Optical DO Sensor (oDo)

HydroTech

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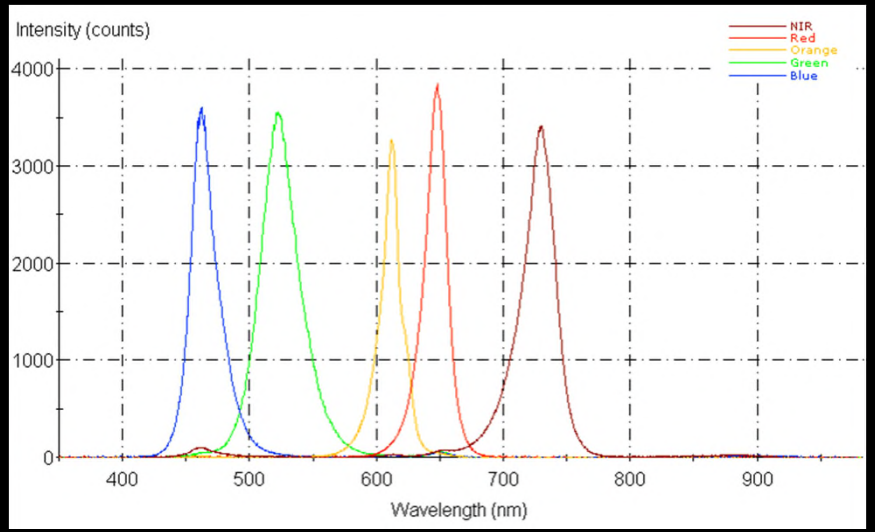
What All Optical Sensors Have In Common

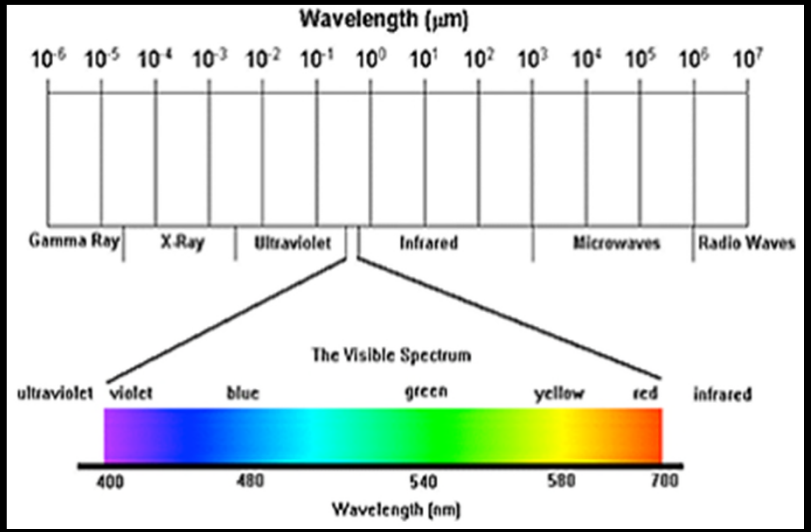
Light source: Usually a light emitting diode (LED).

Light detector:
Usually a Photodetector
Also referred to as Photodiode.

Light filter: Optical filters.

LED





LED emits light at a specific wavelength.

Each wavelength corresponds to a specific color.

Each color can be a different intensity.

Photodiode

A Photodiode is a semiconductor diode that functions as a Photodetector.

Photodiodes convert the light to an electrical signal. (Current or Voltage)

The signal is proportional to light intensity.

