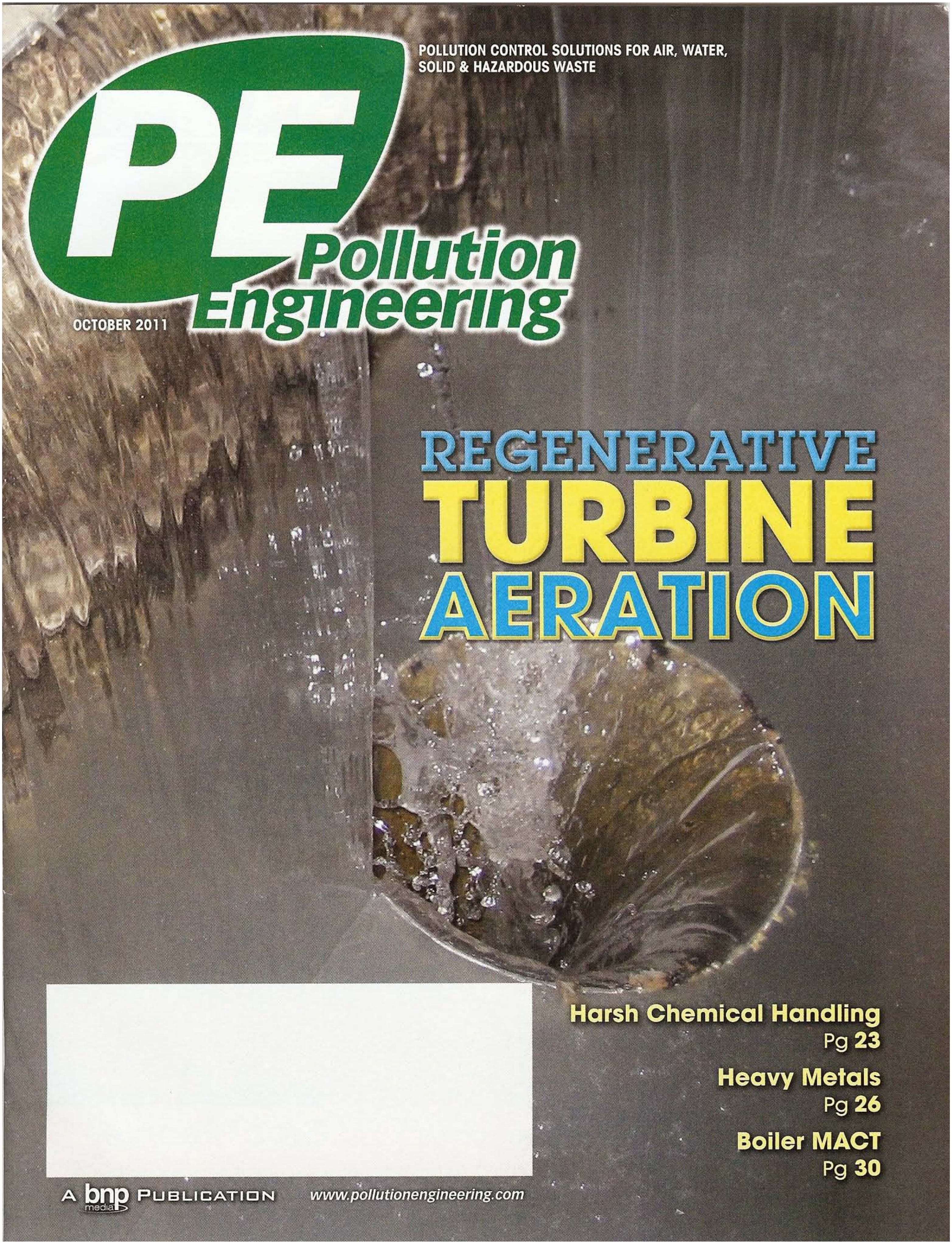

POLLUTION CONTROL SOLUTIONS FOR AIR, WATER, SOLID & HAZARDOUS WASTE

PE Pollution Engineering

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Regenerative TURBINE Aeration TECHNOLOGY

By applying the laws of physics while regularly utilizing properly sized bubbles, managers and technicians can achieve consistent wastewater treatment system results.

By **STUART WARD,** General Manager of Process Engineered Water Equipment

In order to acquire precise control of input and output fluid/gas parameters, wastewater managers and technicians can utilize a regenerative turbine pump, which fully optimizes the gas dissolution process that properly treats wastewater, time after time. Once such parameters have been completely controlled, a well-designed wastewater treatment system should be able to initiate all necessary operating duties after each start-up. To enlighten wastewater professionals as they discover and use such gas-dissolving technology, this feature will focus on the various potential benefits that regenerative turbine technology may offer.

