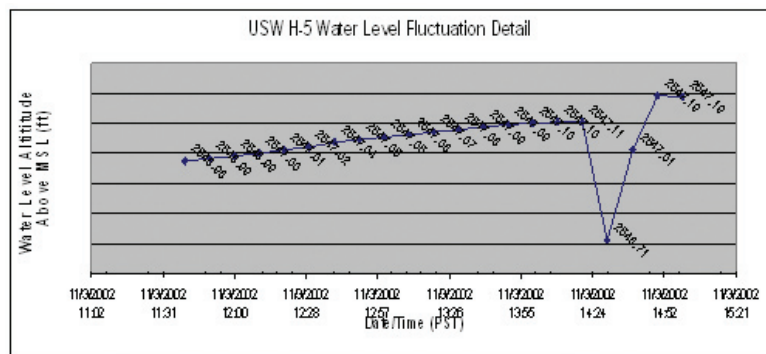
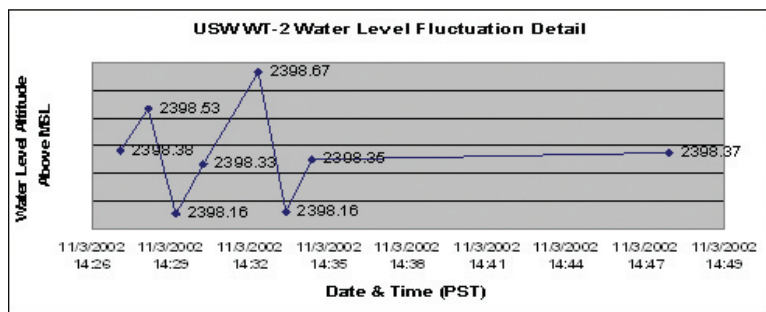


short-term fluctuations induced by earthquakes as distant as the Aleutian Islands have been documented in Yucca Mountain boreholes. Hydrographs (shown at right) from two boreholes show water level fluctuations 16 minutes after the magnitude 7.9 earthquake on Nov. 3, 2002 near Denali National Park, Alaska, nearly 2,340 miles from Yucca Mountain.

While minor water level fluctuations from distant earthquakes may be inconsequential from a repository security standpoint, automation with sensitive instrumentation has demonstrated that seismically induced changes, or hydroseisms, are probably frequent but mostly unnoticed. That earthquakes produce temporary and sustained changes in well water levels



Water fluctuations observed in monitoring wells following an earthquake in Alaska.

has been known for some time. But the exact relationship between an observed groundwater level fluctuation in a borehole and its distance from an

earthquake epicenter of specific magnitude is less well-documented. In 1979, a theoretical relationship was derived involving earthquake magnitude, distance from epicenter, and co-seismic strain; this has shown that when seismically induced strain exceeds a certain threshold, water level changes occur in wells that may be detectable with high-precision instrumentation. These very small changes produced by distant quakes are now being observed at Yucca Mountain.

The Next Step: Network Automation

Besides detecting seismic effects, continuous groundwater level monitoring also improves understanding of barometric and earth tide effects on deep groundwater by revealing long-term water level trends and offering the ability to develop simultaneous system-wide datasets on groundwater fluctuations. Scientists at the Nevada Seismological Laboratory at the University of Nevada, Reno are developing a high-speed data network that could enable remote transmission of groundwater level data directly from borehole to desktop. The logistics of data transmission in this remote, unelectrified environment are daunting, requiring line-of-sight radio via repeaters to a central data collection and processing center.

While the regulatory and political future of Yucca Mountain remains unclear, the environmental monitoring initiatives conducted by independent research institutions will continue to add to the scientific understanding of its physical systems.

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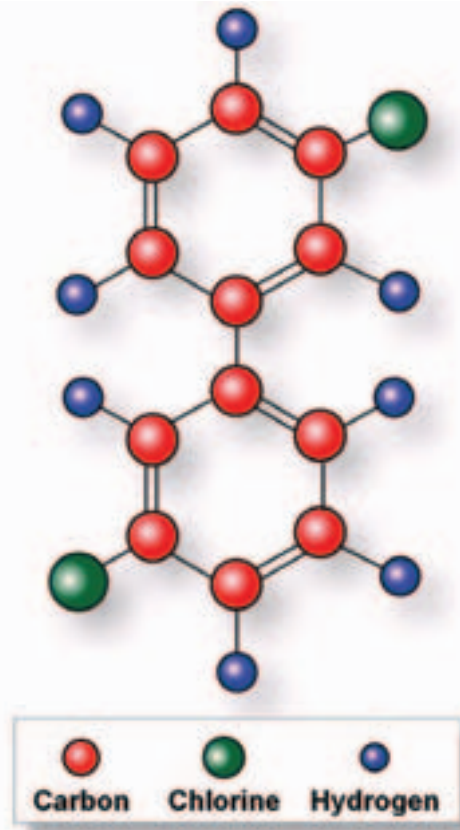
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PCBs—Still an Issue Three Decades Later

Jenny Sterling – Daniel B. Stephens and Associates Inc.

