# $PRO_2$ System Overview

# PURE $O_2$ AERATION

Separation
Oxidation
Remediation

# History - Super-Saturation Technology

- Wayne State University Patents Originating from Medical Application
- TherOx Develops Medial Application for Dissolving Oxygen into blood plasma for cardiac remediation
- New Patents Developed for Wastewater applications under DynamOx (12 Years of field demonstrations)
- Blissfield develops $PRO_2$ and is granted exclusive license from DynamOx, TherOx and Wayne State for wastewater applications.

# PRO$_2$ System
## Hyperbaric Gasification IP

**Wastewater Patents and Patents Pending:**

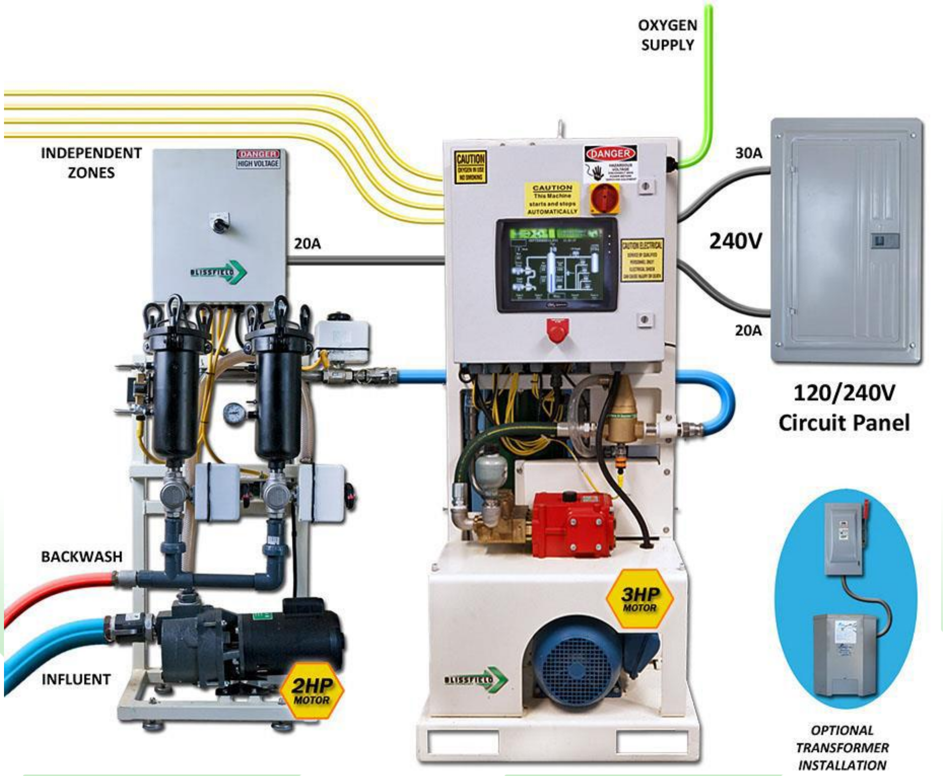
| | |
|---|---|
| US 13/602,793 | Apparatus and Method for Atomizing Fluid |
| US 12/64,663 | Apparatus and Method for Gas Enriching a Liquid |
| US 7,008,535 | Apparatus and Method for Oxygenating Wastewater |
| JP 2002-517196 | Apparatus and Method for Oxygenating Wastewater (Japan; pending) |
| JP 2012-039888 | Apparatus and Method for Oxygenating Wastewater (Japan; pending) |
| EP 1 313 548 | Apparatus and Method for Oxygenating Wastewater (Belgium, Denmark, France, Great Britain, Germany, Italy, Netherlands, Spain and Turkey) |
| US 7,294,278 | Method for Oxygenating Wastewater |

**Industrial Patents:**

| | |
|---|---|
| US 5,569,180 | Method for Delivering a Gas-Supersaturated Fluid to a Gas-Depleted Site and Use Thereof |
| EP 0 767 632 | Method for Delivering a Gas-Supersaturated Fluid to a Gas-Depleted Site and Use Thereof (Belgium, France, Great Britain, Germany, Italy, Netherlands and Spain) |
| JP 3,712,729 | Method for Delivering a Gas-Supersaturated Fluid to a Gas-Depleted Site and Use Thereof (Japan) |
| US 5,735,934 | Method for Delivering a Gas-Supersaturated Fluid to a Gas-Depleted Site and Use Thereof |
| US 6,241,802 | Method for Delivery of Gas-Enriched Fluids |

