Effects of Hurricanes Katrina and Rita on the Chemistry of Bottom Sediments in Lake Pontchartrain, La.

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Concerns about the effect of pumping contaminated flood waters into Lake Pontchartrain following the hurricanes of 2005 prompted the U.S. Geological Survey (USGS) to sample street mud, canal-suspended sediment, and bottom sediment in Lake Pontchartain. The samples were analyzed for a wide variety of potential inorganic and organic contaminants. Results indicate that contamination of lake sediment relative to other urban lakes and to accepted sediment-quality guidelines was limited to a relatively small area offshore from the Metairie Outfall Canal (popularly known as the 17th Street Canal) and that this contamination is probably transient.

Introduction

Flooding of New Orleans by Hurricanes Katrina and Rita inundated numerous urban contaminant sources (sewage-treatment facilities, gasoline stations, automobiles, industrial facilities, commercial buildings and houses, and historically contaminated soils), raising concerns for potential human health effects in New Orleans and adverse effects on Lake Pontchartrain from pumping flood waters into the lake. The objective of this study was to characterize the effect of the discharge of flood waters from New Orleans on the sediment chemistry of Lake Pontchartrain.

Sample types and locations were selected to characterize the sources (street mud: 4 sites), transport (suspended sediment: 5 sites), and fate (bottom sediment in the lake: 27 sites) of sediment-associated contaminants pumped from the city (fig. 1). Sampling and analytical methods and complete chemical data are presented in Van Metre and others (2006a), and additional interpretations are presented in Van Metre and others (2006b). All samples were collected between September 20 and October 21, 2005. A wide variety of chemical constituents were measured, including radionuclides, major and trace elements, nutrients,

