

Monitoring the Effect of Nearshore Development and Production in the Beaufort Sea

The Arctic Nearshore Impact Monitoring in Development Area (ANIMIDA) project was initiated to monitor effects of nearshore development and production in the Beaufort Sea, Alaska. This program was expanded in 2004 with the 5-year Continuation of ANIMIDA (CANIMIDA). Contaminant levels are assessed in sediment, water, and biota, and geophysical measurements are being made to determine the sources and fate of natural and anthropogenic hydrocarbons and metals.

Introduction

Development and production of oil and gas on the North Slope of Alaska has until recently occurred only on land. However, there is an increasing interest in developing the unique offshore environment of northern Alaska. The ANIMIDA project was a 5-year study started in 1999 to assess potential spatial and temporal changes related to oil development and production in the Beaufort Sea. ANIMIDA provided baseline data and monitoring results for potential chemical contaminants from development and natural sources, ecology, and subsistence whaling in the vicinity of the Northstar and Liberty development sites. Monitoring for Northstar included preconstruction, construction, and early production periods; development of Liberty

is on hold, and monitoring there has generated baseline preconstruction data. The 5-year CANIMIDA began in 2004 to continue and expand the nearshore monitoring in this area. The CANIMIDA technical-task objectives include the following.

- Characterize hydrocarbon and metal distributions in sediments in the study area.
- Determine sources, concentrations, and dispersion pathways for suspended sediment and associated chemicals.
- Characterize potential anthropogenic chemicals in amphipods, bivalves, and fish, and determine bioaccumulation and biological effects of anthropogenic chemicals.
- Monitor the unique ecosystem and local subsistence whaling.

Methods

Field surveys are conducted in the spring and summer. Bottom and suspended sediment, water, and biota samples are analyzed for more than 40 polycyclic aromatic hydrocarbons (PAHs), a suite of individual saturated and total petroleum hydrocarbons, chemical biomarkers and tracers, 13 trace and major metals, and supporting geophysical parameters. Deployed blue mussels and semi-permeable-membrane devices (SPMDs) also are used as sampling devices to concentrate contaminants and assess potential for contaminant bioaccumulation. In addition, suspended-sediment transport and loading to the Beaufort Sea (primarily from rivers) are being determined, along with natural sources of contaminants that may also have anthropogenic sources (e.g., from oil and gas activities). Field work is being conducted during the relatively brief open-water season (July and August) and also during the spring high-flow and ice-breakup periods when there is a large influx of fresh water and sus-

pended solids; the spring sampling is conducted both under ice offshore and in the major source rivers.

Separate field activities include monitoring light transmission, suspended solids, and other key parameters for correlation with the ecological quality, growth, and reproduction in the unique Boulder Patch area of the Beaufort Sea. The Boulder Patch is an area with distinctive kelp beds and other special biological characteristics. Additional activities include socioeconomic studies of the Bowhead-whale-hunting activities of native populations and effect of recent oil and gas exploration and production on whale migratory patterns and whaling activities.

Results and Discussion

Sediment. The surficial sediments in the Northstar area and for the whole region exhibit a mixture of primarily terrestrial biogenic hydrocarbons and lower levels of petroleum hydrocarbons. This assemblage is clearly dominated by plant wax normal alkanes. The PAH distributions for most of the surficial sediments show that the PAHs are primarily of a fossil-fuel origin (i.e., petroleum and coal combined) with a biogenic component (perylene) and with lesser contributions of pyrogenic or combustion-related compounds. The petrogenic PAHs account for approximately 90% of the total PAH less perylene throughout the study area. Perylene was abundant in surficial sediments, and it often was the most abundant single PAH compound in the overall PAH distribution.

Concentrations of hydrocarbons in the sediments adjacent to Northstar and Liberty generally are within the observed historical range for these parameters in the overall study area. Typically PAH profiles indicate significant levels of a fossil-fuel-type signature, which appears

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For a limited time, the full-length paper is available free to SPE members at www.spe.org/jpt. The paper has not been peer reviewed.

to be sourced in organic shales brought to the sediments from river runoff and coastal peat. PAH composition and concentration were not significantly different between study years or geographically in the study area. No evidence of any inputs of Northstar-related petroleum hydrocarbons was observed in the surface sediments.

Biota. PAH concentrations in the amphipods and clams were low in the preconstruction samples and remained low after production had begun. The hydrocarbons in the sediment appear not to be readily bioavailable, and the concentration in the overlying water column is so low that accumulation is not evident.