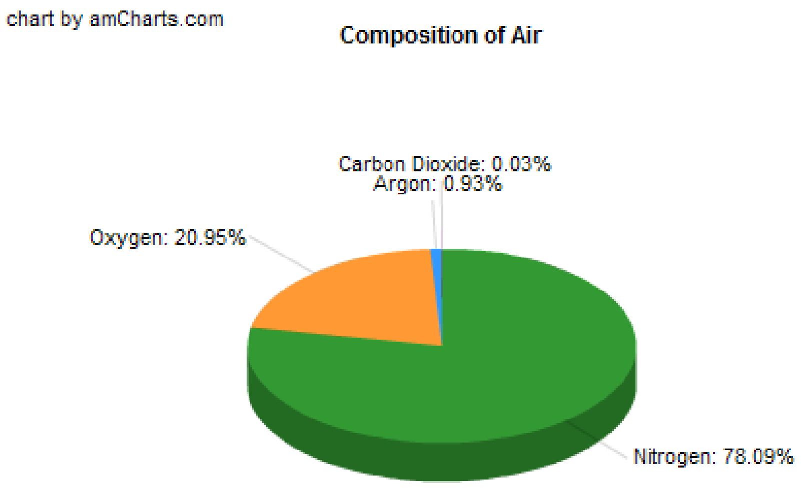
# $PRO_2$ System

***$PRO_2$ System Diagram***



# Air

## Composition of Air

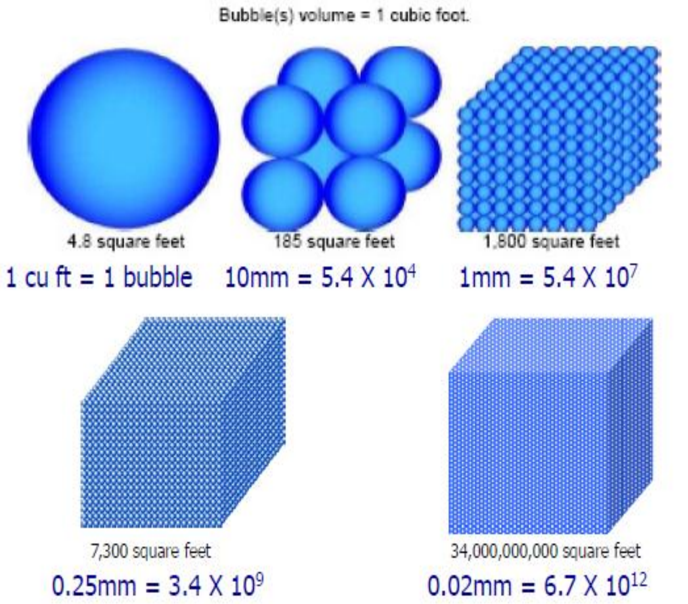



| Component | Symbol | Volume | |
|---|---|---|---|
| Nitrogen | $N_2$ | 78.084% | |
| Oxygen | $O_2$ | 20.947% | |
| Argon | Ar | 0.934% | 99.998% |
| Carbon Dioxide | $CO_2$ | 0.033% | |
| Neon | Ne | 18.2 parts per million | |
| Helium | He | 5.2 parts per million | |
| Krypton | Kr | 1.1 parts per million | |
| Sulfur dioxide | $SO_2$ | 1.0 parts per million | |
| Methane | $CH_4$ | 2.0 parts per million | |
| Hydrogen | $H_2$ | 0.5 parts per million | |
| Nitrous Oxide | $N_2O$ | 0.5 parts per million | |
| Xenon | Xe | 0.09 parts per million | |
| Ozone | $O_3$ | 0.07 parts per million | |
| Nitrogen dioxide | $NO_2$ | 0.02 parts per million | |
| Iodine | $I_2$ | 0.01 parts per million | |
| Carbon monoxide | CO | trace | |
| Ammonia | $NH_3$ | trace | |

# Bubble Size

Bubble Size Relationship
Course = ≥10 mm
Medium = 4-9 mm
Fine = 1-3 mm
Ultra-Fine = 1 mm
Micro = 0.5-0.01 mm
Nano = 0.001 mm