Despite the fact that polychlorinated biphenyls (PCBs) have not been manufactured since the 1970s, they persist in the environment and remain a source of environmental concern in the Southwest, including coastal California areas such as the San Francisco, San Diego, and Santa Monica bays. Inland, PCB contamination has been associated with natural gas pipelines and distribution facilities (USEPA, 1996); abandoned mining equipment such as transformers and capacitors are also considered a potential source of PCB contamination in groundwater (Bench, 2003). The U.S. Environmental Protection Agency (EPA) determined that PCBs are a carcinogen to animals and a probable carcinogen to humans. The agency set a Maximum Contaminant Level in drinking water



Chemical structure of the molecule of one PCB congener.

of 0.5 parts per billion (ppb) and a Recommended Water Quality Criteria in surface water of 0.014 ppb.

PCB Production and Use

PCBs are a class of chemical compounds in which two to 10 chlorine atoms are attached to a biphenyl molecule. Some 209 unique PCB compounds or congeners have been produced (USDHHS, 2000). Monsanto Chemical Company, the primary U.S. producer of PCBs, manufactured and marketed the compounds from 1929 through 1977 under the trade name Aroclor. PCBs were also manufactured and distributed by other producers around the world (Versar, 1976).

Production and use of PCBs peaked in 1970, when Monsanto produced 85 million pounds. A variety of industrial uses were found for PCBs, primarily because they are relatively stable under a wide range of temperatures and resist degradation and alteration. Across all industries, the



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largest use for PCBs was in capacitors and transformers. Applications included those considered to be: 1) relatively closed to the environment, such as in capacitors and transformers; 2) moderately closed to the environment, as when used in heat transfer and hydraulic fluids; and 3) open-ended applications, such as in the coating of carbonless-copy paper, inks, adhesives, plasticizers, wire insulators, metal coatings, pesticide extenders, and petroleum additives (Versar, 1976).

PCBs in the Environment

The San Francisco Bay provides an example of where PCBs concentrate in the environment today. Although PCBs are hydrophobic, their continued presence in the bay is thought to be derived from contaminated soil or sediments from a variety of industrial sources that were transported into the bay. The tendency for PCBs to sorb to particles is illustrated by results from a study undertaken in 1994 by the Regional Monitoring Program, which showed the median concentration in the particulate fraction of water samples from the bay (0.001197 ppb) was 3.5 times greater than the median concentration of dissolved PCBs (0.000341 ppb). The median concentration in sediment was 6 ppb, or 18,000 times higher than dissolved concentrations. Very low concentrations of PCBs in a water body, as in the case of the sub-part per trillion levels mentioned above, can lead to the bioaccumulation of significantly greater concentrations in organisms. Samples of bivalve tissue in the bay had

concentrations of 61 ppb, 179,000 times higher than the concentrations found dissolved in water.

Remediation: Challenging and Costly

Incineration is the most commonly used method to remediate PCB contamination.

In recent years, however, concern has arisen that incomplete incineration could lead to the formation of dioxins and dibenzofurans. Other proposed PCB remediation methods include wet air oxidation, biodegradation, metal-promoted dehalogenation, electrolytic reduction (USDHHS, 2000), and capping.

The physical properties and the distribution of PCBs in the environment can pose unique remediation and cost challenges. For example, sediments on the Palos Verdes Shelf off the coast of Los Angeles have been impacted by a 17 square-mile plume of PCB and DDT disposed by Monsanto into the sewer system. The plume is at a depth of 100 to 2,600 feet in coastal waters. The proposed remediation method is a sediment cap to limit mobility of sediments and prevent impacts to organisms living in the area. The depth, size, and active environment of this plume made the choice of an appropriate remedy difficult and ensured that remediation costs would be high.

Because PCBs tend to sorb quite strongly to solids, they typically are a greater

Matrix	Concentration	Date
Water (Dissolved)	2,856.84 pg/L	3/3/1993
Water (Total)	10,372.50 pg/L	7/30/1996
Sediment	312 ug/L	7/31/1996
Bivalve Tissue	2,024.70 ug/L	5/5/1994

Maximum concentrations of PCBs in San Francisco Bay; pg/L = picograms per liter; ug/L = micrograms per liter. Source: www.sfei.org/rmp/data.htm

concern in soils than in groundwater. In large concentrations, however, PCBs can impact groundwater. For example, at Noranda Aluminum Site in Marston, Missouri, dissolved PCB concentrations in groundwater were as high as 1,164 ppb. When PCB-containing wastes are disposed of near lakes, streams, or oceans, storm runoff and soil erosion can lead to significant suspended and dissolved concentrations in those waters. Because many PCB plumes are submerged and cover a large area, effective remediation may be difficult and expensive.

Even though PCBs have not been used for three decades, their legacy lives on in the environment today. While the highest PCB concentrations occur in soils and sediments, dissolved plumes add to the extent of environmental impacts and the challenge of remediation.

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