NITROGEN TREATMENT IN LAGOONS

Dr. Rakesh Govind
Professor of Chemical Engineering
University of Cincinnati and
President, PRD Tech, Inc.

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NITROGEN REMOVAL

- Over 7000 lagoon systems are used in the United States for the treatment of municipal and industrial wastewater, under a wide range of weather conditions;
- Nitrogen removal capability of wastewater lagoons has been given little consideration in system designs until the past 10 years or so; ammonia is toxic to fish and nitrate in effluent can limit spray irrigation;
- Ammonia-N removal in facultative wastewater stabilization lagoons can occur through the following three processes:
  - Gaseous ammonia stripping to the atmosphere,
  - Ammonia assimilation in algal biomass, and
  - Biological nitrification.

AMMONIA VOLATIZATION

$$[H^+] = \frac{K_W}{[OH^-]}$$

$$C = NH_4^{\ +} + NH_3$$

$$NH_3 = \frac{C}{1 + 10^{pK_W - pK_b - pH}}$$

$$pK_W = -\log K_W = -14$$

$$T = \frac{0.5AT_a + QT_i}{0.5A + Q}$$

A = surface area of pond, m^2

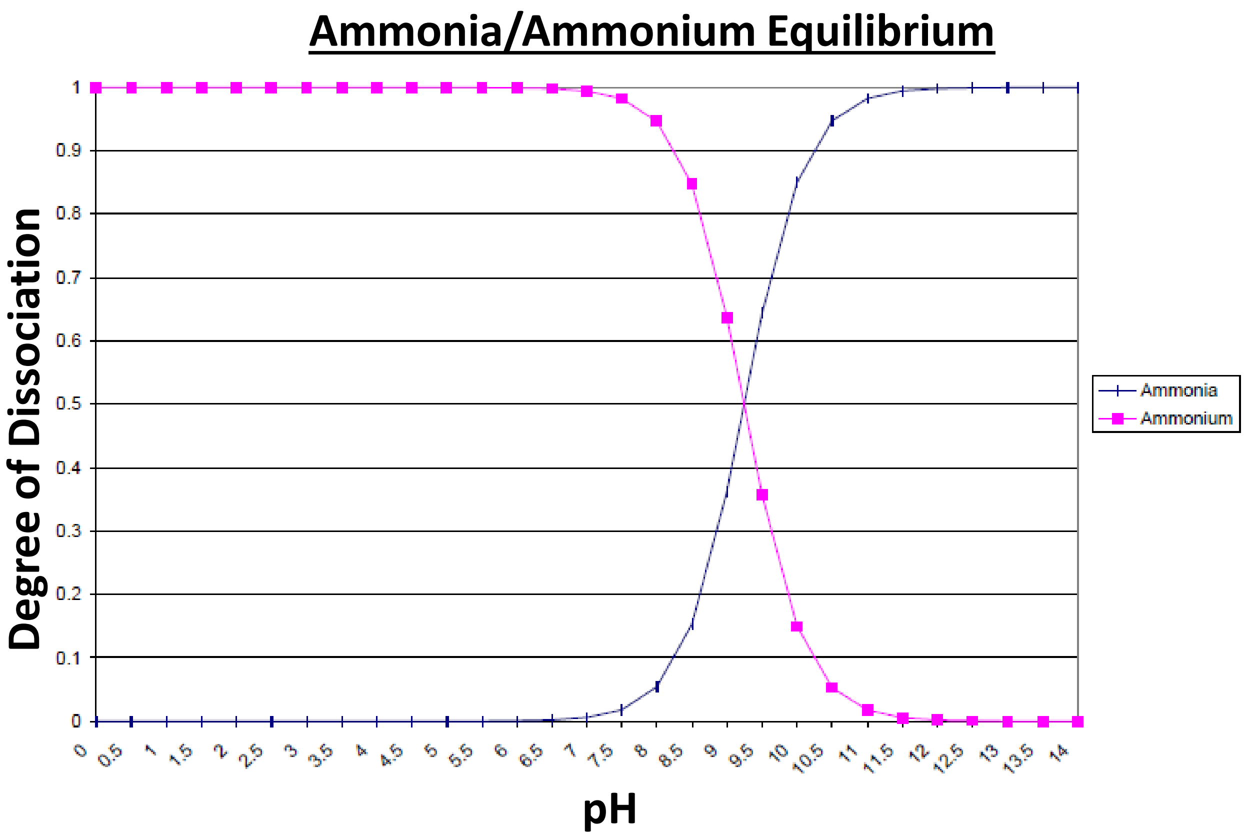
T_a = ambient air temperature, ^oC

T_i = influent temperature, ^oC

Q = influent flow rate, m^3 / day

$$\mathbf{pH = 7.3e^{0.0005ALK}}$$

where: ALK = expected influent alkalinity mg/L



At typical operating pH of 8.0, 95% of ammonia-N is in the form of ammonium, and hence volatilization losses are low

NITROGEN REMOVAL MODELS

Ammonia nitrogen assimilation into biomass depends upon the biological activity in the system and is affected by several factors such as temperature, organic load, detention time and wastewater characteristics;

In lagoons with sludge depths above 2 ft, anoxic decomposition of sludge at the bottom of Lagoon releases Volatile Fatty Acids (VFAs) and ammonia into lagoon water; VFAs contribute to cBOD in the lagoon effluent; Dredging is expensive and generates substantial waste material;

$$\mu = \mu_m \frac{N}{K_N + N} \frac{O_2}{K_{O_2} + O_2} \left[1 - 0.83(7.2 - pH)\right]$$

N = concentration of ammonium ion, mg/L

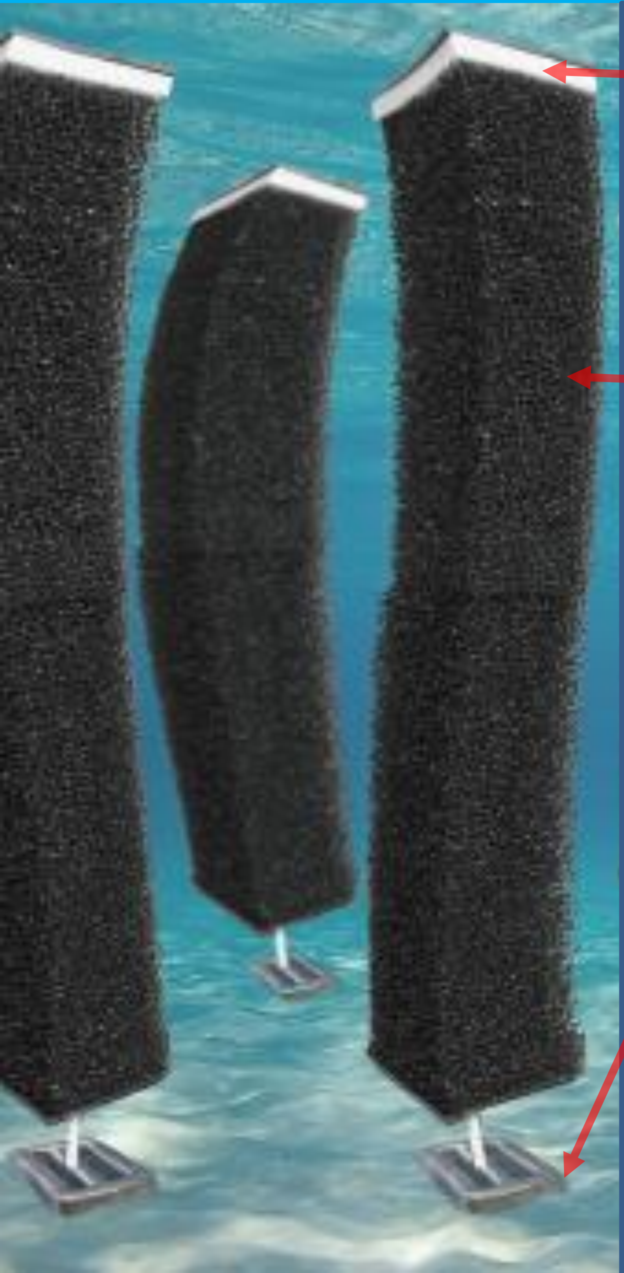
O_2 = concentration of dissolved oxygen, mg/L