Gas dissolution and regenerative turbines

During the first step of the regenerative turbine process, gas is dissolved into a fluid solution through the application of a predetermined amount of pressure. The regenerative turbine pump applies such pressure, through a combined triple-action force (centrifugal, axial and friction), to the gas and fluid during a single pass through the pump head. Whether dissolving compressed or atmospheric air, nitrogen or other gasses to the fluid, the regenerative turbine pump will always achieve the highest possible saturation level at a given temperature.

Gas solubility air example

A common application for such pump technology is the dissolution of air into water. The volume of air that can be dissolved in water increases with the system pressure and decreases as the temperature lowers. While using air as an example, regenerative turbine pump gas dissolution can be calculated. The solubility of air in water can be expressed as a solubility ratio.

$S_a = m_a / m_w$

Where:

S_a = *solubility ratio*

m_a = *mass of air* (lb_m, *kg*)

m_w = *mass of water* (lb_m, *kg*)

Solubility: Henry's Law

Meanwhile, Henry's Law states that "the amount of air dissolved in a fluid is proportional with the pressure of the system." Therefore, while fully utilizing Henry's Law, the following symbols will be used:

$c = p_g / k_H$

Where:

c = *solubility of dissolved gas*

k_H = *proportionality constant depending on the nature of the gas and the fluid*

p_g = *partial pressure of the gas*

Please note that the solubility of oxygen in water is higher than the solubility of nitrogen. Air that is dissolved in water contains approximately *35.6 percent oxygen*; in comparison, ambient air only contains *21 percent oxygen.*

Solubility calculation

According to Henry's Law, at a system temperature of 77°F the volume of air dissolved in water can be calculated as:

Oxygen as O_2 : *756.7 atm/(mol/liter)*

Nitrogen as N_2 : *1600 atm/(mol/liter)*

Molar Weights:

O_2 is *31.9988 g/mol*

N_2 is *28.0134 g/mol*

Partial Fraction in Air:

O_2 is *about 0.21*

N_2 is *about 0.79*

The O_2, which is dissolved in the water at atmospheric pressure, can be calculated as:

$c_o = (1\ atm)\ 0.21 / (756.7\ atm/(mol/liter))\ (31.9988\ g/mol) = 0.0089\ g/liter, \sim 0.0089\ g/kg$

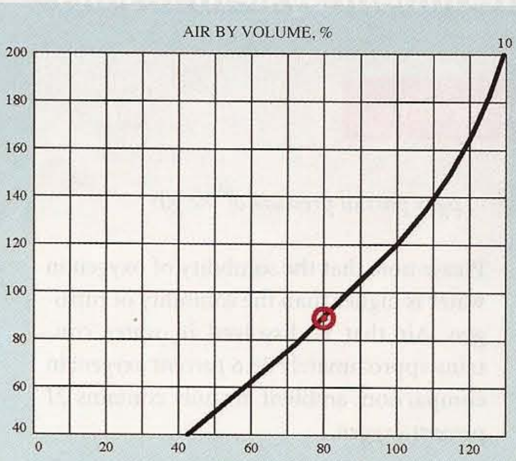
The N_2, which is also dissolved in the water at atmospheric pressure, can be calculated as:

$c_n = (1\ atm)\ 0.79\ /\ (1600\ atm/(mol/liter))\ (28.0134\ g/mol) = 0.0138\ g/liter, \sim 0.0138\ g/kg$

Since air is the sum of nitrogen and oxygen, the following results can be obtained:

$c_a = (0.0089\ g/liter) + (0.0138\ g/liter) = 0.0227\ g/liter \sim 0.023\ g/kg$

By applying such results to the regenerative turbine pump, a performance curve can be graphed. Note that the gas dissolution for air peaks at 10 percent by volume given normal system operating conditions with temperatures that do not exceed 100°F. The regenerative turbine pump discharge pressure meets or exceeds discharge requirements for most dissolved air flotation (DAF) when just 80 to 85 psi was applied in membrane and oil recovery applications. Please refer to **Graph 1** for further information.



Graph 1: Solubility Versus Temperature and Pressure for Air/Water Solutions

Why change?

Of course, wastewater managers and technicians may use several older technological options as well in order to dissolve gasses into a liquid. In comparison to other options, the pump offers a competitive alternative for the following reasons:

- Generates 20 to 30 micron sized bubbles.
- Consumes less energy.
- Dissolves gas at modest pressures.
- Offers users a low wear pump fluid interface.
- Utilizes a simple design that is easy to implement.
- Provides high efficiency without causing cavitation.
- Presents safety and control features that assure reliability.

Design and applications

Typically, a regenerative turbine pump is sized in saturation applications to just 20 percent of the total system flow. Therefore, the pumps are well suited for DAF membrane and oil recovery systems. Wastewater technicians will recognize that these pumps are useful in the food and beverage, laundry, pulp and paper, brewery and petroleum industries. Through further observation, they will also realize there are many other special process applications available as well.

