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Demonstration Bulletin

CAV-OX® Ultraviolet Oxidation Process
Magnum Water Technology

Technology Description: The CAV-OX® technology (see Figure 1) destroys organic contaminants, including chlorinated hydrocarbons, in water. The process uses hydrogen peroxide, hydrodynamic cavitation, and ultraviolet (UV) radiation to photolyze and oxidize organic compounds present in water at part per million to nondetectable levels. Ideally, the end products of the process are water, carbon dioxide, halides, and in some cases, organic acids. The major components of each CAV-OX® system are the cavitation chamber, UV reactor, and control panel unit.

Cavitation occurs when a liquid undergoes a dynamic pressure reduction while under constant temperature. The pressure reduction causes gas bubbles to suddenly develop, grow, and then collapse. Cavitation decomposes water into extremely reactive hydrogen atoms and hydroxyl radicals, which recombine to form hydrogen peroxide and molecular hydrogen.

The CAV-OX® technology induces hydrodynamic cavitation through the shape of its cavitation chamber, which causes pressure variations in a flowing liquid. The cavitation process generates hydroxyl radicals and hydrogen atoms, which recombine to form hydrogen peroxide and molecular hydrogen. Flow can be recycled through the cavitation chamber to control the hydraulic retention time before it is transferred to the UV reactor.

The UV reactor houses low-pressure mercury-vapor lamps that generate UV radiation, which further oxidizes the organic compounds. Each lamp is housed in a UV-transmissive quartz tube, which is mounted entirely within the UV reactor. Hydroxyl and hydroperoxyl radicals are produced by direct photolysis of hydrogen peroxide at UV wavelengths.

Magnum Water Technology manufactures both low-energy and high-energy UV systems. The low-energy CAV-OX® I system contains six 60-watt lamps per reactor. The high-energy CAV-OX® II system contains two UV reactors with one UV lamp each and can operate at 2.5, 5, 7.5, or 10 kilowatts (kW). Flow capacity is estimated to be less than 3 gals per minute (gpm) for the low-energy system and less than 5 gpm for the high-energy system as demonstrated. Three configurations of the CAV-OX® technology were demonstrated: the CAV-OX® I system operating at 360 watts and the CAV-OX® II system operating at both 5 kW and 10 kW.

