of incubating human pathogens in the effluent treatment system. Dryden Aqua fine bubble air diffusers are much more efficient than surface aerators because they do not waste kinetic energy by throwing the water in to the air. Fine bubble air diffusers are also safer, because they do not generate an aerosol, so there is less risk of spreading potentially pathogenic bacteria in the air.

We do not recommend the use of venturi type injectors or forced propeller injectors for activate sludge or extended biological treatment systems. Injectors tend to cause gas supersaturation with nitrogen, bulking of the sludge and foam formation. The injectors also smash up the bacterial floc and reduce the performance of the bacteria.

Aeration and biological system performance

The performance of an extended diffused aeration system is inherently better, more stable and more reliable than a standard activated sludge aeration system, and when combined with Dryden Aqua air diffusers in an optimised process the performance is excellent.

The following table compares performance data for a Dryden Aqua extended diffused aeration system with a standard activated sludge system using membrane diffusers. Examples and literature are cited to verify the performance statements.

	Type of system	Residence time days	AFM tertiary treatment	Typical performance Suspended solids	Typical performance BOD	Typical performance COD	Typical performance ammonium
Municipal waste water treatment	Typical Activated sludge with decantation	0.5 days	no	90%	95%	85%	50%
municipal waste water	Dryden Activated sludge with decantation, tertiary treatment	3 days	yes	>99%	>99%	>95%	>99%
industrial waste water	Dryden Activated sludge with decantation, tertiary treatment	3 to 15 days	yes	>95%	>95%	>90%	>95%
landfill leachate	Dryden Activated sludge, SBR	5 to 45 days	no	>95%	>95%	>90%	>95%

The performance of a Typical activated sludge system using membrane diffusers.
Water 2015, 7, 855-867; doi:10.3390/w7030855

Parameter		**Source Effluent Concentration mg/l**	**Range Removal Efficiency Range**
TSS (mg/L)	literature	20 to 40	87 to 93
	actual	22 to 33	90 to 93
BOD	literature	10 to 40	85 to 97
	actual	21 to 30	77 to 85
COD	literature	30 to120	80 to 93
	actual	41 to 55	76 to 82
TN	literature	>15	<60
	actual	16 to 26	43 to 53

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- Metcalf & Eddy. Wastewater Engineering: Treatment and Reuse, 4th ed.; Metcalf & Eddy, Inc.: New York, NY, USA, 2003.
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7. Applications

- Annex 1: Extended diffused aeration biological wastewater treatment
  - Textile waste water
  - Landfill leachate
  - Municipal wastewater
  - Industrial
- Annex 2: Gas stripping of THMs and Radon from drinking water
- Annex 3: Oxidation of metals such as ferric, manganese and arsenic
- Annex 4: Thermal and chemical destratification of lakes
- Annex 5: Agricultural waste water
- Annex 6: Aquaculture systems

Annex 1: Optimised Extended diffused aeration systems for the Biological treatment of waste water

Introduction

The aeration system and biological process is the heart of the water treatment system. It is responsible for 80% to 90% of all the water treatment and COD reduction. Industrial process water such as landfill leachate, pharmaceutical effluent or textile waste water has a hard COD and, is difficult to treat. It is therefore important to optimise the process to achieve a high efficiency of COD reduction and dye/toxic chemical removal.

The treatment of municipal waste water, or industrial waste water from the food industry is generally much easier to treat than industrial process waste water that contains toxic chemicals and hard COD. However, in both cases it is important that the aeration and biological system is fully understood and maintained. Dryden Aqua air diffusers were designed specifically for this type of waste water.

Basic aspects of extended diffused aeration and biological wastewater treatment are reviewed, and the biology of the process discussed with regards to optimisation for difficult waste water with a hard COD.

Toxic wastewater and ecological impact

Textile waste water accounts for 20% of all the waste water in China and a very high percentage in Bangladesh and India. Indeed, textile waste water accounts for between 5% and 10% of all the waste generated in all countries, it is also one of the most toxic and damaging to the environment.

- Textile waste water
- Pharmaceutical and removal of antibiotics
- Industrial waste water and landfill leachate
- Food processing

A process that can deal with textile waste water would have little difficulty in coping with most waste water generated from municipal or industrial process streams. It will therefore be used as an example in this report and can be applied to other waste water types in Asia, Europe or the Americas.

All waste water eventually ends up in the World's Oceans, priority chemical pollution is known to impact on primary productivity which impacts on climate change. The chemicals also accumulate through a process of chain amplification and impact on the health and well-being of all marine mammals and birds. The stability of the terrestrial ecosystem is also a function of the productivity of the marine ecosystem. Both systems are intrinsically connected, and if we lose the marine ecosystem then the terrestrial ecosystem will also fail. Therefore, the ability to treat toxic waste water such as Landfill Leachate and Textile waste water is of critical importance for everyone.

Water residence time, bacterial species diversity & MBR

One of the most important aspects of biological waste water treatment of difficult water types, is time. The biology must be given time to develop, and mature. Membrane biological reactors MBR provide mechanically clean water but they cannot deal with chemicals in solution, unless they have a long residence time and cater for the biology of the process. Once you have a long residence time, the system goes into endogenous respiration, sludge production drops to zero, and then is then no requirement for membranes, because the water is now mechanically clean. The system takes up more area, but it is inherently more efficient, more stable and a fraction of the cost of MBR systems.

If size is not a factor the residence time may be increased to between 5 and 60 days. The larger the system, the more stable the process and easier it is to manage. This is very important in the context of pharmaceutical waste water, or any toxic waste water where you do not want to deal with sludge. A system in full endogenous respiration does not generate sludge, making management of the system to achieve very high-performance levels much easier.

If the residence time and activity of the bacterial cell biomass are such that all the COD is metabolised, then the bacteria will start to digest themselves (endogenous respiration). The result is CO_2, H_2O and N_2, and the amount of sludge produced almost drops to zero. Sludge production ratios are presented in the following table. Note that the longer the residence time the lower the mass of sludge generated by the system.

Biological Process	**Residence time of water HRT/ hours**	**Sludge age, maximum**	**Sludge loading F/M**	**Sludge production Kg of sludge, per KG of BOD/COD removed**	**Industrial application**
High rate system	1 to 2	12 hours	>1.0	0.7 to 1.0	Organic reduction, food process waste. No space for larger system
Conventional	6 to 12	48 hours	0.2 to 0.5	0.6 to 0.8	Municipal waste water
Low rate	12 to 48	6 to 8 days	<0.1	<0.6	Industrial and process waste water
Extended aeration	48 to 240	20 days	<0.05	0.05 to 0.2	Dryden Aqua industrial process water, optimised Textile systems
Very extend	240 to 1200	100 days	<0.01	<0.01	Dryden Aqua, Landfill leachate treatment, pharmaceutical waste

Multiple aeration tanks and species diversity

The longer the residence time the greater the species diversity. Also, if the system is split into a multiple number of tanks / lagoons, operating in series, then the quality of the water and sludge biomass is going to change progressively from the first tank to the last. The different environmental niches force an increase in species diversity of bacteria, protozoans, nematodes and algae. The design of Dryden Aqua extended diffused aeration systems is optimised for biological oxidation, by long residence times and serial tank water flow.