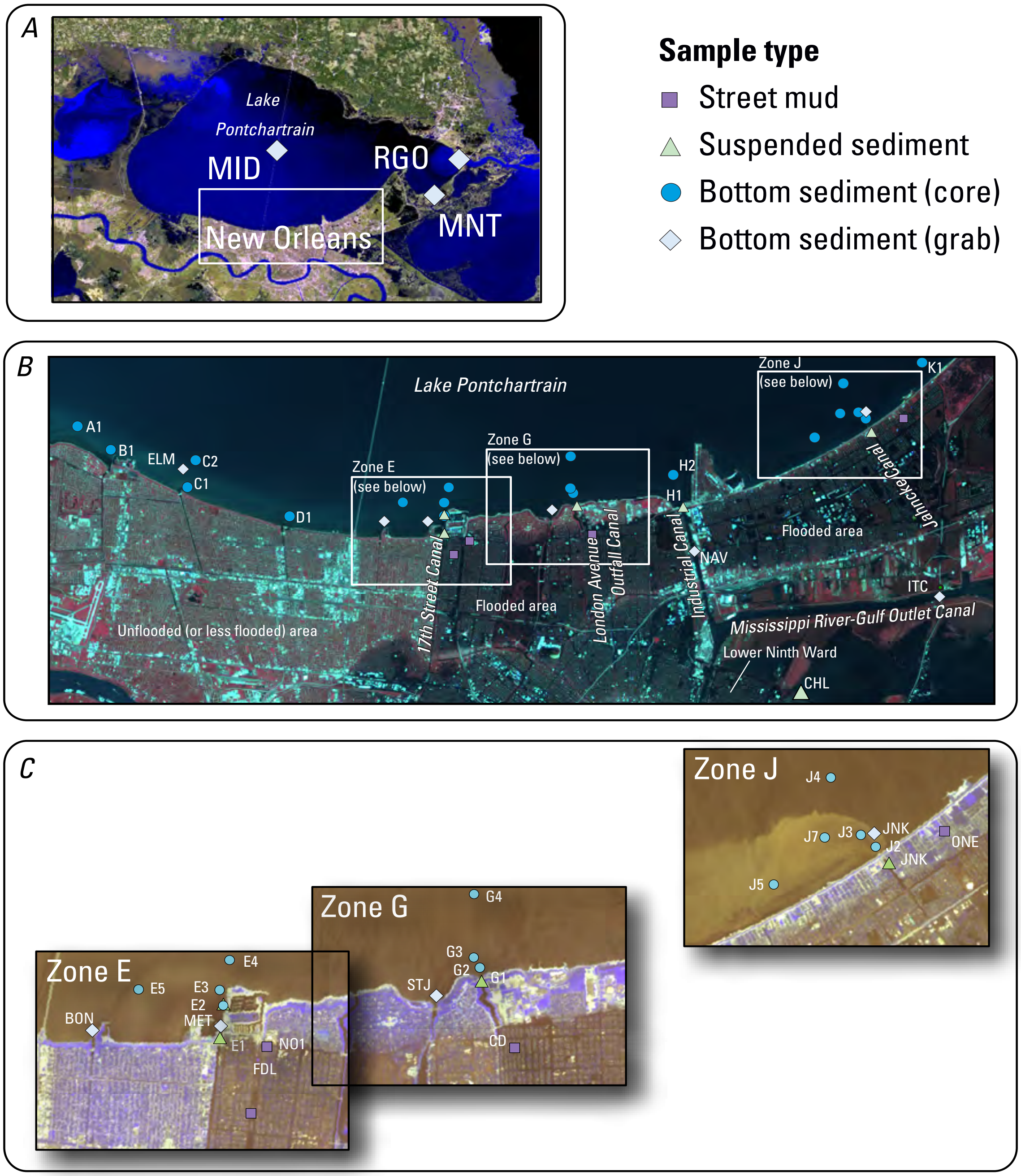

Figure 1. Types of samples taken and locations of sampling sites (indicated by alphanumeric codes) in relation to New Orleans and Lake Pontchartrain, La. (*A*) Satellite image (Louisiana Oil Spill Coordinator's Office (LOSCO), 1999) showing sampling sites farthest from the metropolitan New Orleans area. (*B*) Satellite image (SPOT 5 image, Sept. 2, 2005) showing sampling sites within the area indicated by white box in *A*. (*C*) Satellite images (Advanced Spaceborne Thermal Emission and Reflection Radiometer (ASTER), Sept. 13, 2005) of zones E, G, and J from image in *B*. Sediment plumes are visible in the lake and along the shoreline.

organochlorine pesticides, polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), urban waste-indicator (UWI) compounds, and current-use pesticides. A short-lived (half life of 53.3 days), naturally occurring radionuclide known as beryllium 7 (^{7}Be) was measured to determine whether surficial bottom sediments were recent (from pumpage of floodwaters).

Chemistry of Sediment and Mud

Field observations and radionuclide activities indicate extensive sediment redistribution during Hurricane Katrina (fig. 2) followed by deposition of a new layer of material adjacent to the mouths of some canals as a result of pumping flood waters from the city. One area of new deposition was off the mouth of the 17th Street Canal, an area partly protected from longshore currents by a marina breakwater (fig. 1, zone E). On September 20, during pumping, a plume of turbid water extended 1,000–2,000 ft (several hundred meters) from the mouth of the canal into the lake, past the northern end of the breakwater. Sites E1–E3 were located within the plume, and site E4 was located about 600 ft (200 m) past the plume. Sediment texture transitioned from a soft, fine-grained, organic-rich black sediment layer ~1 inch thick (2 cm thick) overlying a very firm layer (impenetrable to our samplers) at sites E2 and E3 (fig. 3) to an olive-gray silt/clay mixture at site E4. Detectable levels of ^{7}Be indicated that the surface layers at these sites were recently deposited.

Low or nondetectable levels of ^{7}Be indicate less recent deposition of sediment in front of the other canals, and the organic-rich black surface layer was not observed. Satellite images and direct observation indicated sediment plumes extending from the London Avenue Outfall Canal and Jahncke Canal during September (fig. 1, zones G and J). Some sediment samples offshore from these canals had ^{7}Be activities indicating recent deposition, but many, including most samples to the west of the 17th Street Canal, did not. Low or nondetectable ^{7}Be activities off the west-side canals indicate that little or no new hurricane-related sediment had been deposited.

