Report for 2001WA781B: Biodegradation of Non-Point Source Pollutants in Soap Lake, Washington

- Water Resources Research Institute Reports:
  - Peyton, Brent M., and David R. Yonge, 2002, Biodegradation of Non-Point Source Pollutants in Soap Lake, Washington, State of Washington Water Research Center, Washington State University, Pullman, Washington, 39 pp.
- Conference Proceedings:
  - Peyton, Brent M., Victor A. Alva, Celso Oie, and Melanie R. Mormile, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria from Soap Lake, Washington, "in" Proceedings of Research and Extension Regional Water Quality Conference 2002, February 20-21, 2002, Vancouver, Washington, State of Washington Water Research Center, Washington State University, Pullman, Washington, 3 pp.
- Other Publications:
  - Alva, Victor A., Brent M. Peyton, and Celso Oie, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria from Soap Lake, Washington, Invited Presentation at the Inter-Government Conference on Soap Lake, Soap Lake, Washington, April 26, 2002.
  - Peyton, Brent M., Victor A. Alva, Celso Oie, and Melanie Mormile, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria from Soap Lake, Washington, Invited Presentation at the Washington State Lake Protection Association 15th Annual Conference on Lakes, Reservoirs, and Watersheds, Olympia, Washington, April 3-5, 2002.
  - Peyton, Brent M., Melanie R. Mormile, Victor A. Alva, Celso Oie, F. Roberto, and W. A. Apel, 2002, Biotransformation of Toxic Organic and Inorganic Contaminants by Halophilic Bacteria, Presentation at the International Conference on Halophilic Microorganisms, Seville, Spain, September, 2001.

Report Follows:

PROBLEM AND RESEARCH OBJECTIVES

Soap Lake

Soap Lake is a highly saline and alkaline meromictic lake located in the Lower Grand Coulee area of Eastern Washington State. Because of local aridity, the Coulee lies in a region of internal drainage, in which surface streams dry out before they reach the ocean or a major river. Soap Lake is the southernmost lake in a chain of lakes of increasing salinity from north to south (Pickett, 1999). While there is no surface water inlet or outlet, there is water recharge from groundwater seepage, precipitation and runoff. (Anderson, 1958; Edmonson, 1991).

Human activity from transportation (highway runoff) and livestock activity (organic wastes) may contribute to increasing pollution in the area surrounding of the lake. Pollutants originating from those activities may affect the ecology of the lake leading to eutrophic conditions that could threaten the life of the indigenous and unique living organisms that thrive in this extreme environment. To date, very little is known about the biodiversity of the lake, its relationship with the dynamics of the lake and its effect in the lake global ecology.

Measurements of Soap Lake pH with depth indicate that the pH values remain very constant at 9.8 to 10 year round throughout the water column. However, it is known that at least three very distinct macro-environments exist in the lake. These three environments, the mixolimnion, chemocline, and the monimolimnion exhibit very significant differences in ionic strength (20,000 to 140,000 mg/L total dissolved solids), temperature (6-20^{o}C), and dissolved oxygen concentration (8-0 mg/L).

Influx of Pollutants to Saline-Alkaline Environments

In the last 30 years, saline-alkaline lakes as well as fresh water bodies have been protected as part of the nationwide effort to reduce the impacts of contaminant discharges into the environment. Point source pollutant control, promulgated by the 1972 Clean Water Act, has been an effective means of reducing contaminant input into the environment. Unfortunately, non-point control has not progressed at the same rate and, as a result, is a major source of pollution in large areas of the U.S. (U.S. Geological Survey, 1999). In the early 1990s, a Federal water quality initiative was developed with the goal of protecting the nation's waters from nutrient and pesticide contamination. An extensive water quality sampling campaign (National Water Quality Assessment Program) was carried out as part of this initiative, resulting in a significant database of information regarding contaminant type and concentration in surface and groundwater. However, saline and alkaline lakes were ignored in the sampling initiative, presumably because these environments were not considered relevant to the nation's recreational or potable water supplies. Pollutant type and concentration that are likely entering saline-alkaline lakes from non-point sources are primarily a function of local and regional land use. The primary land uses that generate pollutant-bearing runoff include agriculture, urban areas, and highways. As would be expected, agricultural activities generate runoff that contains sediment, pesticides, and nutrients. Numerous PAHs have been detected in highway and urban runoff. Those most frequently detected in Washington State are: pyrene, phenanthrene, fluoranthene, and chrysene (Yonge et al. 2002).

Information regarding the fate and impact of agricultural, highway, and urban pollutants on biological communities in extreme environments is very scarce. Even for neutral pH and low salinity waters, current standards and guidelines are limited to only a relatively few pollutants and do not account for contaminant mixture effects or the effects of long-term, low-level exposure. In addition, guidelines that are "safe" for aquatic systems of low salinity and circumneutral pH may not apply to saline-alkaline ecosystems that may be more sensitive to the influx of contaminants or may altogether lack the degradative capability to remove particular contaminants. The research conducted here will benefit state regulators, concerned citizens, and the scientific community by meeting the following work scope and objectives:

1) A small number of samples were collected to screen for non-point source contaminants present in Soap Lake water and sediments. Samples were sent to an environmental laboratory to determine the type and concentration of contaminants currently present in the lake.
2) Microbial degradation rates of selected non-point source contaminants were quantified in laboratory tests with mixed cultures of Soap Lake bacteria. Our overall goal was to develop data that begin to elucidate the potential impacts of non-point source pollutants on extreme environments like Soap Lake. The ability of these potentially fragile ecosystems to tolerate these contaminants is largely unknown. Our results significantly improve the current understanding of the impacts and interactions between specific anthropogenic contaminants and the haloalkaliphilic bacteria found in Soap Lake. For the scientific community, our results will provide some insight into haloalkaliphilic environments throughout the West that are potentially threatened by anthropogenic pollutants.