# Surface Area by Bubble Size




$PRO_2$
216,000,000,000 + square feet
.001-.0001 mm

# Henry's Law

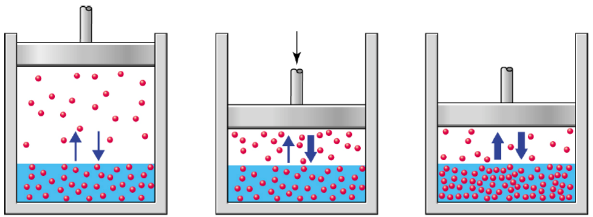
## Henry's Law

- The solubility of a gas is directly proportional to the gas pressure

$$S_g = k_h P_g$$

- When the partial pressure of the solute above a solution drops, the solubility of the gas in the solution drops as well to maintain the equilibrium.
- This can be used to calculate the molar solubility of a gas.

**Gas Solubility – Effect of Pressure**

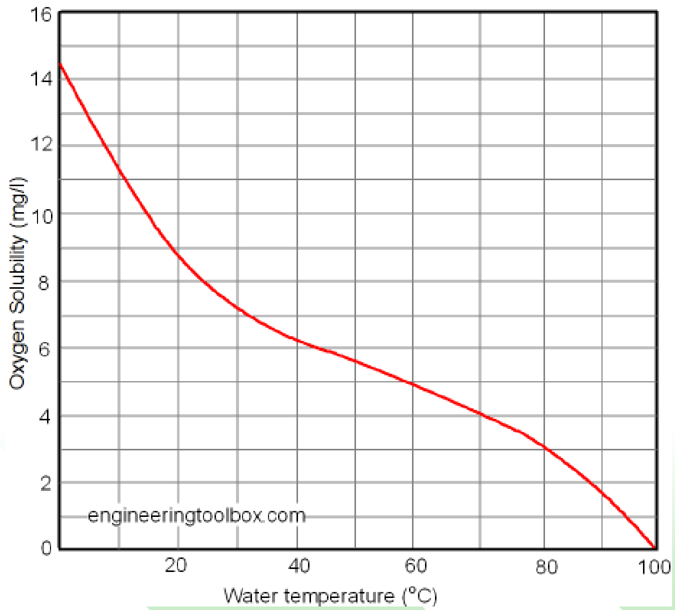


(a) Initial equilibrium (b) Increased pressure (c) New equilibrium

Table 1: Some forms of Henry's law and constants (gases in water at 298 K)[7]

| equation: | $k_{H,pc} = \frac{p_{gas}}{c_{aq}}$ | $k_{H,cp} = \frac{c_{aq}}{p_{gas}}$ | $k_{H,px} = \frac{p_{gas}}{x_{aq}}$ | $k_{H,cc} = \frac{c_{aq}}{c_{gas}}$ |
|---|---|---|---|---|
| dimension: | $\left[\frac{L_{soln} \cdot atm}{mol_{gas}}\right]$ | $\left[\frac{mol_{gas}}{L_{soln} \cdot atm}\right]$ | $\left[\frac{atm \cdot mol_{soln}}{mol_{gas}}\right]$ | dimensionless |
| $O_2$ | 769.23 | 1.3 E-3 | 4.259 E4 | 3.180 E-2 |
| $H_2$ | 1282.05 | 7.8 E-4 | 7.099 E4 | 1.907 E-2 |
| $CO_2$ | 29.41 | 3.4 E-2 | 0.163 E4 | 0.8317 |
| $N_2$ | 1639.34 | 6.1 E-4 | 9.077 E4 | 1.492 E-2 |
| He | 2702.7 | 3.7 E-4 | 14.97 E4 | 9.051 E-3 |
| Ne | 2222.22 | 4.5 E-4 | 12.30 E4 | 1.101 E-2 |
| Ar | 714.28 | 1.4 E-3 | 3.955 E4 | 3.425 E-2 |
| CO | 1052.63 | 9.5 E-4 | 5.828 E4 | 2.324 E-2 |