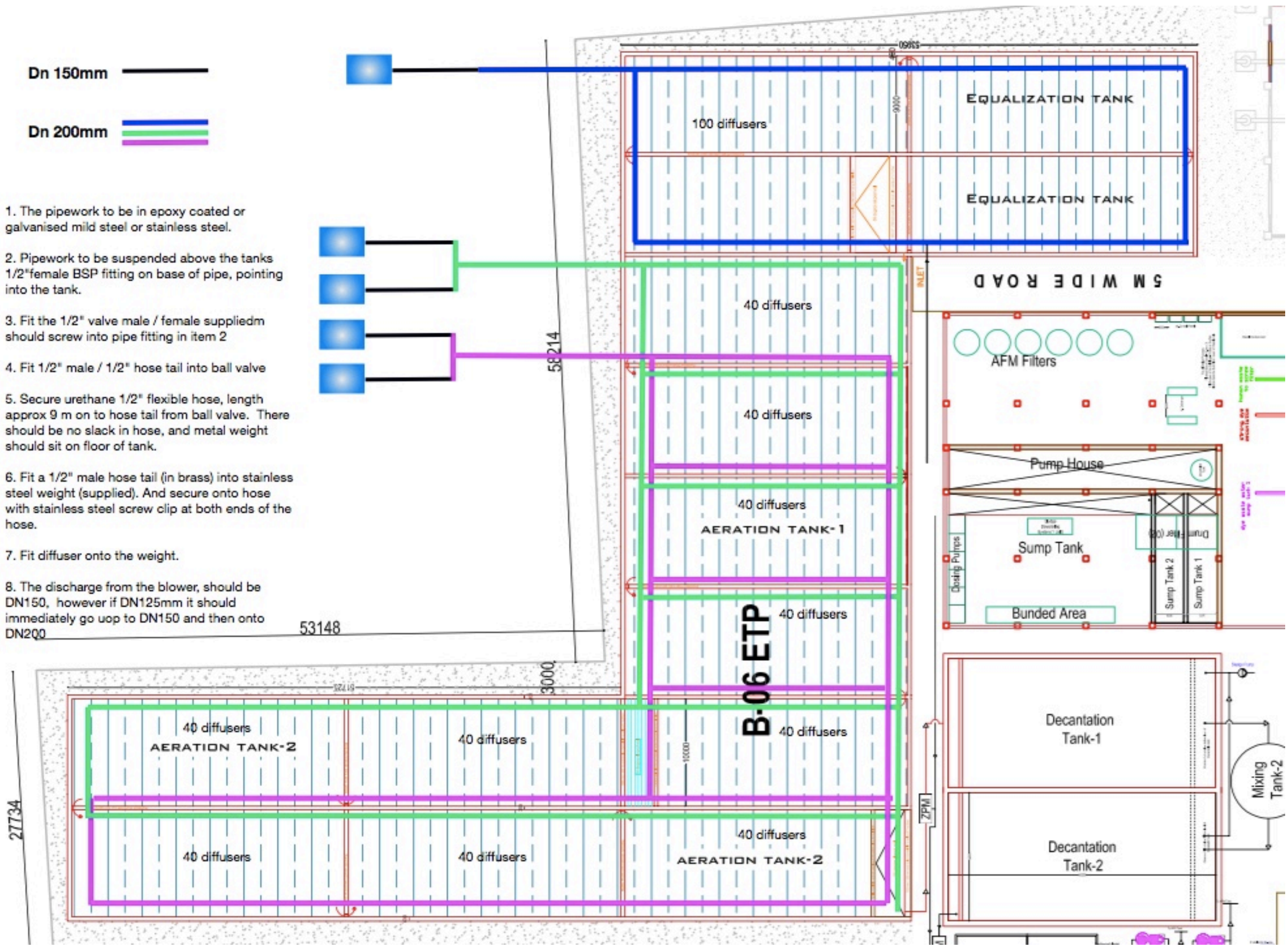
The diagram below is an example of a Textile water treatment system, designed on the basis of a 90 hour residence time in three aeration cells.

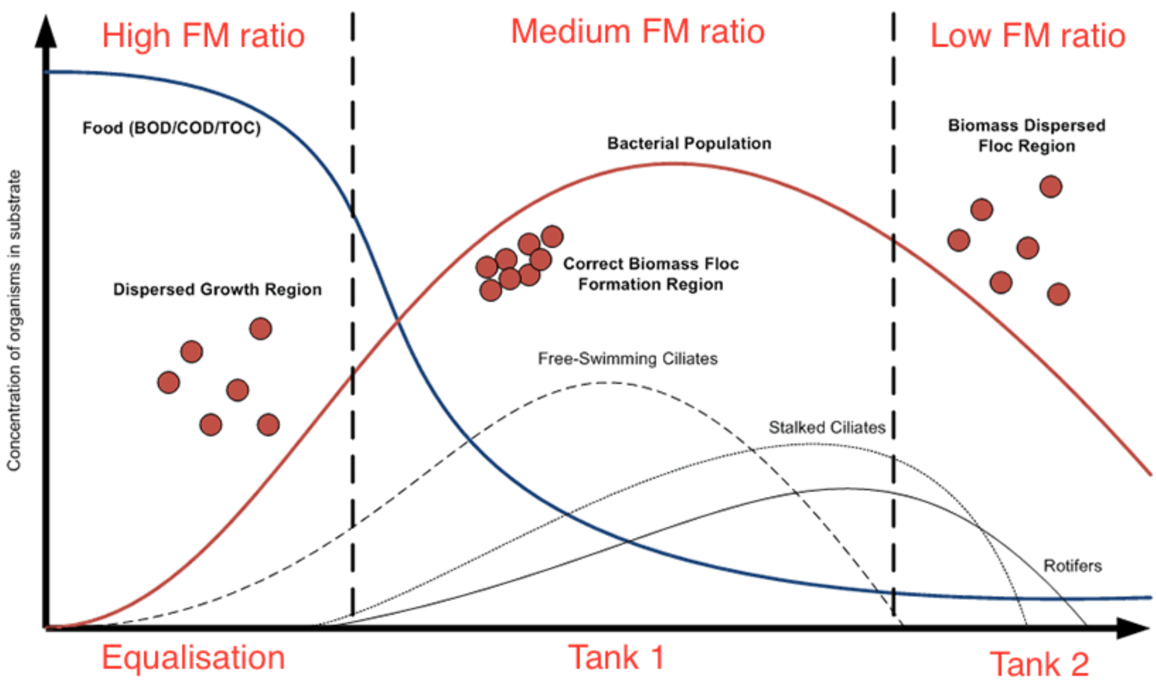
The system is divided into three sections

1. Equalization tank 100 air diffusers delivering 1000m^3/hr of air
2. Aeration tank 1 200 air diffusers delivering 2000m^3/hr of air
3. Aeration tank 2 200 air diffusers delivering 2000m^3/hr of air

It is important that the water quality is stable in terms of temperature, pH and water chemistry. The equalisation tank will buffer the system to provide a consistent water quality to the two-main aeration biological tanks 1 & 2. The water entering the Equalisation tank, should also be stable. Typically, textile waste water has a temperature of >60°C and a pH >11. Heat recovery drops the temperature to 30°C and pH correction drops the pH to pH7.5 entering the equalisation tank. There will still be some fluctuation in water quality in the equalisation tank but conditions should still permit a healthy floc and bacterial cell biomass.

As the water progresses through the system from the Equalisation tanks to aeration tanks 1 & 2, the quality of the effluent will change and the sludge loadings will change as demonstrated in the following diagram.


Dn 150mm
Dn 200mm
1. The pipework to be in epoxy coated or galvanised mild steel or stainless steel.
2. Pipework to be suspended above the tanks 1/2"female BSP fitting on base of pipe, pointing into the tank.
3. Fit the 1/2" valve male / female suppliedm should screw into pipe fitting in item 2
4. Fit 1/2" male / 1/2" hose tail into ball valve
5. Secure urethane 1/2" flexible hose, length approx 9 m on to hose tail from ball valve. There should be no slack in hose, and metal weight should sit on floor of tank.
6. Fit a 1/2" male hose tail (in brass) into stainless steel weight (supplied). And secure onto hose with stainless steel screw clip at both ends of the hose.
7. Fit diffuser onto the weight.
8. The discharge from the blower, should be DN150, however if DN125mm it should immediately go uop to DN150 and then onto DN200
53148
58214
27734
3000
100 diffusers
EQUALIZATION TANK
EQUALIZATION TANK
5 M WIDE ROAD
40 diffusers
AERATION TANK-1
AERATION TANK-2
B-06 ETP
AFM Filters
Pump House
Sump Tank
Bunded Area
Sump Tank 2
Sump Tank 1
Decantation Tank-1
Decantation Tank-2
Mixing Tank-2


High FM ratio
Medium FM ratio
Low FM ratio
Food (BOD/COD/TOC)
Bacterial Population
Biomass Dispersed Floc Region
Correct Biomass Floc Formation Region
Dispersed Growth Region
Free-Swimming Ciliates
Stalked Ciliates
Rotifers
Concentration of organisms in substrate
Equalisation
Tank 1
Tank 2

The textile waste water treatment system used in our example is referred to as a Dryden Aqua Optimised Textile waste water treatment system. The following table compares a Dryden Aqua system against more typical waste water processes that generally have a shorter residence time. Note that with increased residence time, the mass of sludge generated decreases due to endogenous respiration.

Note. sludge age is only a guide, depending upon the species and type of waste water this will be a variable. The F:M (Food to Micro-organism) ratio will drop as the water progresses through the system.

Tank	MLSS mg/l	COD mg/l	F:M	Dissolved oxygen	phosphate
Equalisation	1,500	1,200	0.2	>40%	2 to 10
Aeration tank 1	2,000	400	0.05	>50%	2 to 5
Aeration tank 2	2,500	150	0.015	>60%	1 to 2
FM ratio for the system			0.14		

F:M ratio

The F:M ration is the effective Food to Micro-organism ratio. The figure is usually based on COD or BOD and the MLVSS, Mixed Liquor Viable Suspended Solids load. The MLVSS refers to the viable suspended solid load as opposed to the total suspended solids load.

Q = flow mg/day
COD chemical oxidation demand mg/l
MLVSS mixed liquor suspended solids mg/l
F:M = [(COD, mg/l) x (Q, m^3/day)] / [(MLVSS, mg/l) x (Aeration Volume, m^3)]

example

COD = 1200 mg/l
Q = 7200 m^3/day to the aeration tank
MLVSS = 2000 mg/l
Aeration Tank Capacity = 30,000 m^3

F:M = (1,200 x 7,200) / (2,000 x 30,000) = 0.144

Given the nature of the water to be treated the dye will be adsorbed by the bacterial cell biomass, it is therefore a very aggressive and difficult wastewater to treat. The dyes are toxic to the bacteria and will disrupt cell metabolism by interfering with cell wall transport mechanisms. The system is therefore designed to have a relatively young sludge in the equalisation tank and aeration tank 1 and older sludge in aeration tank 2.