K_{O2} = half-saturation constant for dissolved oxygen, mg/L

$$\mu_m = 10^{0.0413T - 0.944}$$

$$K_N = 10^{0.015T - 1.158}$$

WAVING BIOMEDIA IN LAGOONS

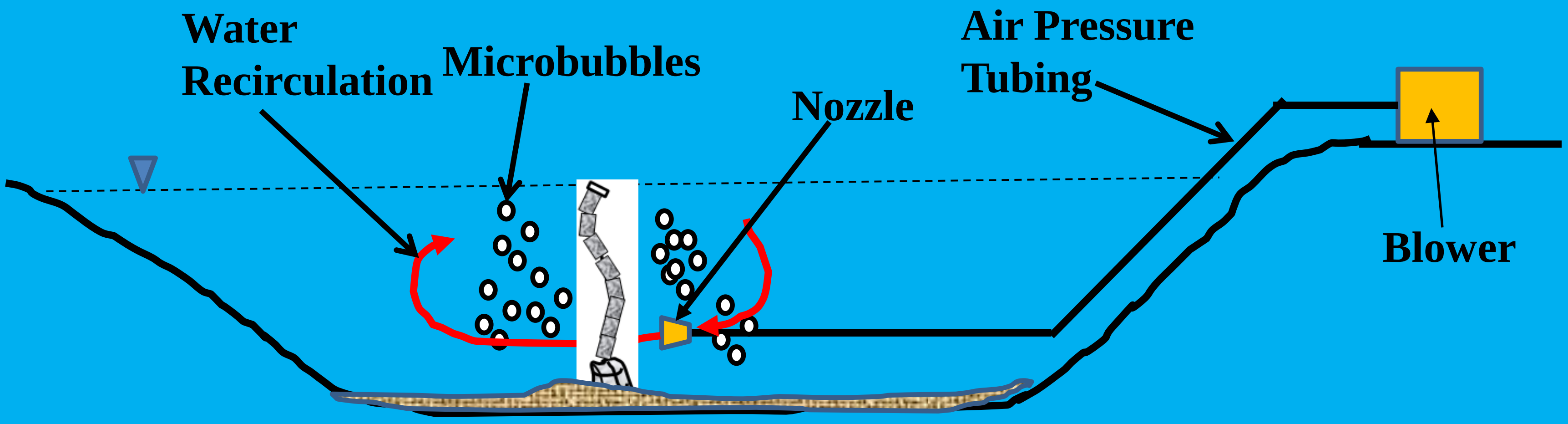


Flotation Foam to ensure that biomedia stays buoyant in the water, even after biofilm growth

Biomedia waves around in the water; High surface area, coated to allow rapid growth of active biofilms; treats BOD and denitrifies Nitrogen content in wastewater

Weighted down to keep biomedia in place

IN-SITU LAGOON WATER TREATMENT



In-Situ **Water Treatment is achieved with no water pump around system.**

Media stack waves around in the water, but stays in place, as the water moves around it, and gets treated by the active biofilms on the surface of the biomedia