# Dissolved Oxygen



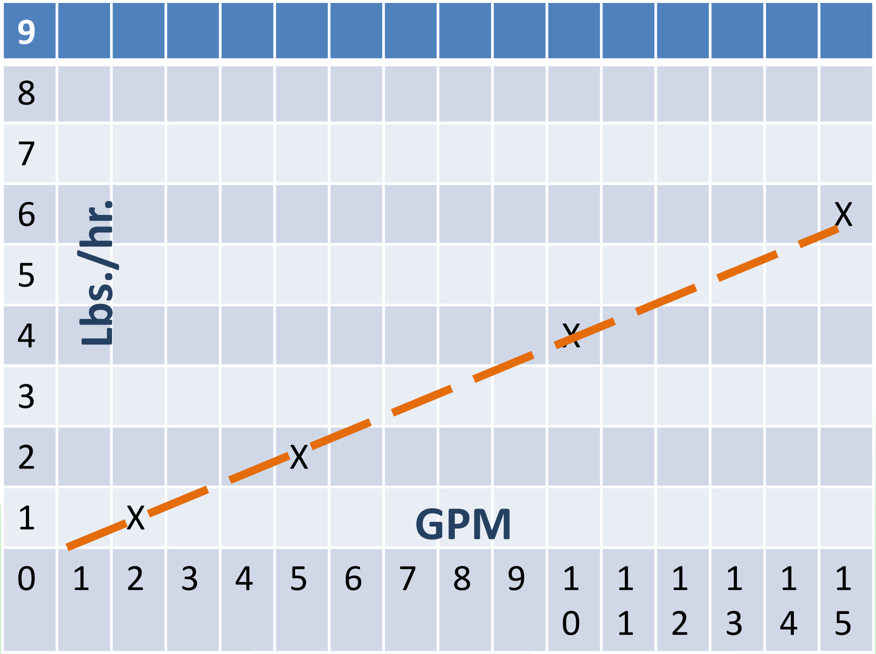

Definition: Oxygen dissolved in a body of water as an indication of the degree of health of the water and its ability to support a balanced aquatic ecosystem; also, the amount of free (not chemically combined) oxygen dissolved in water, wastewater, or other liquid, usually expressed in milligrams per liter, parts per million, or percent of saturation; abbr. DO

# $PRO_2$ Technology

**Supersaturated Carrier Fluid**

- Industrial Oxygen
  - 93% Pure
- OTE
  - 96%
- OTR
  - 600mg/l @ 300psi .4#/gal./hr.
  - 400mg/l @ 200psi
  - 200mg/l @ 100psi

**Fluid Delivery Process OTR Lbs./Hr. @ 300psi**



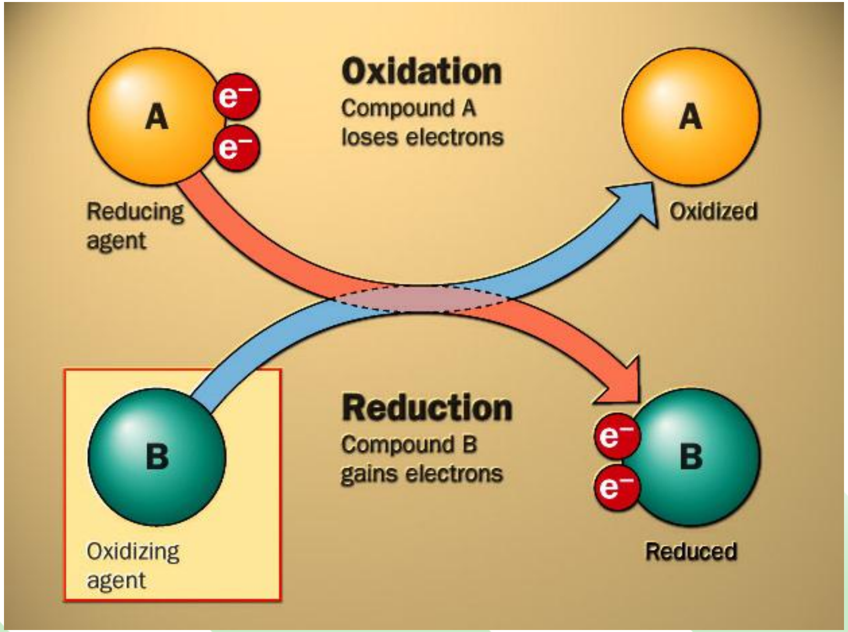
# Chemical Remediation

## Oxidation and Redox

**Redox** (***reduction-oxidation***) reactions include all chemical reactions in which atoms have their oxidation state changed - that is, redox reactions involve the transfer of electrons between species.
This can be either a simple redox process, such as the oxidation of carbon to yield carbon dioxide ($CO_2$)

The term "redox" comes from two concepts involved with electron transfer: reduction and oxidation.[1] It can be explained in simple terms:

- **Oxidation** is the *loss* of electrons or an *increase* in oxidation state by a molecule, atom, or ion.
- **Reduction** is the *gain* of electrons or a *decrease* in oxidation state by a molecule, atom, or ion.