Healthy and actively growing young bacteria will tend to form flocs and will have good settlement velocities. Non-viable bacteria will become planktonic. The design of the equalisation and aeration tanks is such that the system will retain viable bacteria and discharge planktonic bacteria.

Given that the higher percentage of bacteria leaving the system will be planktonic and non-viable, they are also likely to be coated in dye. The system has therefore been designed not to recycle bacterial sludge / cell biomass. However, facilities are in place to permit the recycling of the sludge should if required. It should be noted that the objective is to discharge all the sludge via the decantation tanks to the dewatering system. The waste sludge will be dry with a water content of approx. 6% to 10%

Equalisation tank MLSS 1,500mg/l , COD 1,200mg/l   FM= 0.2

Typically, equalisation tanks operate at up to up to 60ºC in other system designs, the high temperature will not permit the growth of a healthy bacteria cell biomass. In the Dryden Aqua, Technology DAT system, the energy recovery system will drop the temperature of the equalisation tank by 25 to 35ºC. The equalisation tank will therefore become biologically active and will be an integral part of the biological processing of the waste water

There is a risk to the system if the heat recovery systems go off-line, to reduce the risk there are duty and stand-by pumps. If the heat exchangers need to go offline, then this should be programmed into a time when the factory is not producing any hot waste water. It is important not to shock the system by high water temperatures.

The MLSS solids load can be controlled in the first tank by sludge recycling. The objective is not to recycle sludge, because a high percentage of the sludge will be non-viable and it will contain dye. It will therefore be difficult to maintain a high biomass of bacteria in the equalisation tank.

Aeration Tank 1 MLSS 2,000 mg/l, COD 400mg/l   FM = 0.05

Aeration tank 1 receives partially treated water from the equalisation tank, there will have been some water treatment in the equalisation tank, which will reduce COD. Tank 1 also receives the planktonic bacteria from the equalisation tank, this will result in elevation of the MLSS.

Aeration tank 2 MLSS 2,500 mg/l, COD 150mg/l   FM = 0.015

Aeration tank 2 receives the water from Tank 1, the water will have a lower COD, higher concentration of bacterial cell biomass and greater species diversity of bacteria

Sludge generation and Sludge recycling

From the above calculation aeration tank 2 has an FM ratio of 0.015 and is therefore working optimally to support endogenous respiration.

With a water flow of 300m^3/hr and a COD loading of 1200mg/l, the sludge generated based on the above FM ratio will be about 10% of COD = 300 x 1.2 x 0.1 = 54 kg/hr

This represents the maximum amount of sludge generated but, with further optimisation and by ensuring the aeration system maintains a dissolved oxygen concentration over 6mg/l it can be reduced further. Optimisation should focus on:

- The aeration system
- active biomass separation
- sludge processing

The treatment of wastewater is accomplished by developing an aerobic bacterial biomass in the aeration lagoons and by ensuring that the bacteria actively metabolise the dissolved components comprising of organic matter and nitrogenous matter. If the COD is over 10,000mg/l then an anaerobic digester should precede the aeration system and the aerobic process.

The organic metabolising bacteria are heterotrophic, and the inorganic nitrogen metabolising bacteria are autotrophic. Both groups of bacteria are aerobic and require a supply of oxygen, which is provided by the fine bubble diffused aeration system. The aeration system and nutrient dosing is a life support system designed to maintain the bacteria that perform the task of treating the wastewater.

Key points

- bacteria nutrient requirements
- oxygen
- environmental conditions
- trace nutrients
- time & temperature

Bacteria, nutrients and oxygen

The aerobic bacteria use the waste matter in the water as a food source. The heterotrophic bacteria feed on organic matter to reduce the COD (Chemical Oxidation Demand) of the water. As a guide 1 kg of COD reduction will require 2 kg of oxygen. 10Kg of COD will also remove 1 kg of ammonium nitrogen. Heterotrophic bacteria develop very rapidly at a water temperature of 20°C, the bacteria can double every 15 to 30 minutes. The bacteria are also active at low water temperatures and will keep working down to 5°C. The addition of an organic nutrient source such as molasses is however a useful strategy to employ to allow heterotrophic bacteria to reduce ammonium levels in low temperature systems.

Autotrophic nitrifying bacteria use inorganic carbon in the form of carbonates as a carbon source, and ammonium as an energy source. The bacteria convert ammonium to nitrate. Every 1 Kg of ammonium metabolised requires 7 kg of carbonate as $CaCO_3$ + 5kg of oxygen. The air diffusers provide the oxygen and some of the inorganic carbon in the form of carbon dioxide from the atmosphere. However, there is often a shortfall in supply of inorganic carbon, and therefore the pH of the water will tend to become acidic. Under acidic conditions, there is no inorganic carbon in the water and nitrification of ammonium will slow down and stop. It is therefore very important to always maintain the pH of the water above pH 7. If an acid is being injected at the start of a process, then the pH at the end of the process should be > pH 7.

Nitrifying bacteria are very effective in removing ammonium however, at water temperatures below 8°C, bacterial activity is greatly reduced and more reliance may need to be placed on heterotrophic bacteria for ammoniacal nitrogen control.

Relationship between Ammonium, BOD, Phosphate and alkalinity

component required	**Ammonium nitrogen 1kg**	**COD/BOD 1 kg**	**Phosphate 1kg**
Oxygen required in Kg	5 Kg	2 Kg	***
Ammonium nitrogen consumed Kg	***	0.1 Kg	10 Kg
COD/BOD consumed Kg	10 Kg	***	100 Kg
Phosphate required Kg	0.1 Kg	0.01 Kg	***
Alkalinity required			
Sodium hydroxide, or	4 kg (12 litres)		
Sodium bicarbonate, or	12 kg		
Calcium carbonate, or	7 kg		
Magnesium oxide	3 kg		

Alkalinity buffering equation

1. $H_20 + CO_2 \quad <=> \quad H_2CO_3 \quad <=> \quad HCO_3 + H+ \quad <=> \quad CO_3 + 2H^+$

Nitrification equations

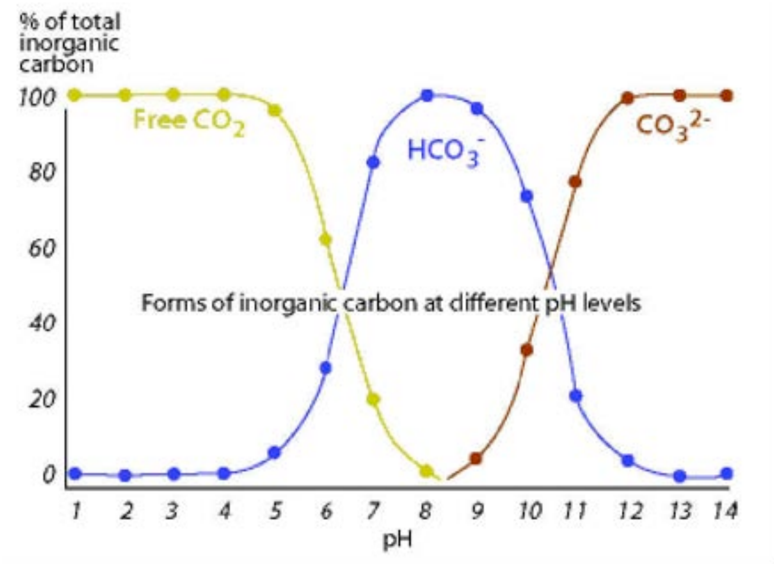
2. $NH_4^+ + 1.5O_2 \quad => \quad 2H^+ + 2H_2O + NO_2^-$

3. $NO_2^- + 0.5O_2 \quad => \quad NO_3^-$

4. $NH_4^+ + 1.83\ O_2 + 1.98\ HCO_3^- \quad => \quad 0.021\ C_5H_70_2N + 0.98\ NO_3^- + 1.041\ H_2O + 1.88\ H_2CO_3^{2-}$

From 1 gram of ammonium:

- 8.59 grams of carbonic acid (H_2CO_3) and
- 0.17 grams of autotrophic nitrifying bacteria cells are produced.



Relationship between Carbonate (CO_3) Bicarbonate (HCO_3) and Carbon dioxide (CO_2)

Environmental conditions

The effluent provides the food for the bacteria and the aeration system provides the oxygen. However, bacteria like to form colonies, and these colonies of bacterial floc need to be kept in suspension. If the floc were allowed to settle out in the aeration vessel, the sludge would become anaerobic and the aerobic bacteria would be destroyed.

The shape and structure of the bacterial floc are also important. The larger the floc, and the greater the species diversity of bacteria and the better the system performs. For intensive aeration systems with a residence time under 5 days, we recommend the application of a fluidised bed biofiltration media. The system is then operated as a fluidised bed biofilter.