Copper (Cu) and zinc (Zn) were the metals with the highest, yet most uniform, concentrations in amphipods. Concentrations of lead (Pb) were low and uniform. The amphipod data for barium, cadmium, Cu, Pb, vanadium, and Zn, as well as for other trace metals, show marked similarity among years and no influence of anthropogenic input from the Northstar development or production. Mean metals concentrations in clams also were relatively uniform among years.

The SPMDs and caged mussels from the reference site and from the Northstar site showed no significant differences in the composition or concentration of the key PAH parameters. The total PAH concentrations in the mussels were higher than the predeployment reference levels, indicating that the mussels bioaccumulated trace levels of hydrocarbons. No significant differences were observed between concentrations of metals in mussels deployed at the reference site in the coastal Beaufort Sea vs. Northstar Island.

The bioaccumulation of trace substances, including anthropogenic contaminants, was investigated in five species of fish: Arctic cod, Arctic cisco, four-horn sculpin, broad whitefish, and humpback whitefish. Two fish biomarkers of contaminant exposure also were evaluated. Slight elevations of high-molecular-weight (pyrogenic) PAH and a few metals (e.g., arsenic), and some P450 induction, were observed in some of the four-horn sculpin and Arctic cisco caught in different coastal locations. These subtle signals appear to be related more to boat and other human activities than to

oil and gas development and production. However, the PAH-residue and biological-marker data indicate a low level of exposure to PAHs.

Sediment Transport and Sources.

The suspended particles in the coastal Beaufort Sea directly influence a variety of important processes including light penetration in the water column, transport and fate of trace metals and organic substances, and adsorption and partial control of concentrations of the more biologically available dissolved metals. To better understand the sources and distribution of suspended sediment, work was performed to determine the amounts and composition of suspended sediment carried to the coastal Beaufort Sea by the Sagavanirktok, Kuparuk, and Colville rivers, and concentrations, distribution patterns, composition, and fate of suspended particles in the coastal Beaufort Sea, especially in areas where construction activities may influence the suspended sediment.

The chemical composition of river suspended sediment was compared with bottom sediment to help identify possible anthropogenic inputs of suspended sediment or contaminant metals to the coastal environment. Differences in the elemental composition of suspended sediment were observed among rivers. The data indicate that the rivers are primary sources of organic compounds, including hydrocarbons from peat and shale deposits.

The ANIMIDA/CANIMIDA study area appears to be a net erosional environment at this time. Much of the large sediment load of the rivers is carried across the nearshore environment to deeper waters of the Beaufort Sea along a freshwater channel under the ice during spring or with summer and fall storms. Therefore, sediment monitoring for contaminants must be coordinated with measurements of radionuclides to ensure that samples are recent and not relict deposits.

Conclusions

Initial monitoring results indicate that any contaminants present in sediments are at or near background concentrations throughout the Alaskan Beaufort Sea, with possible slightly elevated hydrocarbon levels near Northstar that are well below concentrations of ecological concern. Isolated areas with indications of inputs of anthropogenic

chemicals have been identified, but the contamination has not been linked to local development and production activities. In addition, a comparison of the sediments contaminant data from the study region to the Effects Range Low and Effects Range Median sediment-quality guidelines reveals that none of the concentrations exceed the guidelines. Fish, amphipods, and clams do not show evidence of effects from or accumulation of development/production contaminants.

Significant natural sources of hydrocarbons and metals have been identified, primarily the major rivers that flow into the Beaufort Sea. These rivers deliver approximately 80% of the annual suspended-solids input to the Beaufort Sea within a 2- to 3-week period each spring. No significant differences in concentrations of total suspended solids (TSS) that could be linked directly to oil and gas operations were observed in the area. Periodic increases in levels of TSS in the coastal Beaufort Sea can be related to river runoff and resuspension of bottom sediment by strong winds. Natural suspended-sediment inputs from runoff and erosion are large relative to any anthropogenic sediment inputs.

Concentrations of dissolved trace metals and PAHs in the water column of the study area are very low and characteristic of pristine water. Concentrations of some metals can be modeled with a simple distribution coefficient, and active physical, chemical, and biological processes are at work to create a dynamic, yet predictable, distribution of dissolved trace metals. Such information will be useful for long-term monitoring and will provide an evolving capability for predicting effects from any spills or other releases of chemicals within the drainage basin or the coastal sea.

Overall, the results indicated that no significant contaminant inputs from Northstar development activities were detected and that any observed changes in the monitored environmental conditions were well within the natural variability of the study area. The results, coupled with increased knowledge of the chemistry of natural sources of hydrocarbons and metals, indicate that the monitoring and data-interpretation approaches as designed are very sensitive to changes and that if inputs were to occur, the measurement systems set in place would be sufficiently sensitive to detect such inputs. JPT