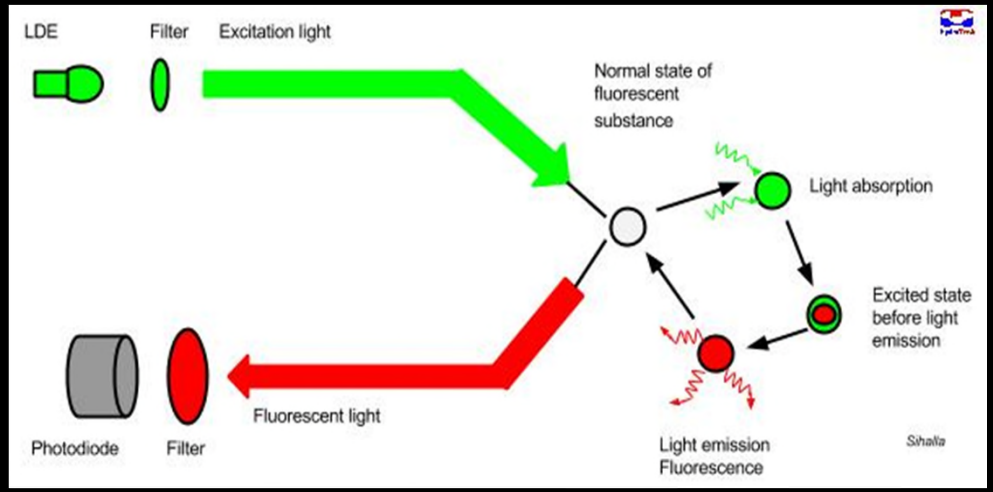
Optical Filters

Eliminate unwanted light from reaching the photodiode

Eliminate noise from LED lights

Basic Design of an Optical Sensor

The most common is a Fluorometer:



A light with a specific wavelength and intensity is emitted from the LED.

The substance being measured absorbs the light and emits a light of different wavelength.

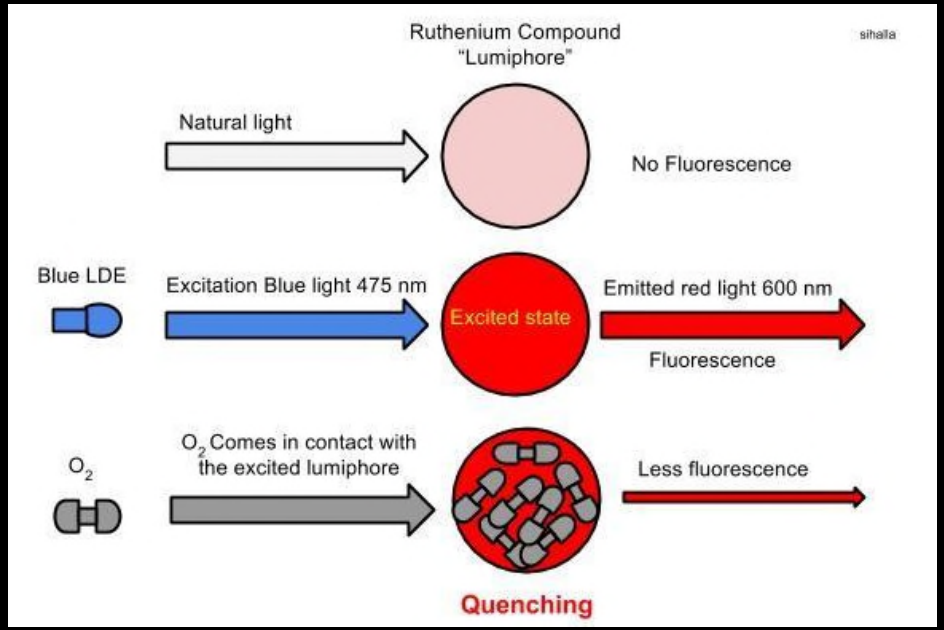
The emitted light is isolated by using a specific filter.

The filtered light is converted to an electrical signal by the photodiode.

Basic Design of an Optical DO Sensor (oDo)

Problem: The oxygen molecule does not have any significant fluorescence to any affordable light source.

However: The oxygen molecule has another optical property:



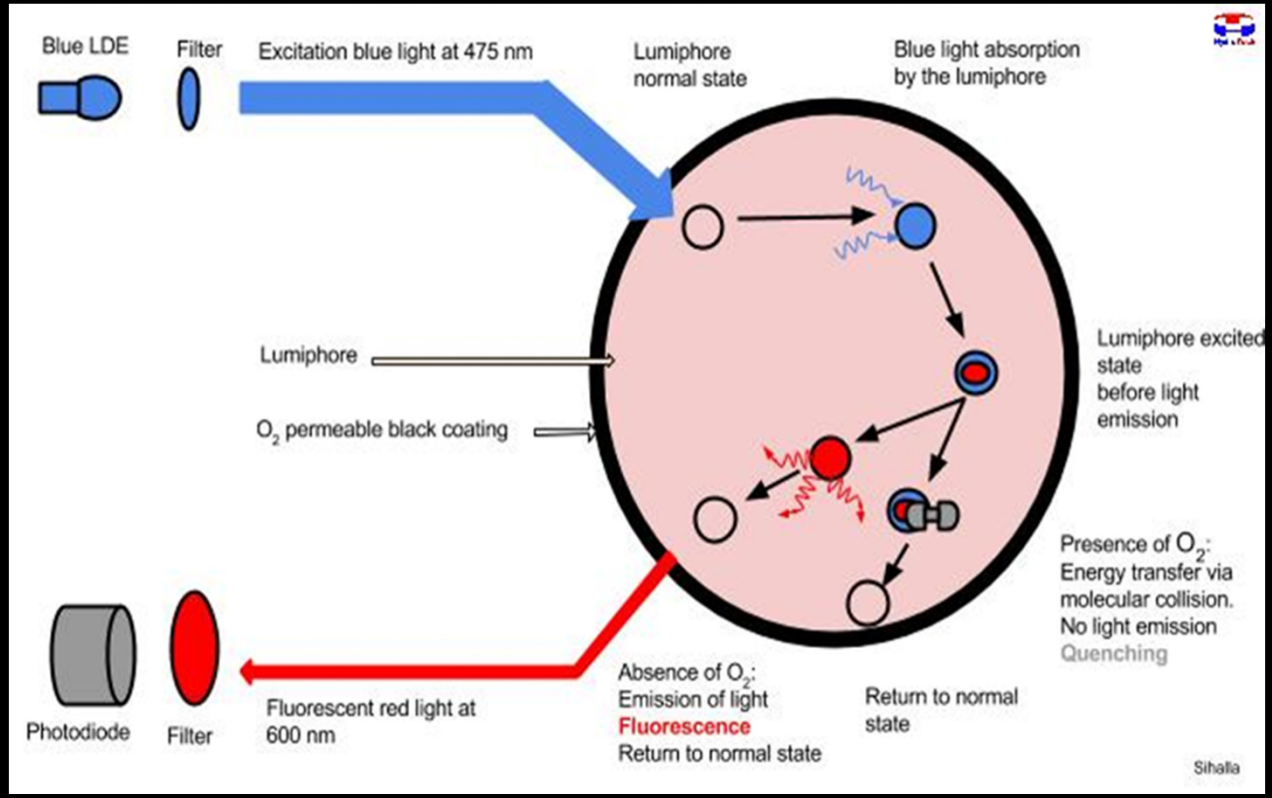
Basic Design of an oDo Sensor

Take the basic design of a Fluorometer and:

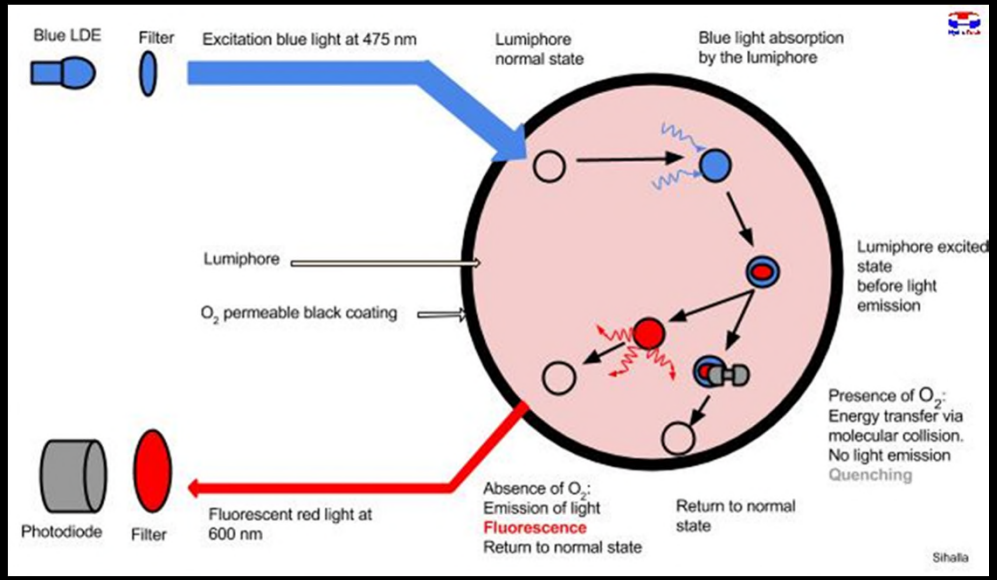
Add a lumiphore

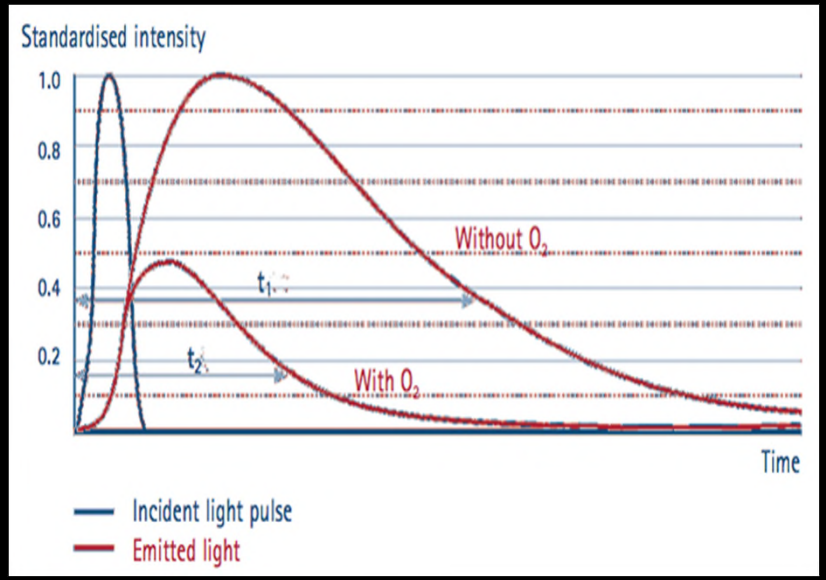
Use an excitation light at 475 nm

Use a 600 nm Photodiode



Fluorescence Time Decay Measurement



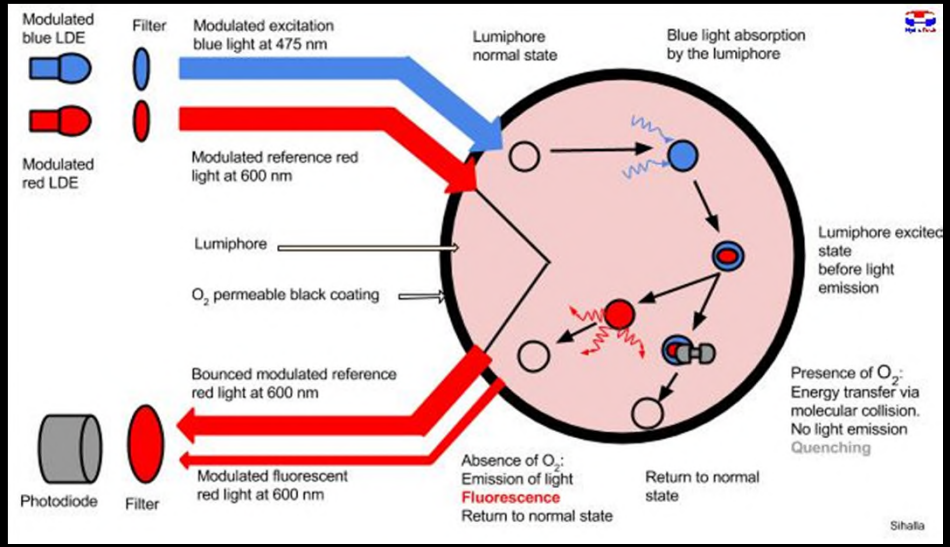


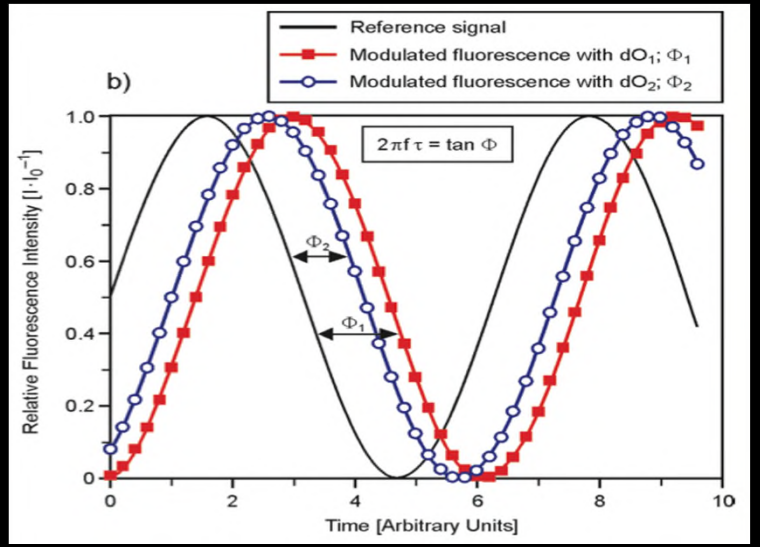
Fade time is measured at 1/e of the maximum intensity.

Fade time is proportional to the amount of oxygen quenching the lumiphore.

However, this measurement is intensity dependent.

Fluorescence Phase Shift Measurement