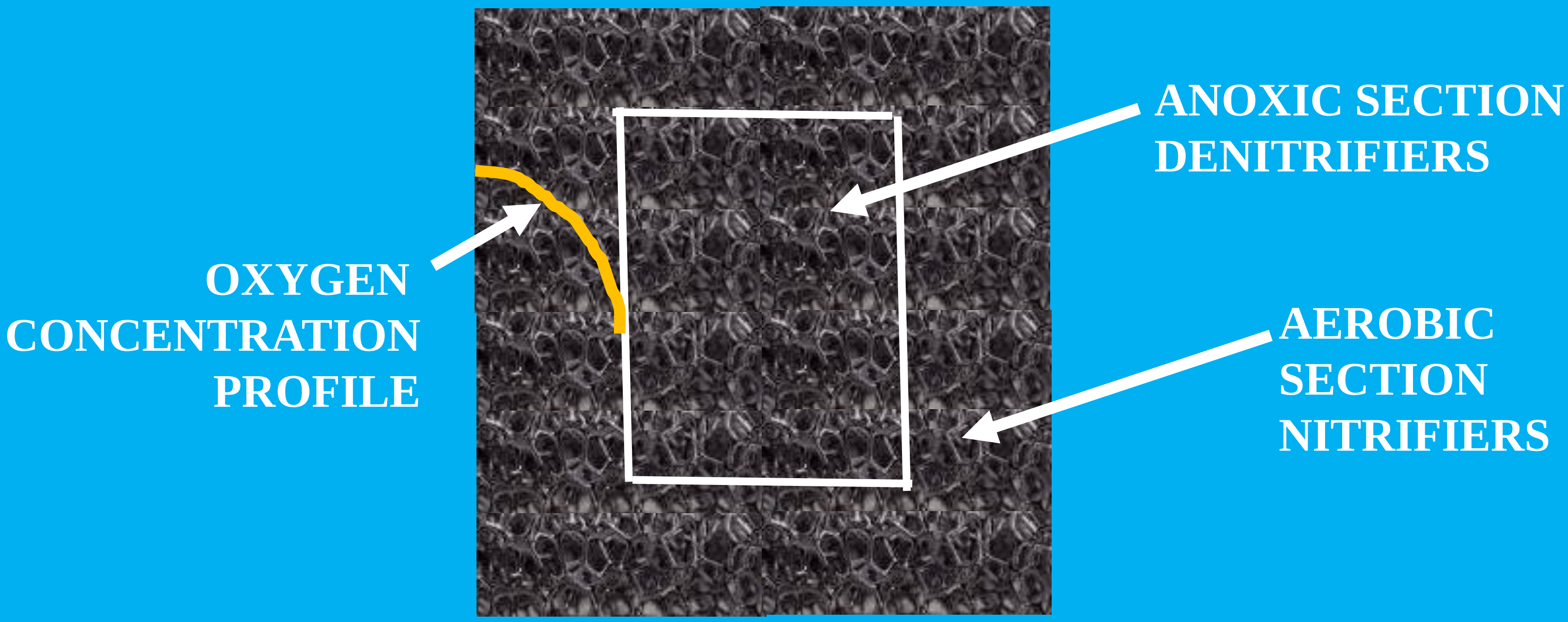
The air is injected in the form of microbubbles at the bottom of the Biomedia stack, and provides dissolved oxygen in the recirculating water

Several Biomedia stacks in one lagoon can effectively treat the water

The air blower is kept outside the water for easy access.

NITRIFICATION/DENITRIFICATION

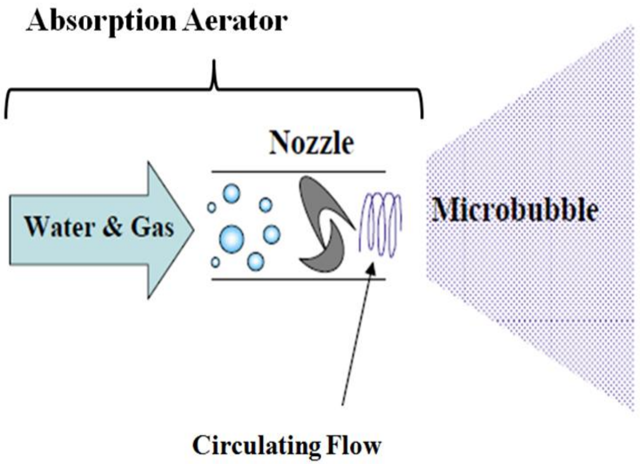
FOAM USED IN WAVING BIOMEDIA



- **Waving Biomedia increases active biomass concentration from 200 – 500 mg/L in facultative lagoons and 1,200 – 2,000 mg/L in aerated lagoons, to 14,000 – 16,000 mg/L, thereby increasing biotransformation rates;**
- **Waving Biomedia retains nitrifiers and denitrifiers; and**
- **Increases sludge retention time (SRT), which allows biomass to decay and not accumulate in lagoon.**