Bacterial biomass

It is important that the bacteria are not lost from the system. Simple vertical tube clarifiers are used to keep the bacteria in the aeration vessel. The vertical clarifier pipe diameter is sized such that the vertical velocity of the leachate being discharged from the tank is slower than the rate at which the bacteria floc settles. Granular activated carbon may be used to improve floc structure in stressed systems. If the residence time is over 5 days, the bacteria should be in endogenous respiration and it is unlikely there will be any sludge development.

Trace nutrients

The wastewater may not provide all the nutrients required by the aerobic bacteria, in which case these nutrients have to be added to the aeration vessel. The principle nutrient is usually phosphate that can be added as phosphoric acid.

Time and temperature

The ability of the bacteria to treat the wastewater is a function of the bacterial activity and of the time the bacteria have to achieve the task.

Biological activity is very closely related to water temperature. From 10 to 30^{o}C biological activity can double for every 5^{o}C increase in temperature. The autotrophic nitrifying bacteria tend to be much more sensitive than the heterotrophic bacteria. Below 8^{o}C and above 35^{o}C nitrification is inhibited. The heterotrophic bacteria are much more temperature tolerant and will keep working down to 5^{o}C.

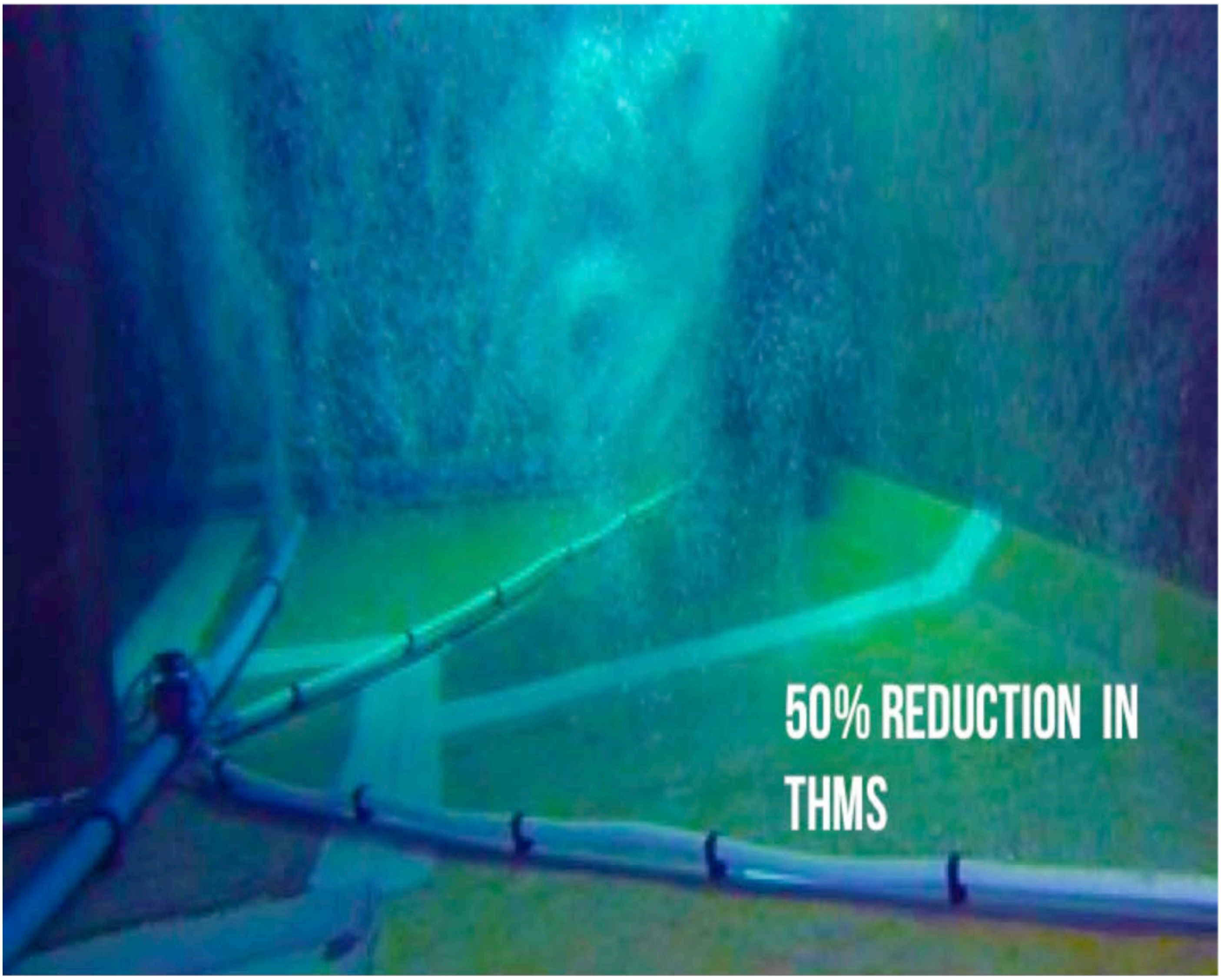
Annex 2: Gas stripping of THMs and Radon from drinking water

Drinking water is usually filtered and then chlorinated. If the water originates from a granite aquifer it may contain radio-active gas called Radon. Dryden Aqua air diffusers are used for scrubbing drinking water in Norway.

In other situations, the chlorinated water will react with dissolve organic precursors such as humic and fulvic acid and will form THMs such as chloroform. The upper limit for THMs in drinking water is 100 µg/l, however, due to a high concentration of dissolved organics acids that act as precursors, it is very difficult to prevent the formation of THMs. Dryden Aqua air diffusers are used to blow-off excess dissolved gases. A small amount of aeration can provide a 25% to 50% reduction in THM's. 1 x diffuser delivering 10m^3/hr of air for 10 to 20m^3/hr of water treated will give a 50% reduction in dissolved gases. For precise calculation variables such as water depth, temperature and contact time must be taken into account.

Some water companies are now adding ammonium to drinking water to react with chlorine to form monochloramine. The chloramine has an oxidation potential 2,000 times lower than hypochlorous acid, but it will still disinfect the water.

Monochloriamine is non-toxic, but when water is consumed in the presence of stomach acids it will be converted to toxic trichloramine. At Dryden Aqua, we therefore neither recommend the addition of ammonium to drinking water nor the practice of chloramination. It is much safer and more effective to gas strip THM's from the water. AFM® activated filter media manufactured by Dryden Aqua should also be used to treat the water. AFM® filters drinking water to a higher standard than is possible with sand and reduces the concentration of the precursors that result in the formation of THMs.



Annex 3: Oxidation of ground water for the removal of ferric, arsenic & manganese

The aeration and gas stripping of ground water makes it much easier to subsequently treat the water for the removal of heavy metals and metalloids. In addition, there are other benefits to be gained:

- Strong aeration to raise the dissolved oxygen concentration and oxidation potential will cause the zeta potential to drop and will initiate particle flocculation. This makes it easier to remove particles from the water using AFM® or sand filters
- Iron in solution (Fe^{2+}, ferrous) is oxidised to ferric (Fe^{3+}). In the presence of oxygen, the ferric acts as a catalyst generating free radicals to oxidise and co-precipitate arsenic, manganese and other heavy metals.
- Aeration blows blows-off excess CO_2 and restores the proper alkalinity balance, the pH of the water will usually increase.
- Aeration blows-off volatile gases such as Radon, organic solvents and other VOCs (Volatile Organic Carbons)

Aeration for pre-treatment of ground water is a very important step in water treatment, that is often ignored. Simple aeration for a period of 10 to 30 minutes or longer can have tremendous benefits that make it much easier to treat the water to a high standard using AFM® filtration..

How to size a system

The aeration water tank should ideally be 3m in depth, if the tank is less than 3m then additional aeration may be required. The dissolved oxygen content of ground water is often zero. The oxygen concentration needs to be increased to near saturation and maintained for 10 – 30 mins (depending on the metal and the level of contamination) in order to ensure oxidisation of metals.

If the water flow is $100m^3/hr$, then 50 to $100m^3/hr$ of air will be required for a period of 30 minutes to gas strip and oxidise the water.

Filtration stage

Application data sheets for AFM® Activated Filter Media are available from www.DrydenAqua.com the aeration is just the first stage of the process, the second stage is filtration by our AFM® filter media to remove the co-precipitated metal oxides from the water.

Annex 4: Thermal and chemical destratification of lakes

To prevent thermal stratification, algal blooms and anoxic conditions, Dryden Aqua air diffusers are used to oxygenate and ensure mixing of water in lakes or reservoirs. Fine bubble diffused aeration is used to ensure water movement by airlift which is the most cost-effective mechanism of generating mass vertical motion of water. A small amount of air can move a massive amount of water for a relatively low energy expenditure. For example, 1m^3 of air, diffused at a depth of 60m will lift in the region of 200m^3/hr of water.