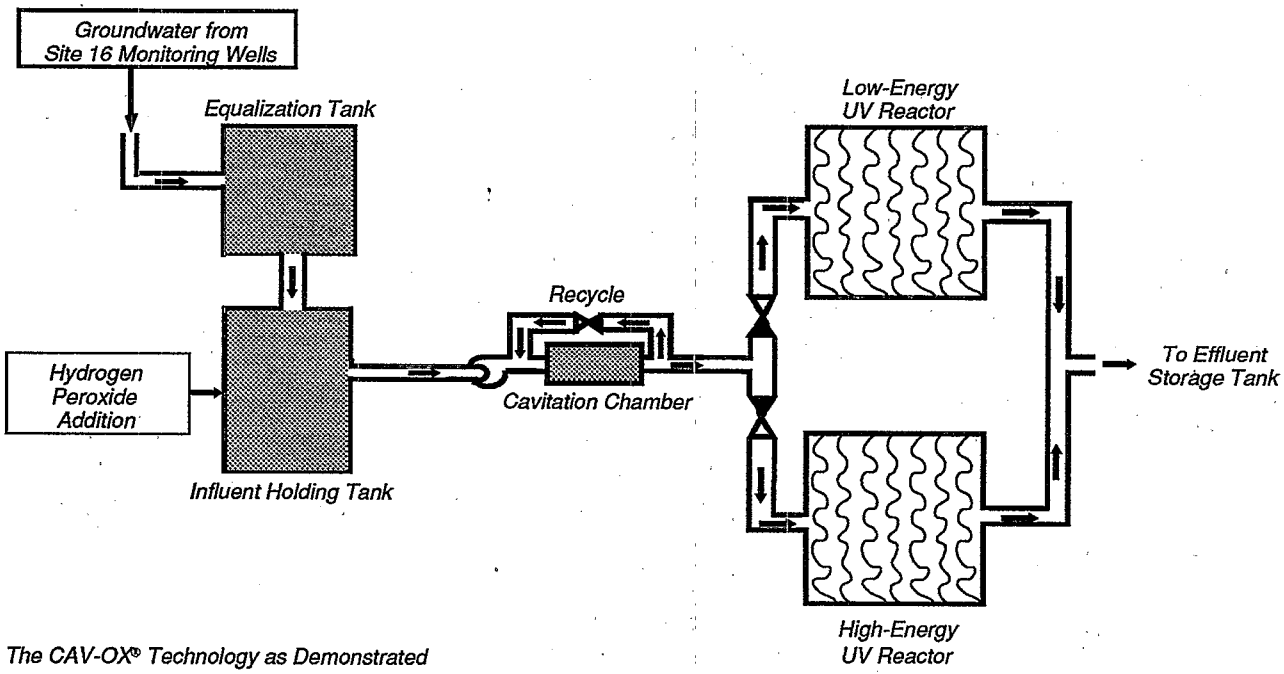

Figure 1. *The CAV-OX® Technology as Demonstrated*

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Demonstration Approach: The CAV-OX® technology was demonstrated at Edwards Air Force Base Site 16 for 2 weeks in March 1993. Almost 8,500 gals of contaminated groundwater from Site 16 monitoring wells were treated during this period. Groundwater at Site 16 is contaminated with volatile organic compounds (VOCs), primarily trichloroethene (TCE) and benzene, toluene, ethylbenzene, and xylenes (BTEX).

During the demonstration, groundwater was pumped from three Site 16 monitoring wells into a 7,500-gallon equalization tank. A bladder tank was used as the equalization tank to minimize variability in influent characteristics. Influent contaminant concentrations included 1,475 to 2,000 parts per billion (ppb) TCE, 240 to 500 ppb benzene, 8 to 11 ppb toluene, and 0 to 100 ppb xylene. From the equalization tank, the water was transfered to an influent holding tank, where hydrogen peroxide was added. The water was then pumped to the cavitation chamber followed by either the high-energy or low-energy UV reactor. Treated groundwater was stored in an effluent storage tank prior to disposal.

The demonstration consisted of 15 runs for each configuration of the CAV-OX® technology. The high-energy system was first operated with the UV reactor at 10 kW and then at 5 kW. Groundwater samples were collected before and after treatment during each run to determine the technology's effectiveness in removing VOCs from groundwater.

The principal operating parameters — hydrogen peroxide dose, pH, and flow rate — were varied during the demonstration to aluate the technology's performance under different conditions. Preferred operating conditions, those under which the concentrations of effluent VOCs were reduced below target levels at the least cost, were used for the last three runs for each configuration. Specific VOC levels and chemical constituents were also monitored.

Preliminary Results: The CAV-OX® I and CAV-OX® II systems achieved removal efficiencies of up to >99.9 percent for TCE and BTEX compounds. No scaling of the quartz tubes was observed. Preliminary results from the demonstration for the CAV-OX® systems are shown in Table 1.

Key findings from the demonstration, including complete analytical results and economic analysis, will be published in an Applications Analysis Report and a Technology Evaluation Report. These reports will be used to evaluate the CAV-OX® technology as an alternative for cleaning up similar sites across the country. Results will also be presented in a project summary report and a videotape.

For Further Information:

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ıble 1. Summary of preliminary demonstration Results - CAV-OX® Systems

Hydrogen Peroxide Target Levels (mg/L)	CAV-OX® I Removal Efficiencies (%)					CAV-OX® I Removal Efficiencies (%)								
	Flow gpm	TCE	Benzene	Toluene	Xylene	Flow gpm	TCE 5-kW	TCE 10-kW	Benzene 5-kW	Benzene 10-kW	Toluene 5-kW	Toluene 10-kW	Xylene 5-kW	Xylene 10-kW
30	0.5	99.9	>99.9	99.4	92.9	1.5	99.6	99.2	99.4	98.8	>99.9	98.6	>99.9	>99.9
30	0.6	99.9	>99.9	>99.9	>99.9	2.0	99.7	99.7	99.5	99.6	>99.9	>99.9	>99.9	>99.9
30	1.5	71.4	88.6	87.4	65.6	4.0	87.7	98.1	89.7	98.7	88.8	97.1	78.7	87.2
60	0.6	99.7	>99.9	>99.9	>99.9	1.4	99.8	99.7	99.8	99.8	>99.9	>99.9	98.7	>99.9
60	0.7	87.8	96.9	94.5	92.1	1.9	98.4	99.3	98.8	99.3	96.9	98.6	93.6	97.0
60	1.5	61.7	81.6	83.8	80.2	3.9	85.1	97.1	89.5	97.8	91.8	97.9	90.4	96.0
90	0.5	96.4	99.4	99.8	98.9	1.4	99.6	99.4	99.6	99.6	99.8	99.8	99.5	99.5
90	0.7	87.1	96.5	97.6	98.1	1.9	97.8	99.2	99.4	99.5	99.5	99.7	99.2	99.7
90	1.5	58.6	86.1	87.3	>99.9	4.0	86.3	98.9	93.5	99.5	94.5	99.6	95.4	>99.9
0	—	—	—	—	—	1.6	94.1	99.2	49.1	68.1	20.7	54.7	43.3	46.7
0	—	—	—	—	—	1.8	80.6	97.6	38.5	60.5	48.6	75.2	56.9	83.8

Notes: — = Not Applicable
mg/L = milligrams per liter

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