Add a modulated blue light which results in a modulated fluorescent light from the lumiphore.

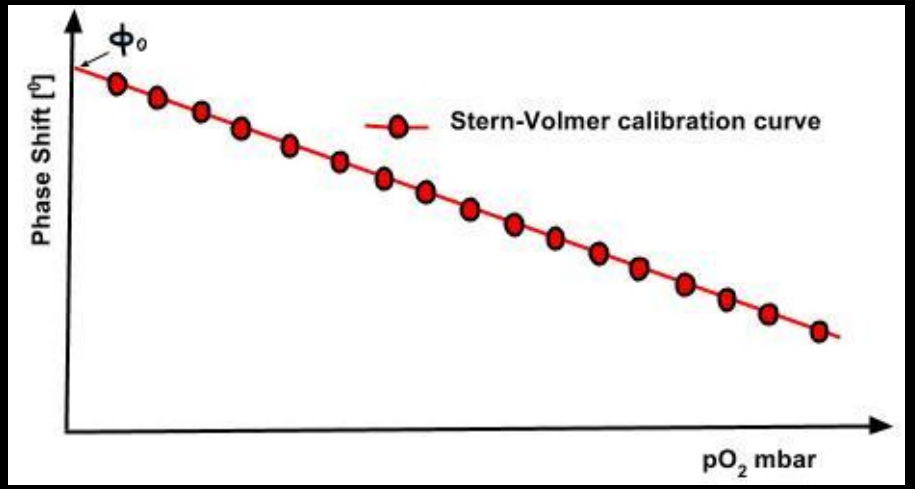
Add a reference modulated red light.

The modulated lights result in a sinusoidal signals with measurable shift between reference and fluorescent lights.

From Phase Shift to Oxygen Partial Pressure

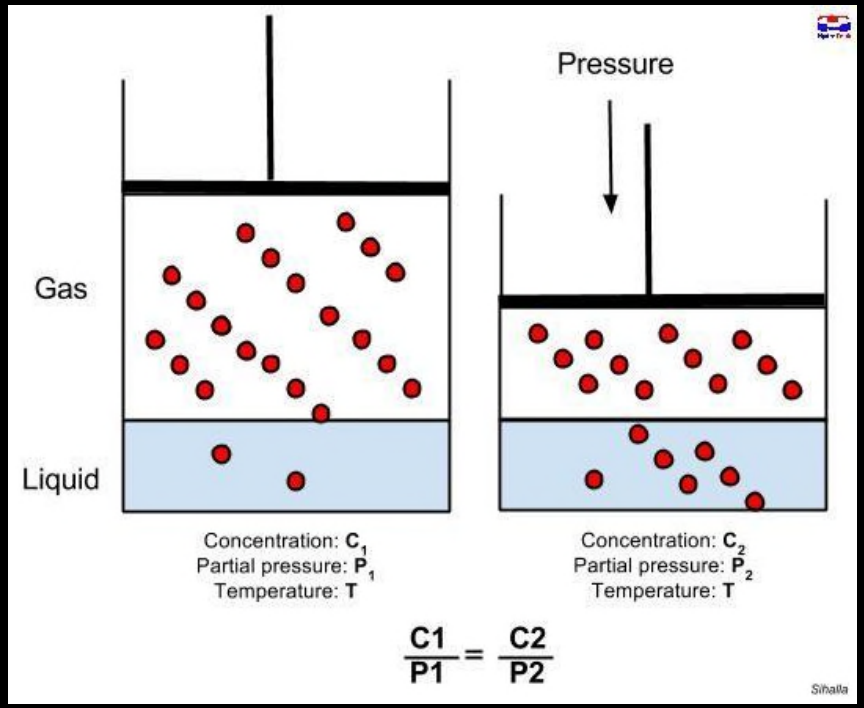
The phase shift is proportional to the dissolved oxygen partial pressure following the Stern-Volmer equation:

$$pO_2 = \frac{(\Phi_0 - \Phi)}{K_{sv}[\Phi - \Phi_0(1 - f_0)]}$$



pO_2: Oxygen partial pressure
Φ_0: Phase shift in the absence of O2
Φ_1: Phase shift for partial pressure equal to dO_2
K_{SV} : Stern-Volmer constant

From Partial Pressure to Concentration
(Henry's Law)



Gas solubility in a liquid changes with pressure and temperature.

As long as the temperature does not change, the partial pressure of the gas is proportional to its concentration in the liquid.

Henry's Law does not apply to Oxygen because it's too soluble.

Therefore, we use the oxygen solubility table to calibrate oDo sensors.

Oxygen Solubility Table

--TABLE I--

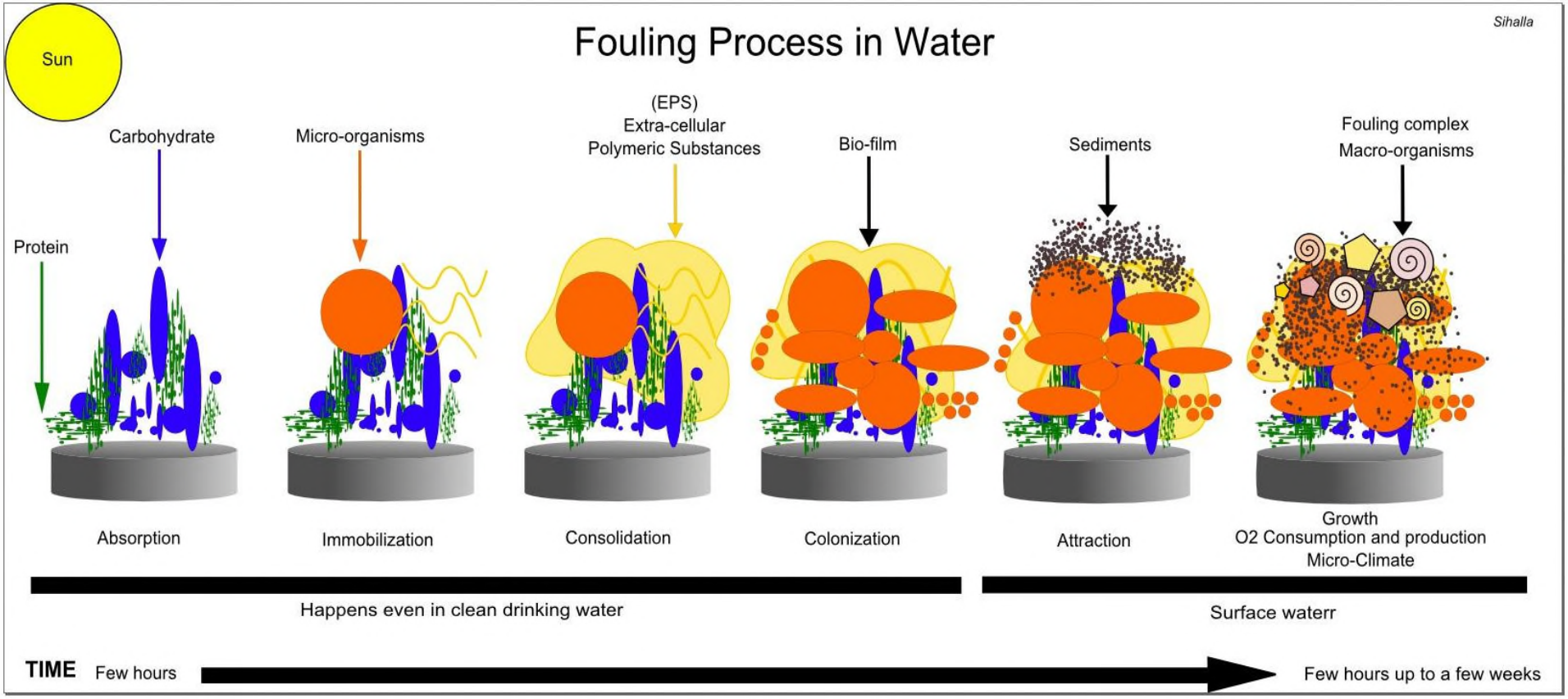
OXYGEN SOLUBILITY AT INDICATED PRESSURE mmHg