In general, street mud, suspended sediment, and samples from off the mouth of the 17th Street Canal had the highest concentrations of common urban contaminants (heavy metals, PAHs, and chlorinated pesticides and PCBs), similar to or higher than median concentrations found in urban lakes across the United States (Van Metre and Mahler, 2005; Mahler and others, 2006; Van Metre and others, 2006a). Concentrations of contaminants off other canals and further from shore were much lower, similar to light urban and undeveloped reference lakes sampled in other parts of the country. This pattern of decreasing levels offshore is illustrated by the distribution of PAHs (fig. 4), a ubiquitous organic contaminant in urban settings. Total PAH, as used here, is the sum of 13 individual PAH compounds and is the same summation as is used for the consensus-based sediment-quality guidelines developed by MacDonald and others (2000). The sediment-quality guidelines are levels of various contaminants in sediment that have been shown to cause adverse effects (for example, toxicity) to aquatic life—for each contaminant that level is called the probable effects concentration (PEC). The PEC for total PAHs is 22,800 µg/kg. The highest total PAH concentration in street mud was from near the levee breach on the 17th Street Canal (fig. 4). They were relatively high in suspended sediment samples from the 17th Street Canal and Inner Harbor Navigation Canal (popularly known as the Industrial Canal), demonstrating transport of PAHs from the city to the lake. Lake Pontchartrain bottom sediment samples offshore from the 17th Street Canal (zone E) had concentrations that decreased from 42,000 µg/kg at the canal mouth (site MET) to 470 µg/kg at E5, the site furthest from the canal (fig. 4). Although PAH concentrations were moderately high in suspended sediment from the Industrial Canal (zone H), concentrations in bottom sediment in zone H were quite low, as they were in most other samples from the lake.

Figure 2. Photograph taken on September 21, 2005, at sampling site NO1 (see fig. 1) of a footprint in the mud that was deposited on the street at the site.

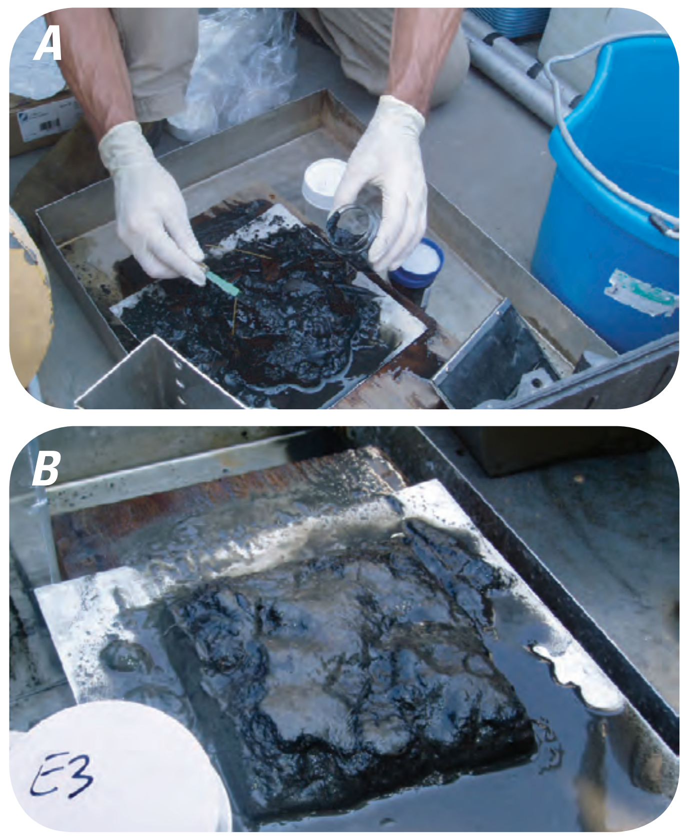

Figure 3. Photographs showing color and texture of surficial sediment in samples from sites E2 (*A*) and E3 (*B*), collected on September 20, 2005, offshore from the 17th Street Canal in Lake Pontchartrain, La.

Elevated levels of metals also were confined to street mud, suspended sediments, and bottom sediment near the mouth of the 17th Street Canal. Metals that were elevated