Water depth in meters	Amount of water lifted by 1 m^3/hr of air passed through a diffuser
3	10 m^3/hr
4	15 m^3/hr
6	20 m^3/hr
10	40 m^3/hr
20	80 m^3/hr
30	120 m^3/hr
40	150 m^3/hr
60	200 m^3/hr

The simple act of moving the water, will improve water quality, the productivity of the system will increase and, in the case of reservoir water treatment, the water become much more stable and predictable. The zeta potential of the water will drop and the oxidation potential will increase which makes the water much easier to filter by sand or AFM® pressure or RGF Rapid Gravity Filters.

Chemically stratified anaerobic water is very difficult to treat and often has a high dissolved organic content, high phosphate levels, bacterial count and heavy contamination of metals including iron and manganese. Thermal and chemical destratification can solve many of the water quality problems, indeed, it is usually possible to downsize the scale of water treatment systems that are subsequently used to draw water from lakes or reservoirs. An ecosystem catchment area management approach to stabilisation of water quality is better than fighting nature and trying to solve biological problems by adopting a heavy engineering approach.

How does the system work?

Stratification in terms of temperature and dissolved nutrients in the water can lead to the development of toxic algal blooms, high concentrations of bacteria, legionella risk and general deterioration of water quality in the water body. Simple aeration at the deepest part of the lake has been shown to be very effective at de-stratifying ponds, lakes and even very large reservoirs. The process is remarkable by the fact that a small amount of aeration at one spot in a lake can have a tremendous impact on water quality over an entire lake containing several million cubic metres of water.

Sizing and design of a system

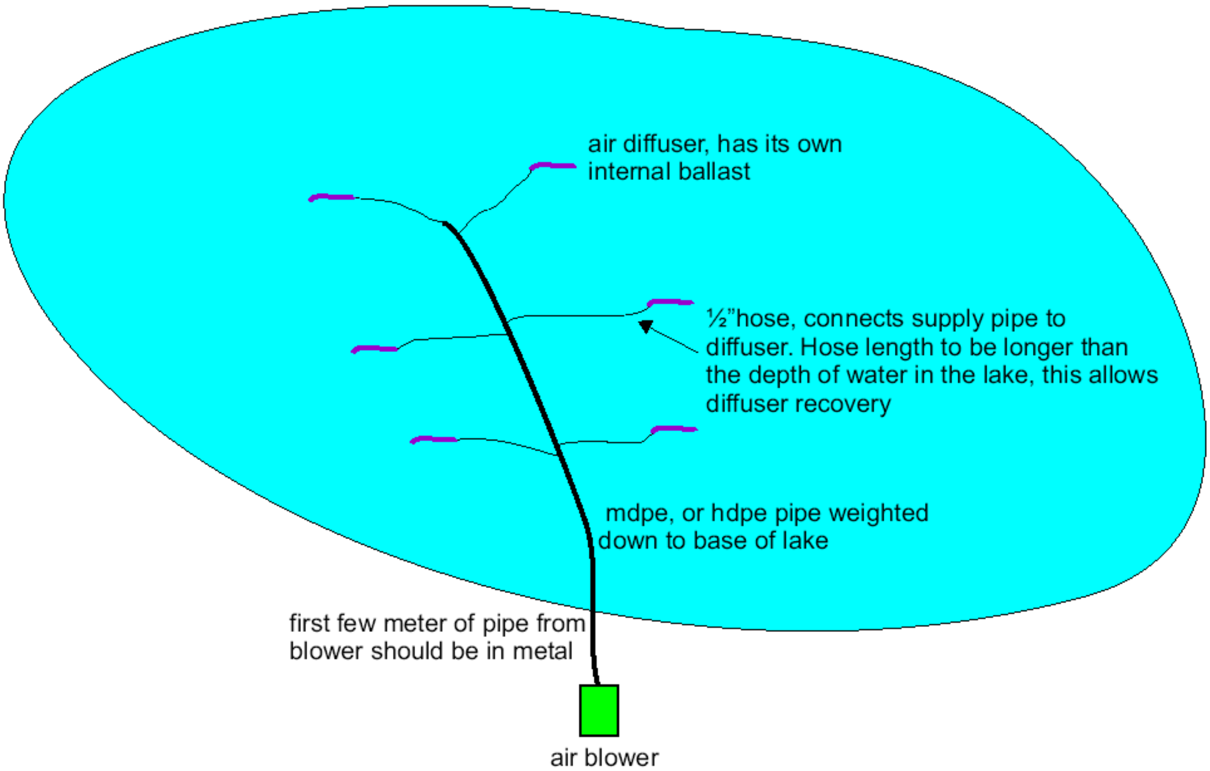
The topography of the lake bottom and its depth will have an influence on the design of the system. If the lake is shallow, with a depth from 1 to 4 metres with a large surface area, then it is best to spread the air diffusers evenly over the lake. However, if the same lake has one point where it is 10 m or deeper, then the deep hole is the part of the lake that should be aerated. The depth profile will therefore dictate the configuration of the diffusers and amount of air required.

Using the table above the amount of water lifted can be calculated. The volume of water in the lake should be estimated, once the volume is known the aeration system is then sized to move a minimum of the entire volume of water in the lake once every 7 days. As a rule of thumb in a typical 3m deep lake a minimum of 1 x 3 m diffusers or 10 m^3 of air/hr will be required for every 1,000 m^2 of water surface area. Turnover may have to be increased in the case of very shallow lakes or heavily stocked fishing lakes.

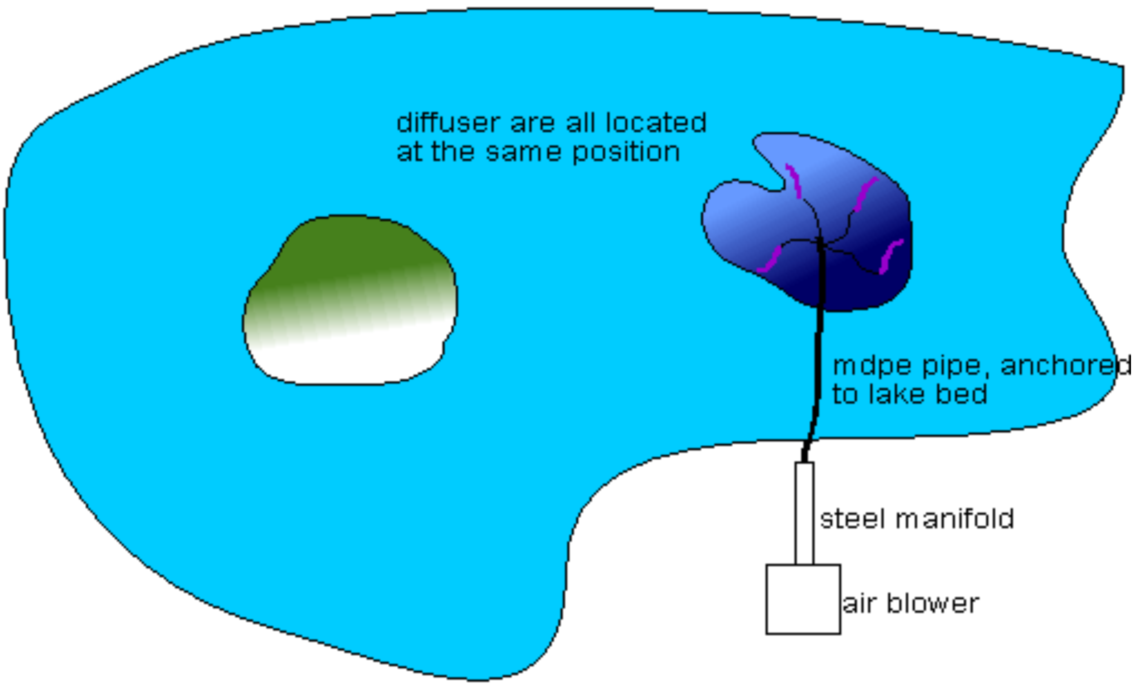
Examples of Lake aeration configurations

The following arrangements may be used for thermal and chemical destratification of lakes or reservoirs, the same approach may be used for Wetland water treatment.