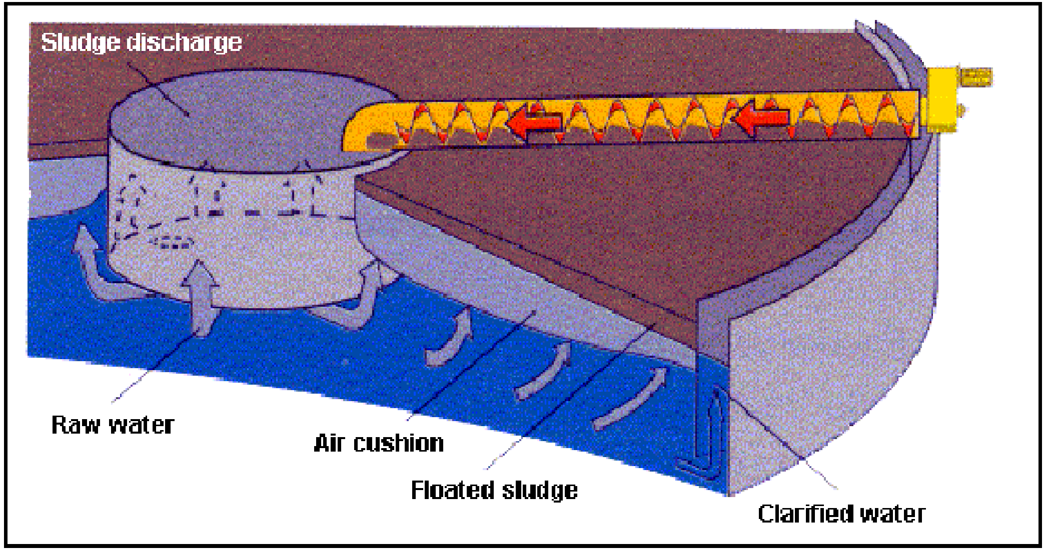


# Fields of Use

- Applications
  - Digesters / Aeration Ditches
  - Lagoons
  - Lift Stations
  - Sand Filters

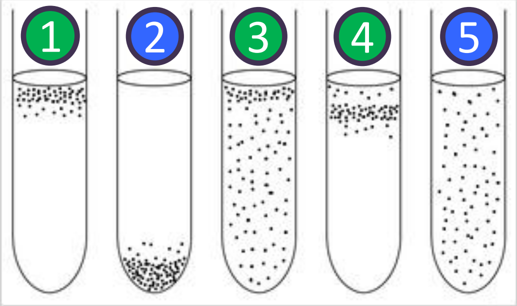
# Separation

The flocculants cause these materials to join together in clusters that are lighter than water and therefore float. Pollutants are concentrated in the material that accumulates on the surface, called the float. Other names for the float include DAF float, skimmings, or sludge.



# Wastewater Remediation

## Digester Bacterial Community

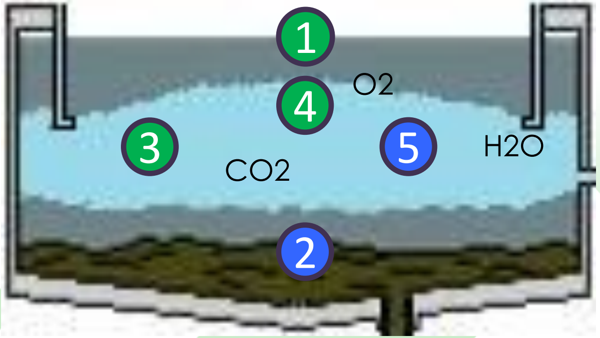



Aerobic and anaerobic bacteria can be identified by growing them in a liquid culture:
1: Obligate aerobic bacteria gather at the top of the test tube in order to absorb maximal amount of oxygen.
2: Obligate anaerobic bacteria gather at the bottom to avoid oxygen.
3: Facultative bacteria gather mostly at the top, since aerobic respiration is the most beneficial one; but as lack of oxygen does not hurt them, they can be found all along the test tube.
4: Microaerophiles gather at the upper part of the test tube but not at the top. They require oxygen but at a low concentration.
5: Aerotolerant bacteria are not affected at all by oxygen, and they are evenly spread along the test tube.