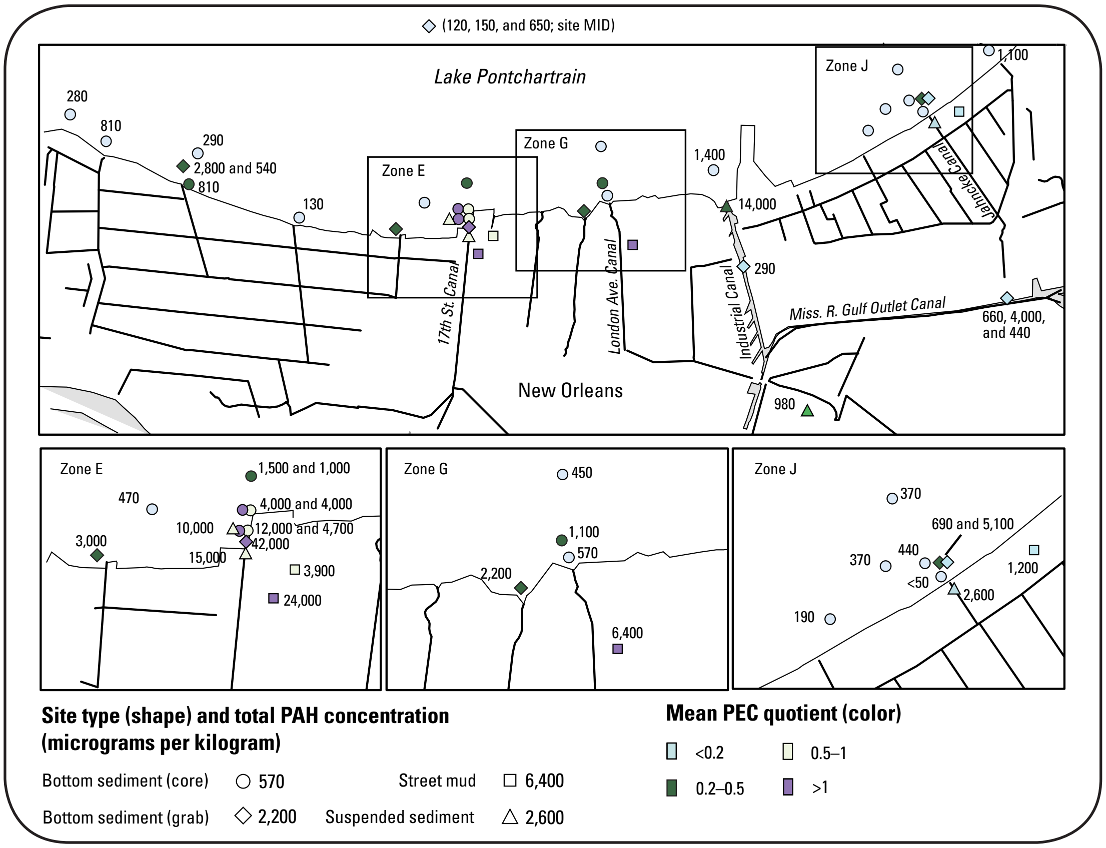

Figure 4. Concentrations of total polycyclic aromatic hydrocarbon (PAH) and ranges of values of mean probable effect concentration quotient (PEC) for Lake Pontchartrain, La., bottom sediment, suspended canal sediments, and street mud samples from New Orleans, La.

included copper, lead, mercury, and zinc. Trends were indicated at sites E2, E3, and E4 by sampling before and after Hurricane Rita. Metal concentrations decreased by about half at E2 after Rita but increased at E3, indicating redistribution of sediment by that hurricane. Historical data from Lake Pontchartrain have shown similar distributions of trace elements (Overton and others, 1985; Noakes, 1988; Manheim and Hayes, 2002).

The occurrence of chlorinated pesticides and PCBs followed the same general spatial pattern as did the PAHs and metals. The most frequently detected of this group of compounds were *p,p'*-DDD, *p,p'*-DDE, dieldrin, chlordane compounds, and PCBs. The highest concentrations were at the E sites, with lower concentrations near the London Avenue and Industrial Canals and mostly nondetections in samples collected further from shore. The samples from sites E3 (September 21) and MET (September 29) had particularly high concentrations of some compounds; however, the post-Rita sample from E3 (October 9) had much lower concentrations than did the pre-Rita sample. Nondetections were reported for most chlorinated hydrocarbons in suspended sediments because of small sample masses and high laboratory reporting levels. Concentrations in street mud samples were variable; there were mostly nondetections at site ONE, but there were some relatively high levels at sites CD and FDL (e.g., concentrations of dieldrin of 12 and 27 µg/kg, respectively).