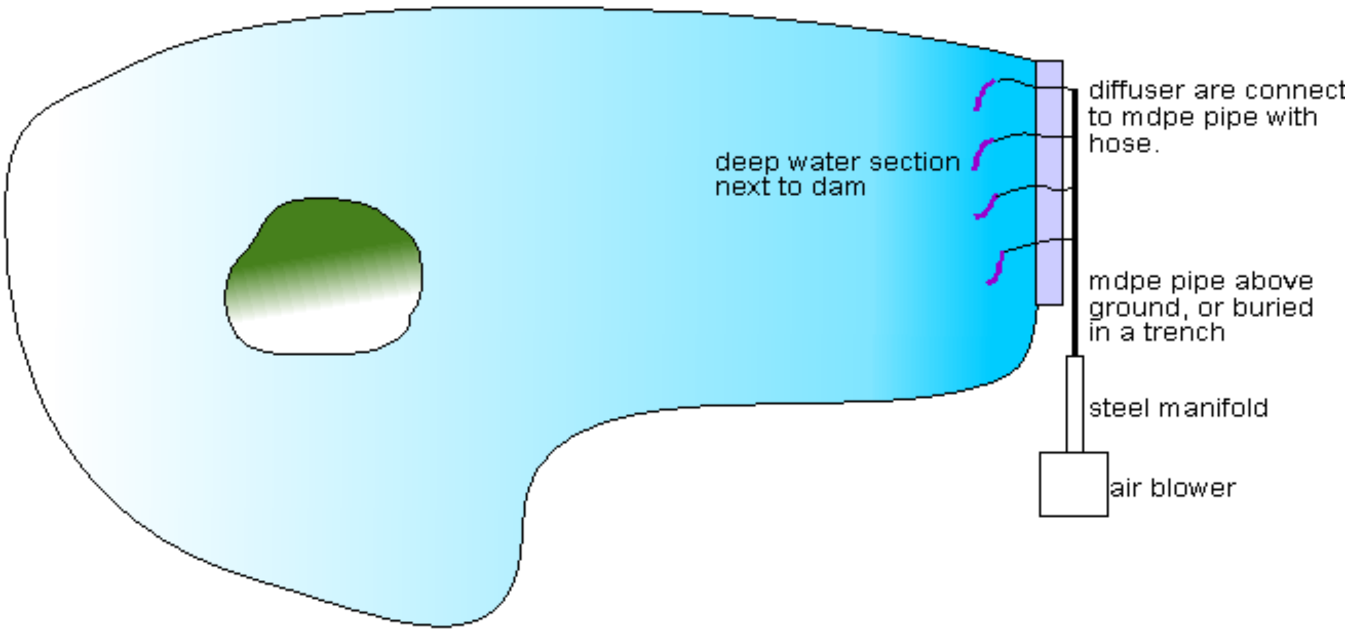
Example 1. A lake shaped like a bowl with gradually sloping sides down to the centre where the depth is constant across the base. The diffusers should be spread out over a large area across the centre part of the lake



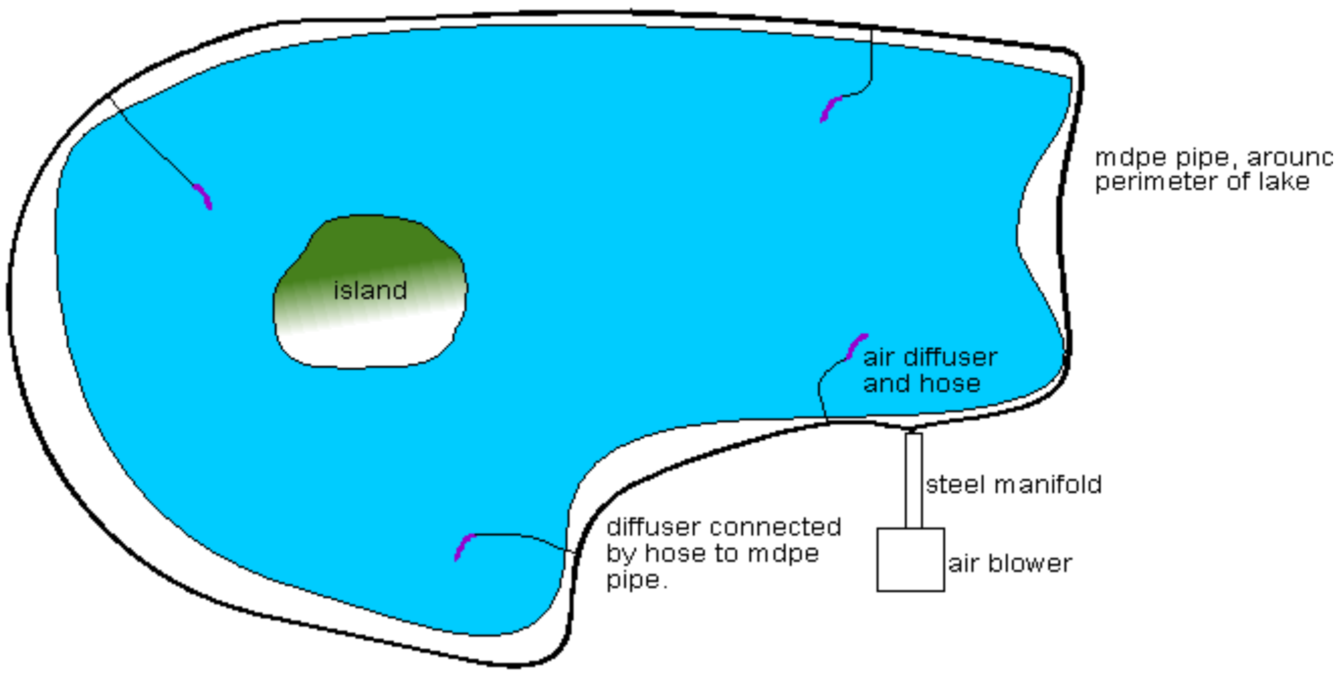
Example 2. There is a deep hole in one part of the lake, this is where all of the aeration should be focused



Example 3. There is a dam at one end of the lake, this is usually the deepest part of the lake and is the area that needs to be aerated. Avoid placing the diffusers near the exit from the lake to prevent entrainment of any air in the discharge. Air bubbles in the discharge would cause gas supersaturation and be harmful to fish and ecology of the river and may also be damaging to the turbines.



Example 4. A lake with step sides that drop down to the maximum depth of the lake. The lake will most likely have the same depth over the full area. The diffusers may be located around the perimeter, or even just around the island if system security is a concern.



Biology and chemical stability of Lake aeration systems

The first step of any pond/lake water treatment system is appropriate aeration for the thermal and chemical destratification of the lake. However, if the lake is subjected to high temperatures and has nutrient input from industry, domestic or agricultural sources, then the aeration system may require some additional help.

Phosphates

If the phosphate concentration in the water is greater than 0.1 mg/l, then phosphate levels will be promoting the growth of algae and bacteria. Consideration should be given to using NoPhos to control phosphate levels. NoPhos will react with the phosphate to form inorganic phosphate precipitate. The inorganic phosphate formed is stable and will no longer act as a nutrient to promote the growth of bacteria and algae.

Careful dosing of NoPhos can clear a lake or a pond of all algae and bacteria, yet there are no oxidising chemicals. The action is initiated purely by removing access to the food source for the organisms. In a natural pond you should not completely eliminate phosphates. For fountains or chlorinated systems, the objective should be to reduce phosphates to below detectable levels when the use of NoPhos can reduce bacterial and algal loads by over 95%.

The following series of photos are taken over a 6-week period. Note that the water progresses from being a thick algal soup to clear water. This result was achieved by controlling the phosphate concentrations using NoPhos.





Once the algae and bacterial concentrations have been reduced, the water may be treated using chlorine dioxide to control biofilm and legionella. Hypochlorous is not effective against biofilm and if you don't remove the biofilm there will always be a legionella risk. Bacteria such as Pseudomonas secrete polysaccharide alginates as a defence mechanism against oxidation by chlorine (hypochlorous), the use of chlorine in these systems, can therefore increase the Legionella risk. Chlorine dioxide is lipid soluble and will diffuse into the biofilm to kill the bacteria. Chlorine dioxide may be used in combination with hypochlorous as a much more effective protection from Legionella.

Algal biodiversity

It is always better to work with nature rather than to fight the process, this applies in natural ponds and lakes, or even in chlorinated systems. Silicates and ferric are micro nutrients for algae, and by the addition of silicates the ecological biodiversity can be shifted in favour of diatoms. The Diatoms are large and wonderful food for crustacea and fish. Water quality will initially deteriorate, but then a new balance will be established, and the water will go clear.

Annex 5: Agricultural waste water

Dryden Aqua air diffusers are used for the treatment of farm slurry waste; the systems are however applicable to any animal waste. In the UK the majority of the applications are for cattle, swine and chicken waste water.

Most farms have lagoons or large tanks that are used to collect the animal waste. The simplest system would be to use our drop-in air diffusers and aerate the tank containing all the solid as well as liquid waste. Aerobic bacteria will become established; the smell will be eliminated, and the effluent generated will be greatly improved. The system can be further optimised by following the design outline and sizing instructions presented in the following section.

Design criteria

The animals produce a solid as well as a liquid waste, the solid waste should be separated from the liquid waste by using a screened sludge pump. The solid waste can then be composted, and the liquid waste sent for treatment. In some cases, the solids are not separated, and all the waste is aerated by our diffusers

Air diffusers

1 x air diffuser and 10 m3/hr of air will mix the slurry from 20 cattle or 100 swine. If several diffusers are required a large diameter polyethylene pipe can be fitted around the perimeter of the tank with diffusers connected via ½" flexible hoses and dropped in to the tank.