Aerobic Bacteria Respiration
$CO_2$ and $H_2O$

Anaerobic / Aero tolerant Bacteria
Respiration $O_2$ and $H_2O$

PRO2 SERIES Increases Respiration by 10 X



# $PRO_2$ System
## Quality of Municipal Decant

***Before $PRO_2$***

***After $PRO_2$***

***Customers have reported results up to:***

Ammonia: Reduced 86% Phosphorous: Reduced 75%
TKN: Reduced 73% TSS: Reduced 70%

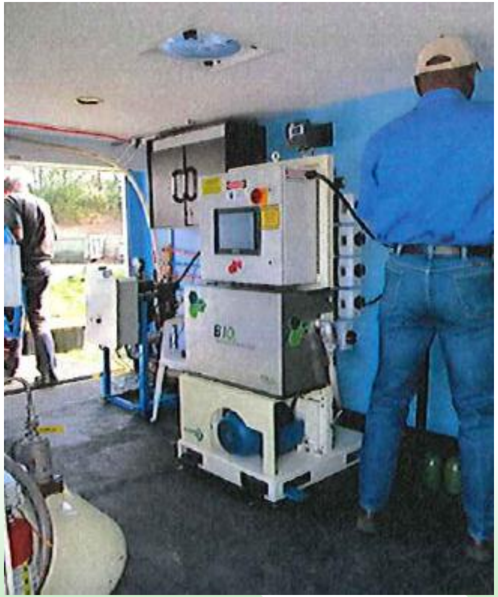
# Odor Elimination

There are a number of sources for odors within wastewater treatment and solids management facilities. Significant potential sources at treatment facilities include:

- Head works area
- Primary clarifiers
- Solids holding and thickening tanks
- Aerobic digesters
- Dewatering systems
- Solids loading areas

# Portable $PRO_2$ System

Set-up in operation within hours of arrival



User friendly integrated system

# Maintenance Lagoon Remediation

## Actual Results in a Ten Day Period

Before $PRO_2$ Treatment

After $PRO_2$ Treatment

| Data Collection: | Pre | +7 Days | +10 Days | Reduction | Change or % Reduction |
|---|---|---|---|---|---|
| Organic Material Depth (in.) | 8 | - | 3 | 5 | 62.5% |
| Secchi (in.) | 2 | - | 4 | 2 | 100.0% |
| pH (test strip) | 6.5 | - | 6.8 | 0.3 | 4.6% |
| DO (mg/l) | 0.1 | - | 10 | 9.9 | 9900.0% |
| Odor | Strong | - | None | Total | 1 |
| TN (mg/l) | 15.16 | - | 8.54 | 6.62 | 43.7% |
| TKN (mg/l) | 15.10 | - | 8.50 | 6.60 | 43.7% |
| NOX (mg/l) | 0.06 | - | 0.04 | 0.02 | 30.0% |
| TP (mg/l) | 2.06 | - | 1.45 | 0.61 | 29.6% |

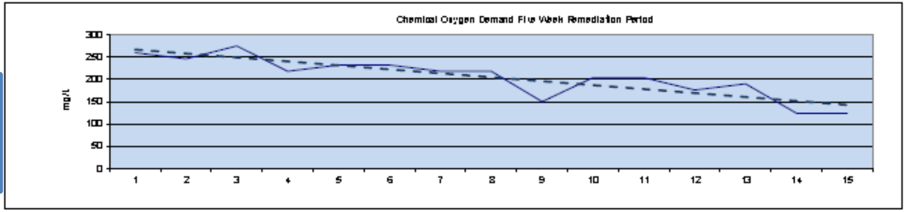
# Truck Stop Lagoon Remediation

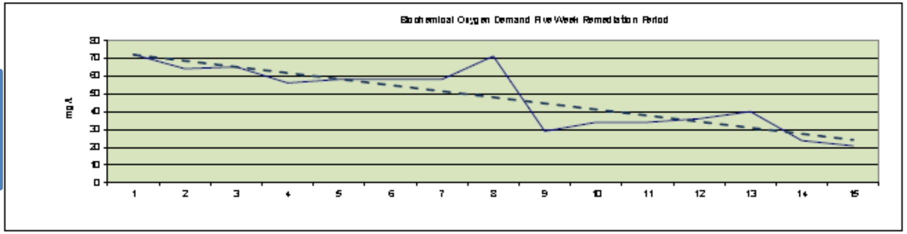
## Actual Results in a Ninety Day Period

