What happens after starting an O_2Tube cell?

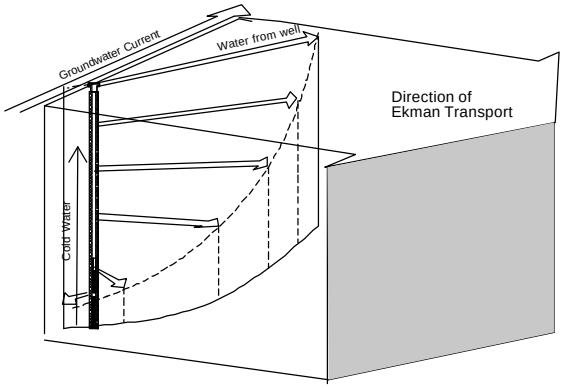
The number one question asked by professionals familiar with bioremediation during the initial break-in period of an O_2Tube system is **"Why did the contaminant levels go up in the monitoring wells"**? The following explanation is based on actual sites during the first month of operation and has been broken down into three categories; physical, chemical and biological:

Physical

The groundwater is flowing across the site in some direction based on the current groundwater level. The O_2Tube system is energized and the air from the Air Panel begins flowing into the O_2Tube cell forming large bubbles which lift water to the groundwater/vadose interface where the water mounds and flows away from the well carrying dissolved oxygen horizontally in all directions. Moving water is subject to the Coriolis effect, and it begins to bend. In the Northern Hemisphere, water is deflected to the right side direction of the groundwater flow. The net effect is that surface flow is at a 45 degree angle to the groundwater flow. As this layer moves , it also begins to deflect. Each successive layer of water beneath the surface layer moves in this way; flowing a bit slower than the layer above it but deflecting under the influence of the Coriolis effect. As a result of the successive movements and deflections of these layers of water, a spiral pattern is created, such that at some depth, the water is actually flowing in a direction opposite to that of the surface waters. This spiral pattern is called an Ekman spiral, named after the man who developed the mathematical formulations to describe this phenomena.

An illustration of the Ekman spiral is shown below. Note that the average direction of water flow, the net transport, is 90 degrees to the direction of the groundwater. This contrasts with the 45 degree angle that surface water moves in relation to the groundwater. You should realize that the water flows slower as depth increases. The transfer of groundwater energy throughout the water column is not 100% efficient. The frictional forces between successive layers of water and soil remove energy from the flow at each successive depth.

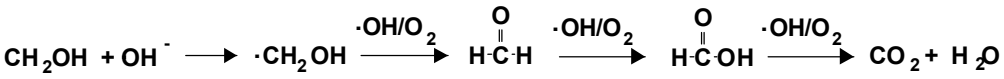
This rotation of water draws material from the outer edge to the center. The site being treated will usually raise in contaminant levels due to initial mixing of site and material being pulled from outside treatment area. This rotation will hold contaminants in the treatment zone where the oxygen and bacteria are waiting to metabolize the compound..



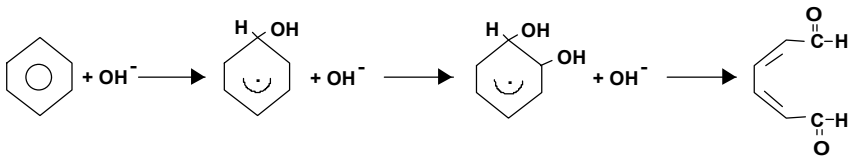
Chemical

Groundwater and its associated soluble and insoluble contaminants undergo electrolysis as they pass through the O_2Tube cell. Water molecules form oxygen ions, hydrogen ions and hydroxyl radicals. Once generated, the hydroxyl radicals aggressively attack virtually all organic compounds. Depending upon the nature of the organic species, two types of initial attack are possible:

1.) The hydroxyl radical can abstract a hydrogen atom to form water, as with alkanes or alcohols.



2.) The hydroxyl radical can add to the contaminant, as is the case for olefins or aromatic compounds.



The attack by the hydroxyl radical, in the presence of oxygen, indicates a complex cascade of oxidative reactions leading to mineralization. As a rule of thumb, the rate of destruction of a contaminant is approximately proportional to the rate constant for the contaminant with the hydroxyl radical. As we see from the table below, most organic molecules break down a million to a billion times faster than ozone.

Reaction Rate Constants (k, in L mole^{-1} s^{-1})
Of Ozone vs. Hydroxyl Radical

Compound	O_3	OH^-
Chlorinated Alkenes	10^{-1} to 10^3	10^9 to 10^{11}
Phenols	10^3	10^9 to 10^{10}
N-containing Organics	10 to 10^2	10^8 to 10^{10}
Aromatics	1 to 10^2	10^8 to 10^{10}
Ketones	1	10^9 to 10^{10}
Alcohols	10^{-2} to 1	10^8 to 10^9
Alkanes	10^{-2}	10^6 to 10^9

As organic compounds are converted to their daughter products, they are more readily absorbed by bacteria as food. The bacteria releases enzymes that free contaminants absorbed to the soil which raises the groundwater's contaminant levels.

Biological

Hydrocarbon degrading bacteria which have been slow-growing or dormant will begin rapidly dividing as a result of the O_2Tube cell producing and distributing dissolved oxygen throughout the treatment area. Many oil-degrading microorganisms produce emulsifying agents (Reisfeld, Rosenburg and Gutnik, 1972), and naturally occurring biosurfactants seem to be very important in the elimination of hydrocarbons from polluted groundwater. These biosurfactants contain sugars, fatty acids and lipids (mono- and diglycerides) and have a strong emulsifying effect on petroleum contaminants.

These biosurfactants have the ability to free hydrocarbons that before were bound to the soil. This release of bound material will show up as a increase in contaminants. Once the bacterial population increases to a sufficient level to consume more contaminant than is being mobilized, the contaminant levels will drop.

In conclusion, the O2Tube system creates the first in-situ dynamic oxygenation system to create the perfect zone for bioremediation to occur. One must be willing to look at the O2Tube system without “rules of thumb”, formed from typical diffusion only systems, too make sense of the data being generated.

New technology is cool!