Parameter ***(the waste water should be screened with a sludge pump or filtered down to 1,000 microns) the data presented is for screened waste water***	**Typical values mg/l**	**Performance**
COD	4,000	>95%
BOD	3,500	>99%
Ammonium*, the ammonium will be removed by assimilation as well as nitrification, so nitrate concentrations will increase*	1,000	>99%
Suspended solids *(if AFM® is installed on the system then performance is improved to 99%)*	1,000	>90%

Aeration in the shed

Air diffusers can be used in the cattle shed to aerate and mix the slurry below the floor. The air diffusers will keep the slurry aerobic and will eliminate many of the noxious gases, this will improve the health and wellbeing of the animals as well as reduce respiratory disease and improve FCR (food conversion ratio).

Note that it is critically important that when the air diffusers are turned on for the first time, there must be no animals in the shed. Noxious fumes of methane, carbon dioxide and hydrogen sulphide may be discharge for a few minutes after turning on the air diffusers. Once the diffusers have been turned on they must never be turned off. If the diffusers are turned off for more than one hour, then the animals must be removed from the building before it is turned back on.

Treatment of the waste water

Stage 1, dewatering

The first stage involves the removal of solid matter. The waste must be screened using a filter or a screened sludge pump to remove all solids above 1,000 microns. The pump generates a solid waste and a liquid waste.

Stage 2, aeration activated sludge

The waste water exits the shed and enters a series of tanks or open lagoons connected in series. The tanks / lagoons are operated as sequencing batch reactors (SBR) or as serial displacement.

If the system is not operated as an SBR but as a simple serial flow arrangement, then a decantation tank is required as the last stage for sludge collection / disposal or bacterial solids recycling.

A typical system for 1,000 cattle would comprise 100 diffusers code 70008, and two roots type air blowers fitted with a 22 kw motor. There will be two or more tanks connected in series, and the total volume in the tanks should give as long a residence time as possible, we recommend 40 + days for best results.

For water treatment 1 x diffuser and 10m^3/hr of air is required per 10 cattle or 20 swine.

Stage 3. AFM tertiary treatment

The effluent from the SBR or decantation tanks should have a suspended solids level below 100mg/l. This effluent can be clarified with flocculants and then filtered by AFM to reduce the suspended solids content down to <5 mg/l.

Technical notes

Some additional information

animals	**Number of air diffusers required to treat the effluent**
swine	5 diffusers and 50 m^3/hr of air is required to treat wastewater from 100 swine. The solids will have been removed, from the wastewater by screening down to 1,000 microns prior to water treatment.
cattle	20 diffusers and an air flow of 200 m^3/hr is required to treat wastewater from 200 cattle. The solids will have been removed, from the wastewater by screening down to 1,000 microns prior to water treatment.

1 x diffuser and 10m^3/hr of air is required to treat the waste from 10 cattle of 20 swine. If the requirement is restricted to mixing the sludge in the shed or a tank, then 1 diffuser may be used per 20 cattle and 40 swine.

Slurry (de-sludged)

The solid matter should be removed from the liquid component. The solid matter can be composted, and the liquid matter treated.

A typical cattle farm raw waste will have the following characteristic

- 56 litres of liquid per day with 6% solids content
- 600 g/BOD and approx. 1.2 kg COD
- 100 g of ammonium nitrogen
- 30g of phosphates

Residence time of slurry in aeration tank 40 to 50 days, summer - winter

The system may require additional calcium and pH correction using MagpHlow (MgO_2), to stop the water from becoming acidic. However, on start-up of a new system with high ammonium levels, acid may need to be added to bring the pH down to 7.5. Once the bacteria are established, the pH will start to fall, which is when MagpHlow media or caustic is needed to bring the pH back up to pH7 to pH7.5.

Note:
The system will not only eliminate odour and mix the waste, but the addition of AFM® filtration will provide class 1 irrigation water / fertiliser.

Annex 6. Aeration of Aquaculture systems

Dryden Aqua have been supplying diffusers and aeration systems to the Fish Farming Industry for many years. We have continued to develop our systems, improve the efficiency of our diffusers, and refine the performance of our aeration system under many different fish farming conditions. A list of some of the applications are included below;

- smolt production, fish transportation by lorry/helicopter/ship
- land based salmon farms, lobster holding units
- cage based salmon farms
- depuration systems
- trout ponds/raceways
- seabass and bream
- shrimp tanks and ponds
- tilapia, milkfish
- barramundi, crayfish

Dryden Aquaculture diffusers and aeration systems are used with a wide variety of species and types of systems, a more detailed review of some of these applications is detailed below.

Efficiency & sizing of system

The efficiency of an aeration system is related to a number of key environmental parameters. If you wish Dryden Aqua to determine your farms aeration requirements some basic information is required of your facility. The following information is all relevant and the more information the more accurate the dimensioning of the system;

- Provide a schematic plan of your farms showing tank spacing
- Dimensions of tanks
- Water depth
- Species of fish/crustacean
- Water flowrate through the tanks
- Type of enclosure, e.g. earth pond/concrete/fibreglass
- Maximum stocking density
- Maximum size of the fish
- Maximum water temperature
- Details on water quality
- Soft or hard freshwater, or sea-water
- Source of water e.g., spring/borehole/river/lake
- Detailed water analysis of water if available, especially BOD / COD
- Salinity of the water

Dryden Aqua diffusers are about 5 times more efficient at moving water and providing oxygen in comparison to any mechanical surface aerator, because kinetic energy is not wasted in throwing the water up into the air or in moving mechanical machines.

At 20^{o}C in relatively shallow 0.75 - 1m deep tanks an air flow of 10m^3/hr of air will deliver on average 250 to 500g per hour of oxygen. In seawater systems, or if the salinity of the water is over 15 ppt, then bubble size is smaller and oxygen transfer efficiency is 350 to 600g/hr. If you know the oxygen demand of the stock, then you can calculate the approximate amount of air and the number / size of diffusers to meet the demand. Another rule of thumb guide is based on the amount of food given to the fish. If you feed 20kg of feed into a tank each day, then you need to deliver 30kg to 40kg of oxygen per day to allow the fish to metabolise the feed.

Water depth, water temperature, salinity and lipid content of the water as measured by DOC, BOD or COD will all impact on O_2 transfer efficiency. Lipids make the bubble size much larger and reduce oxygen transfer. Oxygen tension is also important, at 100% saturation, oxygen transfer is zero, however as the partial pressure of oxygen drops, oxygen transfer increases exponentially.

The air blower should be a 100% oil free positive displacement unit, such as a rotary vane compressor for air flows under 200m^3/hr and a roots type or rotary lobe blower operating at a maximum of 1 bar pressure above 200m^3/hr free air delivery. Actual operating pressure will be a function of hydrostatic heads and pressure drop in the pipework. Typically, the operating pressure is 0.5 bar and oxygen transfer is 5 kg of oxygen per kilowatt of energy expended. The Dryden Aqua fine bubble air diffusers generate a mass vertical movement of water, oxygen transfer therefore results from diffusion through the bubbles, but also transfer from the surface. With paddle wheel aerators or surface aerators, apart from the initial transfer of oxygen to the water, there is little transfer or vertical mixing of the water. For very large ponds, a combination of paddle wheel aerators for horizontal flow and fine bubble air diffusers for vertical mixing can prove very effective.

Smolt production units

In the case of salmonids, the oxygen concentration should be maintained above 7mg/l to avoid stressing the fish and to ensure good feed conversion. If the concentration is between 6 and 7mg/l the fish will all survive. They will however be under a small degree of stress which will affect feed conversion and their resistance to disease. Between 4mg/l and 6mg/l fish mortalities can be expected, the number of mortalities will be related to the condition and well-being of the fish. Below 4mg/l the fish will be under severe stress and mass fish mortalities are likely.

For smolt production units our aeration systems are sized to meet 100% of the oxygen requirements of the fish and to maintain the dissolved oxygen concentration at approximately 70% saturation with no influent water to the tanks. Some of the benefits which can be gained from our aeration systems are given below.

- As security for approximately 24 hours against complete failure of the influent water. The time limit is dictated by ammonium concentrations.
- To support the fish during periods of low water flow rate and or high-water temperatures.
- To support the fish during disease treatments.
- For aeration systems on tank-based farms
- For peace of mind that fish will not be lost through low oxygen during pump failures etc.

Sizing a system

The amount of air required depends on the depth of water in the tank, salinity, water temperature, size of fish and amount of feed given to the fish. If there is no water flow though the tank, then it is essential that no feed is given to the fish, on two accounts:

1. The feed will exert an additional oxygen demand

2. Lipids from the feed destabilise the zeta potential. Bubble size from the diffuser will then increase and oxygen transfer will decrease.

Given that there are many variables, the following calculation should be taken as a guide. The amount of air required is based on the maximum biomass of fish that will be held in the tank. While smaller fish have a greater oxygen demand per unit mass, more oxygen will be required at the higher stocking densities with larger smolts. The volume of air required is based on 1000kg of fish at water temperatures below and above 15°C

- 1000kg of smolts below 15°C, require = 10 - 20m^3/hr of air

- 1000kg of smolts above 15°C, require = 20 - 30m^3/hr of air

Select the size and number of diffusers to give the required air flow, refer to page 4, or our website at www.DrydenAqua.com

The choice of air blower will usually be a rotary carbon vane for air flow under 200m^3/hr of air and a rotary lobe above 200 m^3/hr. The limitation is 1 bar discharge pressure and tank depth of approx. 5 metres with the blowers. The air diffusers may be used down to any depth.