MICROBUBBLE AERATION

ABSORPTION AERATOR MECHANISM

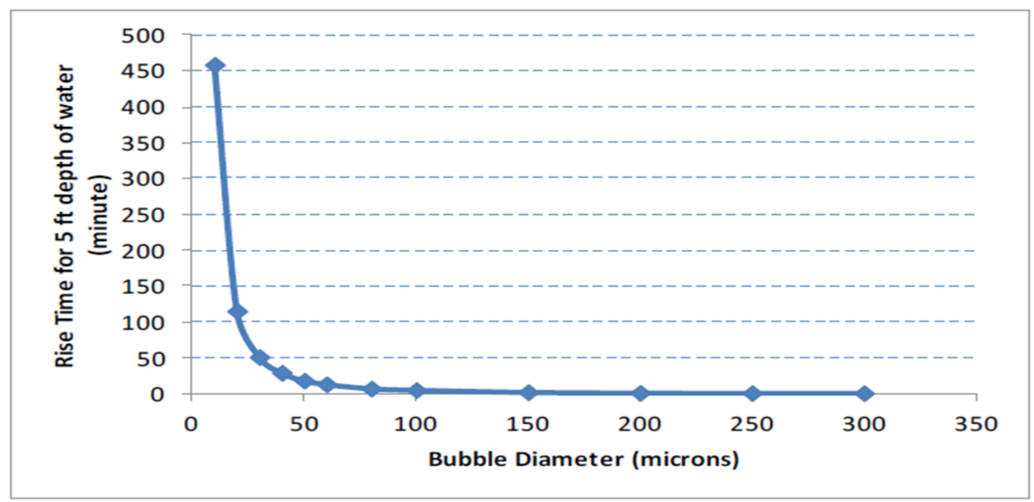


- Following are various AOTR's for mechanical aeration devices: lbs. O_2/hp/hr
- **Absorption Aerator** **2.73 -3.06**
- Surface aerator w/draft tube 1.2 - 2.1
- Surface high speed 1.2 - 2.0
- Submerged turbine 1.0 - 2.0
- Submerged turbine/sparger 1.2 - 1.8
- Surface brush and blade 0.8 - 1.8
- Fine Bubble Diffusers 0.5 - 1.5