Close coupled pump can lower flows.

Flex coupled pump provides higher flows.

Pump features

Regenerative turbine pumps also have a robust construction. According to the list below, managers and technicians may consider the following reference points as they determine which quality pump design they will actually choose:

- Materials: stainless steel, iron, brass
- Close and flex-coupled models
- May be mounted in many locations
- Capacities of five to more than 120 GPM
- Pump heads in excess of 200 feet
- Economical seals

Hydraulic design

Regenerative turbine pumps can also be offered in single- or dual-impeller mechanical units. The internal hydraulic cavity is engineered to achieve maximum capacity and pressure while minimizing horsepower requirements. Such a design optimizes the fluid pumping dynamics within the interior passageway to improve the efficiency and overall pressure that users hope to achieve. Consequently, near complete dissolution of entrained gasses can be acquired at the highest volume possible during the pump cycle. This process is completed during a single pass, which leads to minimized horsepower requirements.

Impeller tuning

Each regenerative turbine impeller has a profile that is uniquely performance tuned. Tuning is based on engineered and field testing by optimizing the width and length of the impeller vanes. To efficiently dissolve gas into the fluid, horsepower must be reduced; such reduction usually improves off-peak horsepower requirements as well.

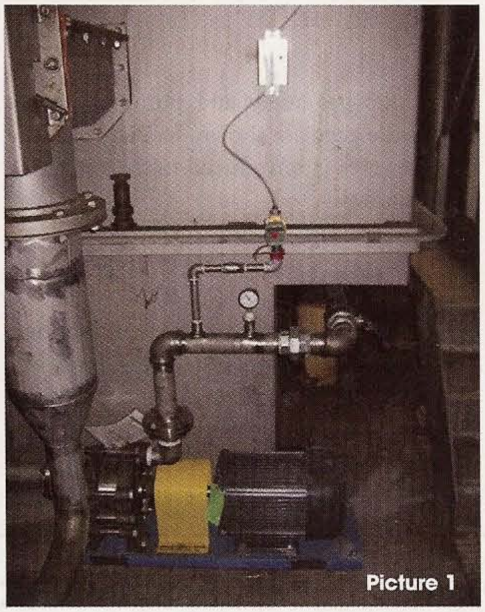
Blade efficiency

Impellers are built with blade profiles and counts, which have been engineered for their particular fluid passageway cross-sections. Impeller blade counts increase efficiency without leading to complex blade contours. Thus, the regenerative turbine pump yields high-performance characteristics that typically exceed those of more expensive units.

Adding it up

While examining the air solubility calculations and also applying the regenerative turbine pump design, it appears that the results are within the expected

Above is an optimized hydraulic cavity.



Picture 1

Picture 1: The pumps are set up in the system.

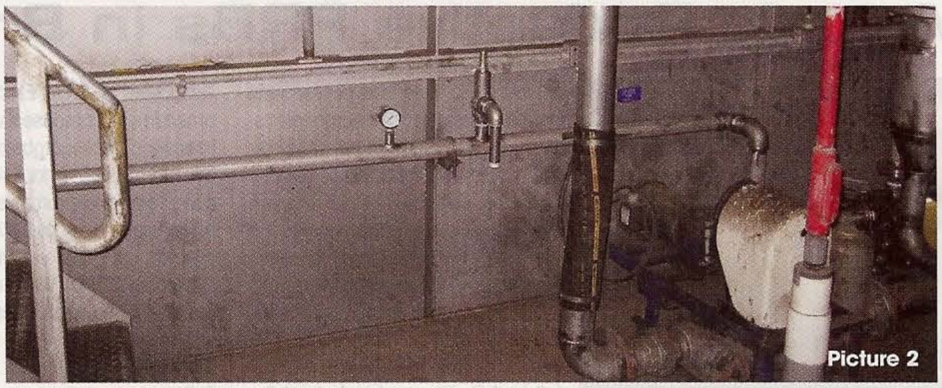
Picture 2: Safety valves in the system protects against catastrophe.

Picture 3:The whitewater is being introduced into the tanks.

Picture 4: Supersaturation forms what is commonly called whitewater with tiny bubbles in the 20 to 30 micron size range.

Picture 5: Above is the clarified effluent ready for the next step.

efficiency range. Each of these results can be verified by using an air rotometer indicator, which should match the calculated volume. Accordingly, the net result equals a dissolved air release with 20 to 30 micron bubbles. **Picture 4** vividly illustrates those bubbles within a DAF vessel; such bubbles are often referred to as "whitewater."