Trout Farms Aeration & Oxygenation

In the case of large-scale trout farms with earth ponds, oxygen concentrations in the water tend to be variable due to different soil types and degree of fouling in the pond. Some rivers, especially slow meandering rivers, tend to exhibit massive fluctuations in dissolved oxygen concentration over a 24-hour period. An aeration system should therefore have the capacity to cope not only with the oxygen demand of the fish but the diurnal change in levels of the influent water, and oxygen requirements due to respiration of the pond.

In comparison with salmon smolts, rainbow trout are more tolerant of low dissolved oxygen levels, however due to the nature of the environment detailed above, an equivalent amount of aeration is often required.

Oxygen concentrators/generators are often proposed for trout farms. In these cases, in order to make maximum use of the oxygen, medium to high pressure oxygen injection systems capable of achieving supersaturation levels are sometimes used. However, if the output from the concentrator is not 100% pure, then nitrogen gas will also be injected into the water along with the oxygen. Under these conditions gas bubble disease can develop. The oxygen should therefore either be diffused into the water or injected into the water under ambient atmospheric conditions.

We believe Dryden Aquaculture has installed the largest trout farm aeration systems in the UK. The systems are monitored with D.A. dissolved oxygen monitoring systems which are also used to control the air blowers, thus maximising the efficiency of the system.

By preventing the development of low dissolved oxygen levels the stress to which the fish are exposed is minimised. This has been shown to result in improved feed conversion as well as a greater resistance of the fish to disease such as PKD. In terms of feed conversion only, our aeration systems have been shown to give a payback in 1 to 2 years. When improved quality, reduced disease outbreaks and security of the system from pollution incidents are taken into account, the return in capital can often be measured in weeks or months.

The aeration systems increase the level of oxygen discharged from the fish farm, this level can be set so as to maintain levels of oxygen above minimum discharge criteria. Diffused aeration of the water also improves water quality in the ponds by reducing ammonium levels, anaerobic conditions, BOD and stabilising the pH. Aeration therefore greatly improves the environmental conditions for fish and also improves the quality of the water discharged from the farm.

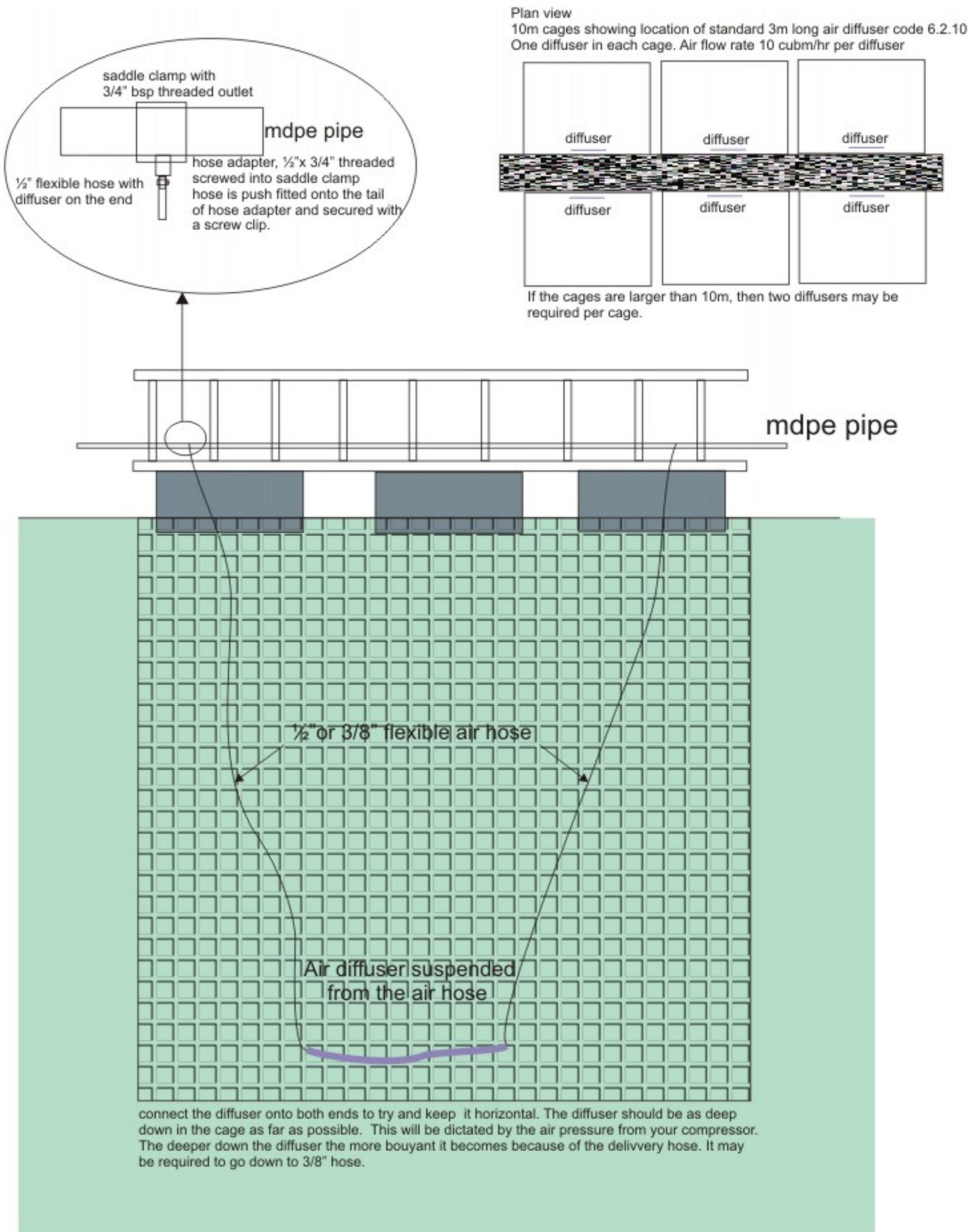
As a general guide 10 to 20 m^3/hr of air are required per tonne of trout.

Sea cage airlift aeration and destratification system

Dryden Aqua have developed an aeration system for use in sea cages to help mix the water in the cage. The following section presents a description of the system. The system comprises the following components

1. Air blower (s)
2. Air blower discharge metal pipe
3. Air ring main
4. Hose fittings
5. Air diffusers

The system is designed just to move water and bring clean water into the cage to provide oxygen and also help to remove waste water and protect the cage from jellyfish. The air diffusers may be located at a depth of 6 to 10 metres or more below the surface. The great depth induces a mass upwelling of water from below the cage, thus a relatively small amount of aeration can deliver a massive amount of oxygen. Typically, 1 x diffuser and 10m^3/hr of air will be sufficient for up to 10 tonnes of salmonids or most species of about 0.5 kg in size.



DRYDEN AQUA

Tropical shrimps, seabass, bream & tilapia etc

Our aeration systems are in use for a wide range of species including sea bass & bream, tilapia, catfish and tropical shrimp such as *Litopenaeus vannamei, Penaeus monodon and Penaeus japonicus.*

In tank culture systems for sea bass, bream and tilapia, aeration requirements are calculated taking into account the environmental conditions prevailing in the tanks. Aeration is employed in order to achieve production stocking densities. Due to the high-water temperature, the air requirements are often approximately twice the level required by salmonids or cold water (<15°C) tank-based systems. The situation is however very different for pond culture of marine fish and crustaceans.

The aeration efficiency and water mixing characteristics of the diffusers are enhanced in marine applications, such that a relatively small amount of diffused aeration can have a tremendous impact on the oxygen levels and quality of the water. In a shrimp pond environment, it is easily possible to circulate the entire water volume in the pond every 10 minutes, thereby preventing thermal stratification and stabilising water quality.

An installation of a simple diffused aeration system in a shrimp pond 30m x 30m x 2m deep with 4 diffusers and 40m^3/hr of air will turn over the water every 10 minutes and could provide 100% of the oxygen demand of the shrimps (or fish) depending on the stocking density.

- In temperate waters 4 diffusers and 40m^3/hr of air could support 4 tonnes of shrimp….10m^3/hr of air & 1 x 3m diffuser/tonne of fish.

However, tropical waters and under conditions of higher stocking density and higher feed levels,

- at water temperatures above 25°C, 4 x diffusers and 40m^3/hr of air are required per tonne of shrimps/fish.

To summarise, water depth, temperature and feed intake must always be taken into account when determining air and diffuser requirements:

- For temperature and water depth see tables on pages 4 & 6.
- At temperatures of up to 20°C, if you feed 20kg of feed into a tank each day, then you need to deliver 30kg to 40kg of oxygen per day to allow the fish to metabolise the feed………1 – 1.5kg of O_2 per day per kg of feed.