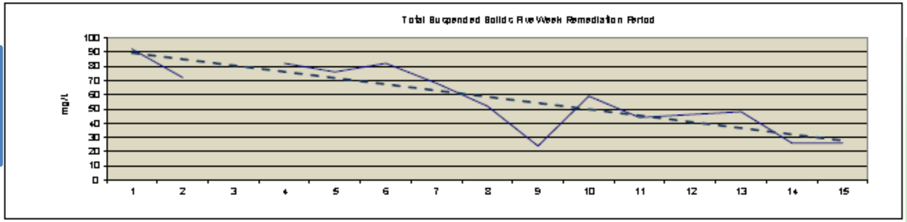
BOD 71% Reduction

COD 52% Reduction

TSS 72% Reduction



# Technology Comparisons

| Bubble Size / Retention | Technology | Operating Cost |
| --- | --- | --- |
| Bubble Size 10mm Retention Seconds | Coarse Bubble Diffuser<br>12% $O_2$<br>88% Wasted Energy<br>150hp. for .5 MGD | Operating Cost Electric $12 / hr. @ $0.11kwh |
| Bubble Size 1-3mm Retention Minutes | Fine Bubble Diffuser<br>32% $O_2$<br>68% Wasted Energy<br>125hp. for .5 MGD | Operating Cost Electric $10 / hr. @ $0.11kwh |
| Bubble Size .1-.001mm Retention Days | PRO2-154 System<br>96% $O_2$<br>4% Wasted Energy<br>3hp. for .5MGD | Operating Cost Electric $0.25 /hr. @ $0.11kwh |

PRO $O_2$ SERIES

# $PRO_2$ System

## PRO2-154 Operating Costs


Oxygen Cost between $0.05 - $0.47 / hr. @ 15 gpm

| | |
|---|---|
| Gas Cylinder (251scf) | $0.93 / m3 = $0.65 / hr. |
| Small Liquid tank | $0.30 / m3 = $0.50 / hr. |
| Large Liquid tank | $0.20 / m3 = $0.45 / hr. |
| Generator | $0.10 / m3 = $0.30 / hr. |

Electrical Cost @ $0.11 / kWh $0.25 / hr. @ 15 gpm

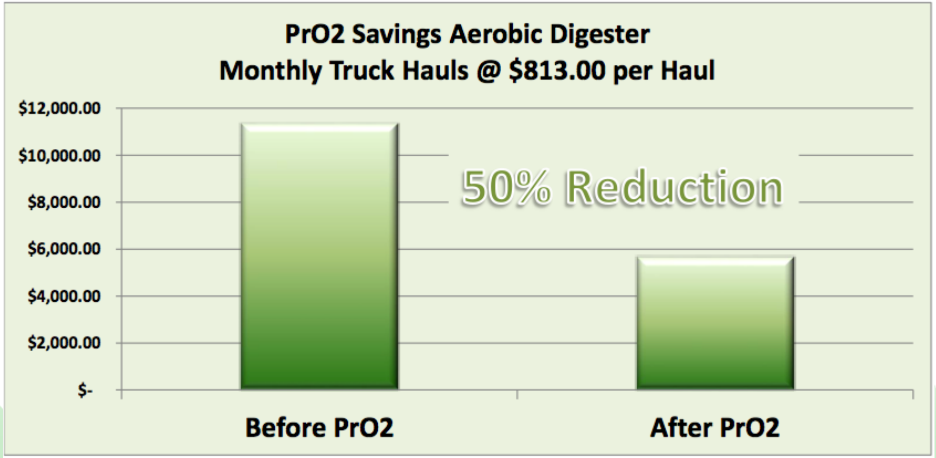
Unit: PRO2-15 H/P 3 Cost Per kWh $0.11 = $0.245./ hr.