Among the 63 compounds analyzed by the new current-use pesticide method (Mast and others, 2006), 13 were detected at least once. The most frequently detected were chlorpyrifos and three fipronil degradates (fipronil sulfide, fipronil sulfone, and desulfinyl-fipronil), which were detected in 40 percent or more of the samples. Parent fipronil was detected in 25 percent of samples. About a third of all detections were in samples of street mud (current-use pesticides were not analyzed in suspended sediments). Similar to concentrations of other contaminants, the highest concentrations of current-use pesticides in lake samples were at the E sites, but relatively high concentrations also were found in samples from G3 and J4. Both chlorpyrifos and, more recently, fipronil have been applied in New Orleans for control of termites, as well as for other insects (Louisiana State University Agricultural Center, 2005, 2006).

The urban waste indicator (UWI) method measures a diverse suite of organic compounds that reflect the inputs from urban nonpoint sources and wastewater inputs to surface waters (Kolpin and others, 2002); methods for their analyses in sediment were only recently developed (Burkhardt and others, 2005). Sixty compounds were reported for the UWI method, and 16 of those were detected in 50 percent or more of samples, including selected PAHs (also measured by using the PAH method discussed above), anthraquinone, indole, 3-methyl-1H-indole, para-cresol, cholesterol, and *beta*-sitosterol and *beta*-stigmastanol. Phenol was detected in 43 percent of samples, and bis(2-ethylhexyl) phthalate was detected in 45 percent of samples; both also were reported in one or more Katrina floodwater samples (Pardue and others, 2005). Detection frequency was less than 17 percent for all other compounds except carbazole (39 percent), bisphenol A (29 percent), and 3-beta-coprostanol (37 percent), a fecal steroid that is generally a strong indicator of human or animal wastewater sources and that was detected in 85 percent of U.S. stream water samples (Kolpin and others, 2002).

In most cases, suspended sediment samples had much higher concentrations of the wastewater compounds than did bottom sediment and street mud samples, indicating transport of wastewater compounds to the lake by pumping of flood waters. The occurrence of UWI compounds in lake-bottom sediments was different, however, than other common urban contaminants. In zone E, for example, the highest concentrations of cholesterol, phenol, and *beta*-stigmastanol were measured at E5, the site with the lowest concentrations of PAHs, metals, and organochlorine compounds. These differences likely reflect differences in sources (many have natural as well as human sources) and in how these wastewater compounds were transported and accumulated in sediment.

Overall Sediment Quality

To assess overall sediment quality relative to potential toxicity to benthic biota, the mean PEC quotient was computed. The mean PEC quotient combines the ratios of concentrations of 16 metals and organic compounds to their PEC to provide a reliable basis for assessing sediment-quality conditions (MacDonald and others, 2000). MacDonald and others (2000) found that sediment with a mean PEC quotient above 0.5 was 85 percent likely to have adverse effects on benthic organisms and above 1.0 was 92 percent likely to have adverse effects on benthic organisms.

Ten of the 44 samples (23 percent) collected in this study for which mean PEC quotients could be calculated had values greater than 0.5, and five of those were greater than 1.0 (fig. 4). All of the samples with mean PEC quotients greater than 0.5 were street mud or sediment from near the mouth of the 17th Street Canal. The highest mean PEC quotients were 3.2 (E3 on September 21, before Rita) and 2.2 (MET on September 29, after Rita). The low mean PEC quotients for the other samples and the overall distribution of quotients indicate the limited spatial extent of human effects on sediment quality in Lake Pontchartrain (fig. 4). With the exception of a small area within about 1,000 feet (a few hundred meters) of the 17th Street Canal, sediments in Lake Pontchartrain were cleaner than is typical of other urban lakes in the United States, and substantial adverse affects on aquatic life are unlikely (Van Metre and others, 2006b).

Conclusion

The results of this study indicate that relatively contaminated sediment was discharged from New Orleans into Lake Pontchatrain by the pumping of flood waters but that deposition of contaminated sediment in Lake Pontchartrain was spatially and perhaps temporally limited. These conclusions are consistent with those from studies carried out prior to Katrina (Manheim and Hayes, 2002). The relatively high concentrations of urban-related contaminants in sediments measured offshore from the 17th Street Canal by this and other studies could be the result of the location of a marina breakwater extending into the lake on the east side of the canal. Because the breakwater provides some protection from currents at this site, sediment redistribution may only occur during major storms, allowing for longer term deposition of fine-grained contaminated sediments discharged from the canal. Transport of these types of sediments from the other canals as a result of longshore currents might explain why contaminant concentrations in bottom sediments off the mouths of the other canals generally are low.

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