T.DEG C	P(H20)	760	755	750	745	740	735	730
0	4.58	14.57	14.47	14.38	14.28	14.18	14.09	13.99
1	4.93	14.17	14.08	13.98	13.89	13.79	13.70	13.61
2	5.29	13.79	13.70	13.61	13.52	13.42	13.33	13.24
3	5.68	13.43	13.34	13.25	13.16	13.07	12.98	12.90
4	6.10	13.08	12.99	12.91	12.82	12.73	12.65	12.56
5	6.54	12.74	12.66	12.57	12.49	12.40	12.32	12.23
6	7.01	12.42	12.34	12.26	12.17	12.09	12.01	11.93
7	7.51	12.11	12.03	11.95	11.87	11.79	11.71	11.63
8	8.04	11.81	11.73	11.65	11.57	11.50	11.42	11.34
9	8.61	11.53	11.45	11.38	11.30	11.22	11.15	11.07
10	9.21	11.26	11.19	11.11	11.04	10.96	10.89	10.81
11	9.84	10.99	10.92	10.84	10.77	10.70	10.62	10.55
12	10.52	10.74	10.67	10.60	10.53	10.45	10.38	10.31
13	11.23	10.50	10.43	10.36	10.29	10.22	10.15	10.08
14	11.99	10.27	10.20	10.13	10.06	10.00	9.93	9.86
15	12.79	10.05	9.98	9.92	9.85	9.78	9.71	9.65
16	13.63	9.83	9.76	9.70	9.63	9.57	9.50	9.43
17	14.53	9.63	9.57	9.50	9.44	9.37	9.31	9.24
18	15.48	9.43	9.37	9.30	9.24	9.18	9.11	9.05
19	16.48	9.24	9.18	9.12	9.05	8.99	8.93	8.87
20	17.54	9.06	9.00	8.94	8.88	8.82	8.75	8.69
21	18.65	8.88	8.82	8.76	8.70	8.64	8.58	8.52
22	19.83	8.71	8.65	8.59	8.53	8.47	8.42	8.36
23	21.07	8.55	8.49	8.43	8.38	8.32	8.26	8.20
24	22.38	8.39	8.33	8.28	8.22	8.16	8.11	8.05
25	23.76	8.24	8.18	8.13	8.07	8.02	7.96	7.90
26	25.21	8.09	8.03	7.98	7.92	7.87	7.81	7.76
27	26.74	7.95	7.90	7.84	7.79	7.73	7.68	7.62
28	28.35	7.81	7.76	7.70	7.65	7.60	7.54	7.49
29	30.04	7.68	7.63	7.57	7.52	7.47	7.42	7.36
30	31.82	7.55	7.50	7.45	7.39	7.34	7.29	7.24
31	33.70	7.42	7.37	7.32	7.27	7.22	7.16	7.11
32	35.66	7.30	7.25	7.20	7.15	7.10	7.05	7.00
33	37.73	7.18	7.13	7.08	7.03	6.98	6.93	6.88
34	39.90	7.07	7.02	6.97	6.92	6.87	6.82	6.78
35	42.18	6.95	6.90	6.85	6.80	6.76	6.71	6.66
36	44.56	6.84	6.79	6.74	6.70	6.65	6.60	6.55
37	47.07	6.73	6.68	6.64	6.59	6.54	6.49	6.45
38	49.69	6.63	6.58	6.54	6.49	6.44	6.40	6.35
39	52.44	6.52	6.47	6.43	6.38	6.34	6.29	6.24
40	55.32	6.42	6.37	6.33	6.28	6.24	6.19	6.15
41	58.34	6.32	6.27	6.23	6.18	6.14	6.09	6.05
42	61.50	6.22	6.18	6.13	6.09	6.04	6.00	5.95
43	64.80	6.13	6.09	6.04	6.00	5.95	5.91	5.87
44	68.26	6.03	5.99	5.94	5.90	5.86	5.81	5.77
45	71.88	5.94	5.90	5.85	5.81	5.77	5.72	5.68

Hydrolab Corp

How Fouling Affects oDo Sensors ?