METHODOLOGY

Three locations in Soap Lake were sampled for water and sediment in May 2001. Samples were collected from the deepest part of the lake in the monimolimnion and overlying chemocline and mixolimnion, and from two much shallower sites in the mixolimnion. The first sampling point (P1) was in the southern part of the lake (GPS coordinates N 47 25' 9" W 119 3' 23"), the second (P2) at the central part (coordinates N 47 24' 39" W 119 30' 5") and the third point (P3) was at the northern part of the lake (coordinates N 47 23' 20" W 119 29' 11"). Samples of both water and sediments (identified as S) were collected. At the central part of the lake (P2), samples were taken at 10, 20, 24, and 26 m. Samples from these points are identified as P2-10, P2-20, P2-24 and P2-26, respectively.

Collected samples were used to challenge the native microbial communities with selected contaminants. In addition, chemical analyses were performed to characterize the bulk water chemistry (pH, O_2, temperature, and conductivity) and to detect the possible presence of anthropogenic PAH and pesticide contaminants. An existing Hydrolab Surveyor 3 connected to a field data logger was used to measure pH, temperature, conductivity and dissolved oxygen. Water and sediment samples for aerobic microbial enrichments were immediately transferred to previously sterilized HDPE bottles and cooled to $4^{o}C$. All samples were kept on ice until they reached our laboratories in Pullman,Washington, on the same day as they were collected.

Individual PAHs and atrazine concentrations were measured using a Hewlett Packard Series 1100 high-pressure liquid chromatograph (HPLC). Degradation tests were performed under aerobic and anaerobic conditions. Tests were carried out in a temperature-controlled chamber, with the flasks shaken at 150 rpm in the dark. For each set of experiments, abiotic controls were run in parallel. Additional anaerobic tests were also carried out with addition of a mixture of thioglycolate and citric acid, used as an oxygen scavenger. In the screening experiments with PAHs and atrazine, the water from the lake was used as media for degradation experiments. In further experiments with atrazine, artificial media with 4 different compositions were also tested to verify the ability of the microorganisms to grow in different concentrations of sulfate, sodium chloride and carbonate.

PRINCIPAL FINDINGS AND SIGNIFICANCE

The amount of Total Dissolved Solids (TDS) in the lake increases from 15,000 mg/L in the mixolimnion to 130,000 mg/L in the monilimniom. The most important ions are sodium, chloride and sulfate. Sodium increases from 4,500 mg/L (0.2M) in the mixolimnion to 38,000 mg/L (1.6 M) in the monilimniom, which qualifies this lake as a moderate halophilic environment (Ventosa et al, 1998). In addition, the high concentration of sulfate in the monilimniom and the strong sulfide odor, may indicate the presence of microbial communities of sulfate reducing bacteria that use sulfate as electron acceptor in their metabolism.

Contaminants

PAH analysis performed by Sound Analytic Services (Tacoma, WA) indicated no presence of PAHs or pesticides in the liquid samples. However, sediment samples showed low level traces of phenathrene (P2-S), and the pesticides DDT, dieldrin and endrin (P3-S).

Biodegradation tests

Experiments performed aerobically with phenol as a control in water from Soap Lake demonstrated that almost all the samples collected from the lake degraded phenol completely in less than 12 days. Only the samples from the bottom of the lake did not degrade any of the phenol. Degradation experiments under anaerobic conditions with lake water from the depth of 26 meters (P2-26) provided negative results for phenol.

From the 9 samples tested for phenanthrene, only one sample resulted in any degradation after 120 days. The sample P2-10, collected at sampling point 2 and at a depth of 10 m, resulted in almost 60% degradation over the 120 day incubation period. Results with fluoranthene were similar to phenanthrene, but in this case, only the sample P2-26 presented slight degradation capacity for this substrate. After 84 days, approximately 50% of the substrate was degraded. These results indicate that if significant amounts of PAH pollutants were allowed to enter the lake, these compounds may be very long lived and in fact the PAH, phenanthrene, was one of the few contaminants detected in Soap Lake sediments.

Atrazine provided the best degradation results in the screening tests, and was studied in more detail. In the screening tests, water from the lake was used as the medium for atrazine degradation. The cultures present in the anaerobic sample P2-26 demonstrated the highest capacity to degrade atrazine. With an initial concentration of 23 mg/L, at $6^{o}C$, complete degradation occurred after 170 h, while at 30°C complete atrazine degradation took 50 h. These microorganisms also demonstrated high adaptability to changes in media composition, indicating the ability to degrade atrazine in different conditions.

In summary, these results are an important step in the study of non-point pollutants and their biodegradability in environments of extreme pH and salinity. While phenol and atrazine were degradable under some conditions, phenanthrene and fluoranthene (both PAH's) do not appear to be generally biodegradable under high salt and high pH conditions found in Soap Lake. These results may be important to designing unique protection strategies for Soap Lake (an other extreme environments in the Northwest) that may not be adequately protected from contaminant influx at this time.

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