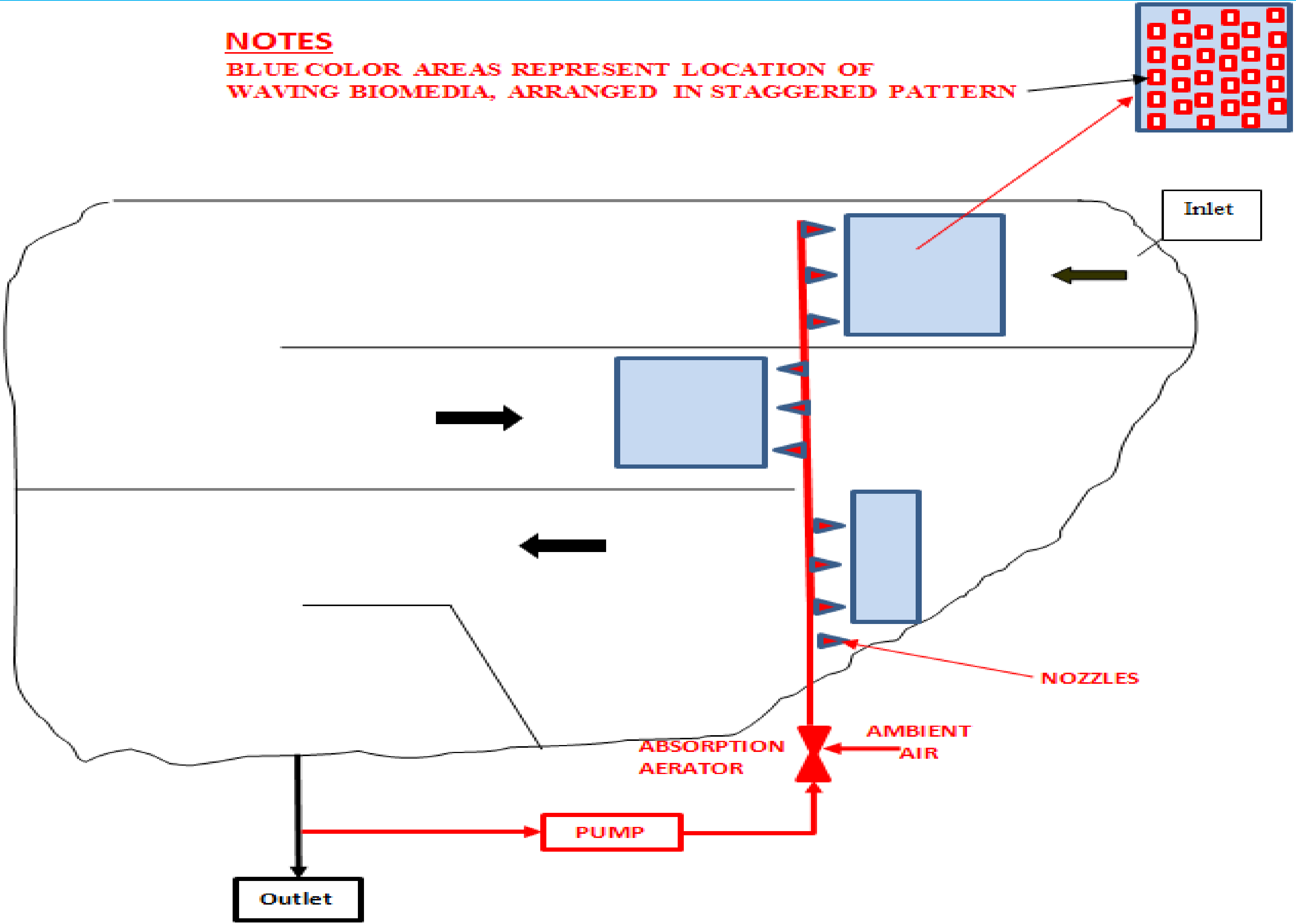
Bubble Size (μm)	Production Method	Properties
> 50	Submerged aeration, sparging, surface aeration, etc	Bubble coalesce into larger bubbles, rise quickly and break on the surface; oxygen transfer efficiency is less than 10% in clean water and less than 6% in wastewater
< 50	Absorption Aerator	Negatively charged surface of bubble prevents coalescence and bubble spends enough time within the water to achieve enhanced oxygen transfer; Once the bubble size becomes smaller than 10 μm due to air dissolution, the bubble does not rise to the surface, since its mass is balanced by its buoyancy; Microbubbles smaller than 10 μm effectively attach to submerged surfaces, thereby never rising to the water surface

RISE TIME FOR MICROBUBBLE

(Depth of water = 5 ft)



APPLICATION OF WAVING BIOMEDIA AND MICROBUBLE AERATION IN LAGOONS



LAGOON PERFORMANCE SIMULATION

LAGOON WITH WAVING MEDIA
Waving Media Bioreactor (WMBR)

Lagoon Information		
Name of Lagoon	Lagoon 1	
Volume of Lagoon	5,264,963	Gallons
Length of Lagoon	425	feet
Width of Lagoon	400	feet
Depth of Lagoon	15	feet
Influent Wastewater flowrate	1,300,000	gallons per day (gpd)
Influent temperature	77	deg F
Lowest Ambient Temperature	40	deg F
Highest Ambient Temperature	85	deg F
Number of cells in lagoon	1	
Type of Aeration system	Facultative	Surface Aerators: 1; Submerged Bubble Aeration: 2 Absorption Aerator: 3
Influent Biological Oxygen Demand (BOD)	8091	mg/L
Influent Total Suspended Solids (TSS)	2277	mg/L
Influent Total Kjeideihl Nitrogen (TKN)	96	mg/L
Influent Ammonia (NH3)	0	mg/L
Influent Chemical Oxygen Demand (COD)	24272	mg/L
Dissolved oxygen concentration in Lagoon	3	mg/L
pH of water in Lagoon	7	
Desired BOD Removal Efficiency in Lagoon	92	%
Desired TKN Removal Efficiency in Lagoon	92	%
Power from Surface aerators in Lagoon	0	HP