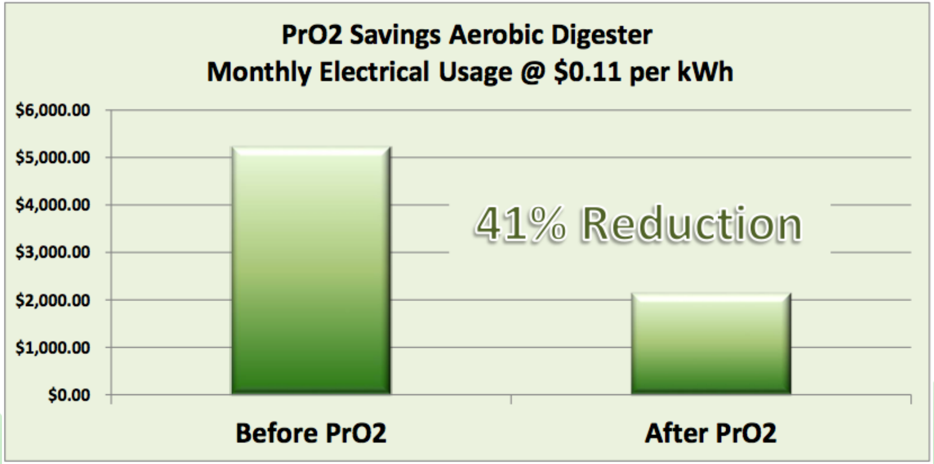
Total Budgetary Cost Using LOX @ 15 gpm

**$0.75 / hr.**

# Digester Operation Savings

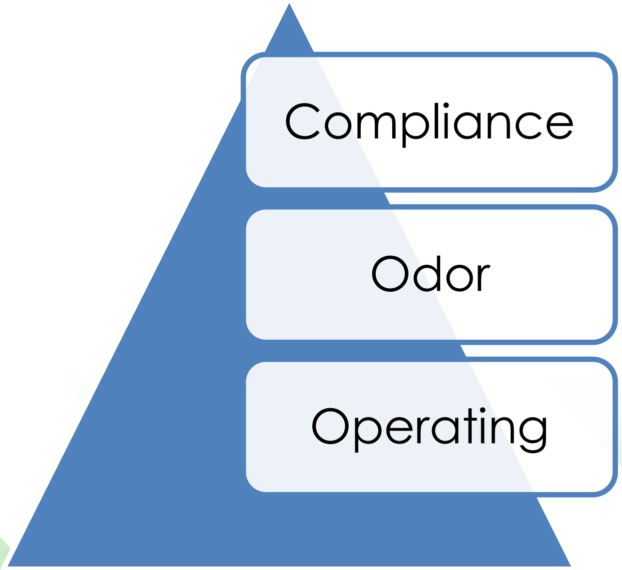
| PRO2 Series Bio2 Accelerator | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| State | Location | Type | Size MGD | Install Date | Machine No | VNC id | Energy Savings | Energy Savings / Hr. | Hauling Savings | Total Op Savings | Hours | Gallons | Date | GPM | Decant |
| Florida | Apopka | Municipal | 4.5 | 1/9/2012 | 0005 | 166.140.145.233 | $178,990.07 | $14.11 | $153,657.00 | $332,647.07 | 12,686 | 6,304,455 | 5/16/2014 | 8.28 | |
| Michigan | Blissfield | Municipal | 1 | 6/6/2011 | 0003 | 166.140.140.37 | $20,120.95 | $8.20 | $91,692.00 | $111,812.95 | 2,453 | 1,256,354 | 5/4/2014 | 8.54 | |



# Typical Savings and Benefits

- Electrical
  - 50 to 60%
- Hauling
  - 20 to 30%
- Equipment maintenance and runtime
- Odor
- Improved Decant
  - Quality
  - Quantity
  - Time reduced 50 to 80%
- Polymer
  - 30 to 50%



# $PRO_2$ System
# Human Machine Interface - HMI

***Touch Screen***

The controls for the $PRO_2$ System are touch screen, and PLC based.

- Password protected with 4 levels of access.

# $PRO_2$ System
## Product Line and Maximum Delivery

### $O_2$ Delivery

- 2 gpm - 163,200 mg/hr.
- 5 gpm - 408,000 mg/hr.
- 15 gpm - 1,224,000 mg/hr.

# $PRO_2$ System
## Optional Remote Communications

The $PRO_2$ system can be controlled and monitored remotely through a cellular modem or the Internet. It is Smart Phone, Tablet, Laptop and PC accessible, with a SCADA connection for integrated monitoring.

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