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STUDY TITLE: Contribution of Produced Water Discharge Oxygen Demand in the Development of Hypoxia

REPORT TITLE: Relative Contribution of Produced Water Discharge Oxygen Demand in the Development of Hypoxia

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BACKGROUND: The northern Gulf of Mexico is the site of the world's second largest zone of anthropogenic coastal hypoxia (water with dissolved oxygen less than 2 mg l^{-1}, ppm). The northern Gulf of Mexico is also an area of extensive oil and gas exploration and production activity. The United States Environmental Protection Agency (USEPA) is tasked with protecting the nation's water quality while the Department of the Interior, Minerals Management Service (DOI MMS) is tasked with managing the development of hydrocarbon resources while protecting the environment. In this overlapping area of concern on the Gulf of Mexico Outer Continental Shelf (OCS) is the large area of hypoxia off the Louisiana and Texas coasts that occurs each spring through summer.

Produced water is a waste product generated during the production of oil and gas. It is a mixture of hypersaline water with varying volatile, water soluble, and more recalcitrant hydrocarbons, sulfur and nitrogen compounds, as well as residual chemicals added to assist in production or to treat the produced water prior to discharge.

Many studies of the cause and effects of the hypoxic zone have been published. Similarly, many studies have documented the impacts of OCS produced water discharges on sediment, water, and biota. The discharge of the Mississippi River, which directly influences the formation and dynamics of hypoxia, has made it difficult to isolate the influences of the river from those related to offshore production activities. A toxic endpoint resulting from oxygen depletion has not been a part of prior MMS studies or NPDES regulation. The potential for produced water constituents to contribute to the biochemical oxygen demand (BOD) in offshore waters has not been studied. Relevant information exists in many studies that can be summarized and synthesized to address this question.

OBJECTIVES: The objective of this analysis is to evaluate the relative contribution of produced water organic and nutrient compounds in relation to those of the Mississippi and Atchafalaya discharges in the context of hypoxia formation on the continental shelf. Relevant information includes:

(1) geographic extent, severity and duration of the hypoxic zone;
(2) causes of hypoxia;
(3) produced water constituents, volumes, and geographic location;
(4) relative inputs of organic matter and nitrogen from produced water and river discharge;
(5) oxygen utilization as a result of chemical constituents of produced water; and
(6) potential for nutrient-enhanced production related to produced water nutrients.

Rather than collect new data, this report summarizes published information, unpublished data relevant to the question at hand, and existing summaries of industry or MMS data. These data allow insight into the dynamics of hypoxia, the characterization of produced waters and their discharge into the northwestern Gulf of Mexico, and the relative contribution of oxygen demanding materials and nutrients from produced waters compared with those of the Mississippi River and *in situ* marine phytoplankton production.

DESCRIPTION: The relative amounts of organic carbon and ammonium in produced water discharges were compared to those delivered by the Mississippi and Atchafalaya rivers to the adjacent continental shelf. Estimates were made both across the large area where hypoxia occurs and in a smaller area in the core of the hypoxic zone where more detailed data on oxygen and carbon dynamics are available. The inputs from the Mississippi River are well characterized and modeled as to their effects on the continental shelf over a broad spatial scale from the Mississippi River to the upper Texas coast. The comparisons of limited available produced water constituent loads with much better characterized Mississippi River data are made with numerous assumptions.

How well multiple forms of data for organic carbon correspond and what nitrogen compound concentrations are in produced water are not known. The first order estimations lean to worst-case scenarios for the produced water carbon and nitrogen inputs, but the expected dilutions and dispersions correspond to available models. The oil and grease loadings do not track well to the total organic carbon content of produced water nor do they distinguish among the hydrocarbon compounds that vary with regard to volatility, solubility, photo-oxidation, likelihood of adhering to sedimenting particles and susceptibility to microbial degradation. All hydrocarbons included in the oil and grease content and loadings were included in calculations of organic carbon that would reach the lower water column and sediments and contribute to respiratory reduction of dissolved oxygen. This, of course, is not the case. Estimates of produced water ammonium were compared to river ammonium, nitrate, and nitrite (dissolved inorganic nitrogen) and total nitrogen that include both dissolved and particulate organic nitrogen, because all can stimulate phytoplankton production. The role of dissolved inorganic nitrogen in the dynamics of hypoxia is better understood than the organic fraction of total nitrogen.

SIGNIFICANT CONCLUSIONS: First order estimations of the contribution of carbon and nitrogen in produced water discharges were compared to the Mississippi River contribution. Carbon and nitrogen in produced water contribute minimally in comparison to the river within the area subject to hypoxia.

STUDY RESULTS: The produced water ammonium discharged within the area subject to hypoxia is estimated to be 0.013 percent of the total nitrogen delivered by the Mississippi River system, 0.008 percent of the total dissolved inorganic nitrogen and 0.002 percent of the total ammonium.

Up to 4 percent of the organic carbon delivered to the Gulf of Mexico, which includes terrestrial material along with oil and grease from nonpoint source runoff, is estimated to contribute to respiratory demand in water below the pycnocline in the area of hypoxia. The produced water oil and grease load for the Gulf of Mexico is 10.9 percent of the oil and grease load from the Mississippi River that might contribute to hypoxia. Without appropriate total organic carbon, dissolved organic carbon and particulate organic carbon (TOC, DOC and POC) data for produced water discharges in the area of hypoxia, it would be inappropriate to compare produced water oil and grease loads to riverine TOC data. However, considering that the Gulf produced water oil and grease load is a relatively small percent of the Mississippi River load that might contribute to hypoxia, it is reasonable to expect that this small percentage would also be overwhelmed by the nutrient-enhanced surface *in situ* production offshore. The *in situ* production is estimated to be 96 percent of the organic matter loading that drives the oxygen and carbon budgets of the continental shelf where hypoxia occurs, compared with the up to 4 percent riverine organic loading that might contribute.

STUDY PRODUCT(S): Rabalais, N. N. 2005**.** Relative Contribution of Produced Water Discharge Oxygen Demand in the Development of Hypoxia. OCS Study MMS 2005-044. U.S. Dept. of the Interior Mineral s Management Service, Gulf of Mexico OCS Region, New Orleans, La. 47 pp. + Appendix 10pp.