LAGOON PERFORMANCE SIMULATION

Kinetic Rate Constant for BOD at 20 deg C	1.2	day-1
Yield of Biological Solids by BOD degradation	0.67	
Temperature parameter for kinetic constant	1.06	
Biomass decay constant	0.07	day-1
Ratio of Volatile Suspended Solids to Total Biological Solids	0.8	
Conversion factor from BOD5 to BOD liquid	0.68	
Rating of surface aerators	3	lbs oxygen/hp.hr
Dissolved Oxygen concentration at 20 deg C	9.08	mg/L
Horse power required for complete mixing	0.6	hp/1000 ft3
Surface area of Waving Biomedia	280	ft2/ft3
Volume of each Wave Biomedia (4 in x 4 in x 6.5 ft)	0.72	ft3
Surface area of each Wave Biomedia	202.22	ft2
Maximum BOD Treatement Rate by Biomedia	0.005	lb BOD/ft2.day
Maximum TKN Treatment Rate by Biomedia	0.0004	lb TKN/ft2.day

LAGOON PERFORMANCE SIMULATION

Design Calculations		
Surface area of Lagoon	170000	ft2
Lowest Lagoon Water temperature	54.4	deg F (If this is less than 32 deg F, there is possibility of freezing)
	12.4	deg C
Highest Lagoon Water temperature	81.9	deg F
	27.7	deg C
Hydraulic Retention Time	14.67	days
Kinetic constant for BOD in winter	0.7727	day-1
Kinetic constant for BOD in summer	1.8811	day-1
Exit BOD concentration in summer without Waving Biomedia	282.91	mg/L
Treatment Efficiency in summer without Waving Biomedia	96.50	% reduction in BOD
Exit BOD concentration in winter without Waving Biomedia	655.83	mg/L
Treatment Efficiency in winter without Waving Biomedia	91.89	% reduction in BOD
Concentration of Biological Solids Produced without Waving Bior	2581	mg/L VSS in summer
	2458	mg/L VSS in winter
Suspended Solids in the Lagoon before settling without Waving B	5503	mg/L in summer
	5349	mg/L in winter
Amount of biological solids produced that settle	27981	lbs of sludge/day in summer
	26645	lbs of sludge per day in winter
Effluent TKN Concentration without Waving Biomedia	40	mg/L
Effluent Ammonia concentration without Waving Biomedia	0	mg/L
Oxygen consumption without Waving Biomedia	75404	lbs/day in summer
	71936	lbs/day in winter
Dissolved Equilibrium Oxygen Concentration in water.	10.71	mg/L in winter
	7.91	mg/L in summer
Correction factor for Oxygen Dissolution	0.60	at winter temperature
	0.55	at summer temperature
Field Transfer Rate of Oxygen	1.81	lbs oxygen/hp.hr at winter temperature
	1.66	lbs oxygen/hp.hr at summer temperature
Horse Power required for surface aerators, if surface aerators ar	1896	HP in summer
	1656.80	HP in winter
Surface Aerator Power required for complete mixing	422	HP
Degree of mixing in Lagoon	0.00	

LAGOON PERFORMANCE SIMULATION

Design Calculations with Wave Biomedia (WMBR) & Aeration		
Surface Area of Wave Biomedia needed	321,851	ft2
Number of Wave Biomedia pieces needed	1592	
Additional Oxygen Needed by Absorption Aerator	2910	lbs of oxygen/day
Flowrate of Recycle Water	416	gpm
Number of nozzles in Lagoon	14	
Flowrate through each nozzle	30	gpm

CONCLUSIONS

- **Facultative and aerated lagoons are unable to remove nitrogen effectively, due to limited concentrations of Nitrifiers and Denitrifiers, lack of dissolved oxygen and low temperature, in winter;**

- **Use of Waving Biomedia retains and increases concentration of active biomass, including nitrifiers and denitrifiers, thereby reducing total nitrogen concentrations in the effluent; spray irrigation of lagoon effluent requires low nitrate levels;**

- **Microbubble aeration increases dissolved oxygen levels and mixing levels in the lagoon, thereby improving lagoon effluent quality; and**

- **Lagoon computer simulation program, allows treatment levels to be determined with and without Waving Biomedia and microbubble aeration.**