Picture 2

Setting up gas dissolution systems

Wastewater technicians should select pumps and piping materials according to the fluid type and temperature they expect to encounter. Operators must have full control of the system, as well as all built-in automatic safety features. The system should be also piped so that saturation time is maximized. The regenerative turbine pump ought to also match the overall system flow and hydraulic capacity. Of equal importance, technicians should also consider the following system limitations:

Discharge Pressure	125 psi
Seal Pressure	200 psi
Suction Vacuum	26 inches Hg
Speed (Flex)	1,750 rpm
Speed (Close)	3,450 rpm
Temperature	-20°F to 150°F

Picture 3

Picture 4

System components

A well-designed gas dissolution system will also have a number of components beyond just the pump itself. These items, which are usually either schedule 80 PVC or stainless steel, include the following:

- Regenerative turbine pump
- Inlet fluid control valve
- Fluid vacuum gauge
- Gas flow meter with adjustment knob
- Gas tubing
- Injection check valve
- Discharge pressure gauge
- Saturation and coalescing purge tank *(optional)*
- Safety relief
- Swing check valve
- Discharge control valve
- All necessary connecting piping
- Mounting frame or plate

Picture 5

Example setup

The following pictures illustrate a typical DAF system upgrade. In **Picture 1**, a regenerative turbine pump is fed clarified effluent water through a control valve with air injected via an acrylic rotometer. A slight vacuum is applied when atmospheric air is utilized. Wastewater technicians may find more controllable results by using compressed air pressures that range from 10 to 20 psi. Such pressures assure a more even flow and discourage fouling of the airline and rotometer. In **Picture 2**, a 125-psi safety and pump discharge pressure gage are shown. In **Picture 3**, the whitewater is introduced to the incoming system flow.

Regenerative turbine results

As a result of these efforts, a fully operable gas dissolution system can be developed. Over time, treatment operators will discover that they not only have a low maintenance unit, but reliable efficiency as well. **Picture 4** shows the whitewater that is produced by 20 to 30 super saturated micron bubbles, as well as the formation of a dry sludge layer on the surface of the water. The final results are depicted in **Picture 5** with the spillage of clarified water over the DAF effluent weir. ***PE***

Stuart Ward is the general manager for Process Engineered Water Equipment LLC. Visit www.pewe-llc.com for more information.

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Treating a CVOCS Groundwater Plume Using Multiple Reductive PRBs in Brazil

ADVERTORIAL

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Background:

Groundwater at an active industrial facility in São Paulo, Brazil, is impacted with CVOCs, including chlorinated ethenes, ethanes and methanes. There are two separate plume areas: the first measures 50 m long by 50 m wide by 4 m deep (from 14 to 18 mbgs) with baseline total CVOCs concentrations up to 7,926 µg/L; the second plume measures 180 m long x 100 m wide x 5 m deep (from 18 to 23 mbgs) with baseline total CVOCs concentrations up to 1,099 µg/L and lower levels of zinc and cobalt.

Site Characteristics:

The site heavily slopes towards the adjacent coastline and access was therefore restricted in some areas. Silt is the predominant lithology and the linear groundwater velocity has been estimated at 18 m/year. Groundwater level varied across the site from 10 to 20 mbgs. Baseline conditions were relatively oxic with a DO of 1.2 to 5.1 mg/L and ORP generally ranging from 100 to 130 mV. Groundwater pH ranged from 4.6 to 6.7. The goal is to treat the CVOCs without mobilizing metals present in the soil.

Challenge:

The coastline is an environmental protection area, next to the city water supply source. In this particular area, the organic matter is high.

Remediation Approach:

Considering the plume extent areas, access restrictions and relatively low concentrations, a passive treatment approach using multiple Permeable Reactive Barriers (PRBs) was selected. The PRBs were installed across the plume areas via injection of EHC® to promote In Situ Chemical Reduction (ISCR). EHC is a solid amendment composed of controlled-release, complex organic carbon plus ZVI that quickly establishes reducing conditions and promotes abiotic and biotic degradation of CVOCs. EHC was injected as slurry via direct push in December 2009. Very limited access areas required manual application.

Results:

Subsequent performance monitoring conducted in January, February, March and April 2010 showed up to 99.8% total CVOCs removal measured within the PRBs. Results in downgradient wells vary with distance from the PRBs. In Area 1 Plume, the average CVOC concentrations measured within the targeted area decreased by 90% in 120 days (from a baseline of 2,823 µg/L to a current average of 289 µg/L). In Area 2 Plume, the remedial goals have been met in 6 out of 8 wells, however, concentrations remain unchanged in two of the central wells. The PRBs were spaced between 25 to 90 m apart based on access; therefore, considering a linear groundwater velocity of 18 m/year, complete plume cleanup would be expected first after approximately 5 years. Continued monitoring is expected to show a decrease in CVOCs in downgradient wells.