Fouling Process



Fouling Affects oDo Sensors:

By reducing the oxygen permeability of the black protective coating.

However:

An oDo sensor works just fine even with ¾ of the surface of the lumiphore clogged. (Practical testing)

Reducing the contact surface of the lumiphore does not affect oDo sensors based on phase shift method.

The permeability reduction is minimum.Therefore its effect on the oDo measurement is negligible.

Fouling Affects oDo Sensors:

By creating a microclimate with altered oxygen concentrations.

Depending on the nature of the biological organisms in the fouling complex:

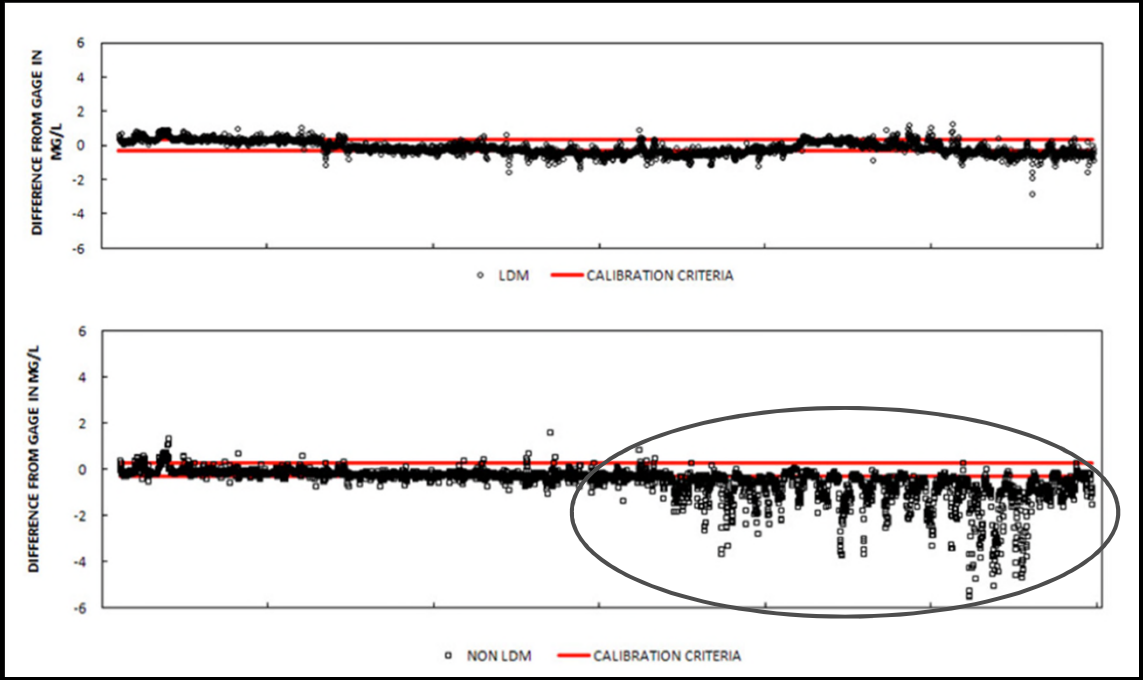
Creation of oxygen:

Quick release in the water

Minimum effect on the oDo sensors

Fouling Affects oDo Sensors:

Consumption of oxygen:
Supported by actual long-term deployment data



Reference data from an LDM equipped multiprobe. No fouling.

Data from non-LDM equipped multiprobe. Fouled sensors.

Example of Fouling Complex

Fouling complex formed in Corpus Christi Bay

Absence of fouling on an LDM equipped unit.

Example of Fouling Complex

Fouling complex formed in the Pearl River.

Examples of oDo Sensors

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Thank you