Soil and Sediment Chemistry in the Mississippi River Delta Following Hurricane Katrina

By Emitt C. Witt III, Craig D. Adams, Jianmin Wang, David K. Shaver, and Youssef Filali-Meknassi

In October 2005, the U.S. Geological Survey's (USGS) Mid-Continent Geographic Science Center and the University of Missouri-Rolla's (UMR) Environmental Research Center for Emerging Contaminants partnered to collect perishable environmental data along the Mississippi River Delta to catalog the effects of Hurricane Katrina, a category 3 storm that caused nearly complete destruction to the delta's population support structure and industry. The data presented here begin the process of characterizing the chemical composition of sediments and soil along the delta following this significant natural disaster.

Introduction

On Monday, August 29, 2005, Hurricane Katrina, a category 3 storm, made landfall near the town of Buras, La., on that portion of the Mississippi River Delta associated with the main stem of the Mississippi River, which extends southward into Louisiana's rich but fragile coastal marsh system. This segment of the delta hosts a series of small communities that support the State's fishing industry. As a result of Katrina, much of the Mississippi River Delta was severely impacted, as was much of the fleet that supported the fishing industry.

The storm surge was recorded at 47 ft (14.3 m) (National Oceanic and Atmospheric Administration (NOAA) buoy 42020, Public Advisory 25b) and spilled into the narrow strip of land between the levees, removing homes from their foundations, scattering fuel oil tanks and their contents, and damaging oil refineries. After the storm passed, boats, vehicles, and debris from homes, businesses, and cemeteries remained in numerous piles along the delta (figs. 1 and 2).

In October 2005, 1 month after Katrina made landfall along the Mississippi River Delta, a team of USGS and UMR scientists deployed to the devastated area to collect perishable environmental and engineering data. While the damage and displacement that this event caused our Nation was serious, it provided our team with a once in a lifetime opportunity to catalog the storm's effects and characterize the contamination that remains as a result of the mixing of new contaminants with those already associated with the sediment of the Gulf of Mexico and the Mississippi River Delta. This study focused on collecting as many samples as possible along the delta before cleanup efforts would alter the poststorm depositional setting. The logistics of this effort so early after the passing of the storms proved very chaotic because of the many piles of debris, damaged watercraft, and damaged transportation infrastructure.

Synoptic Sampling

During the 2-week deployment to the area, 75 soil and sediment samples were collected along Highway 23 from New Orleans and through Empire, La., near where the eye of Katrina made landfall (fig. 3), to just north of Venice. Two procedures were used for sample collection: a coring procedure to characterize trace element and organic compound stratification and a surface grab sample to characterize the sediment deposited from the flood water. (Grab samples are collected by scooping from the surface by using a precleaned hand shovel and then are deposited in a shipping container.) In the coring procedure, a hand-held soil core tool was used to collect both a shallow (0–3.9-inch (0–10-cm)) and a deep (3.9–7.87-inch (10–20-cm)) sample. Samples were placed in 100-mL septum bottles and transported on ice throughout the deployment until placed under refrigeration at the UMR Environmental Research Center laboratory, Rolla, Mo.

Of the 75 samples collected, 11 were selected for chemical analysis (fig. 3). The selected analyses included a headspace gas chromatograph/mass spectral (GC/MS) analysis of the petroleum-based organic compounds benzene, toluene, ethylene, and xylene (BTEX) and a liquid-liquid extraction GC/MS analysis for the pesticide compounds simazine, atrazine, methoxyclor, and prometon. A slightly modified U.S. Environmental Protection Agency (EPA) Method 1312 was used to obtain leachate samples to study the availability of trace metals under simulated acid rain conditions (U.S. Environmental Protection Agency, 1994). Selected trace elements arsenic, cadmium, chromium, copper, lead, and vanadium were measured by using PerkinElmer ELAN™ DRC-e Inductively Coupled Plasma Mass Spectrometry (ICP-MS). Mercury concentrations were determined by using a Tekran™ Series 2600 ultra-trace level mercury analyzer based on the EPA Method 1631 (U.S. Environmental Protection Agency, 2002). These constituents and resulting analyses were selected to fit the team's observation of the most likely contamination to be incorporated in the sediments and to provide a starting point for characterizing additional analytical scenarios for the remaining samples and future Gulf Coast sampling efforts.

The Sampling Scheme

The landscape of the delta is characterized as the narrow strip of land between the levees and extends more than 70 mi (130 km); only about 60 mi (111 km) of that distance is served by major roads. The last major town is Venice, La., a community of about 2,200 individuals occupying almost 5 mi^2 (12.9 km^2). Forty-nine percent of Venice's jurisdictional area is water and marshland (U.S. Census Bureau, 2000). The major industries supporting the region are commercial fishing, maritime shipping, and oil refining and support industries. Also evident during the reconnaissance trip were numerous stone-fruit orchards, almost all of which were destroyed by inundation of salt water during the storm.

Almost all of these industries were completely destroyed, and the contaminants associated with their operations were distributed throughout the region by flood water and high winds (fig. 4). The sampling scheme used in this study targeted contamination relative to damaged industries' effect

Figure 1. Photograph showing destructive force of Hurricane Katrina's flood waters on a local cemetery and adjacent community in Empire, La.

Figure 2. Photograph showing debris and displaced boats on a levee embankment across a field where homes stood prior to Hurricane Katrina near Port Sulphur, La.

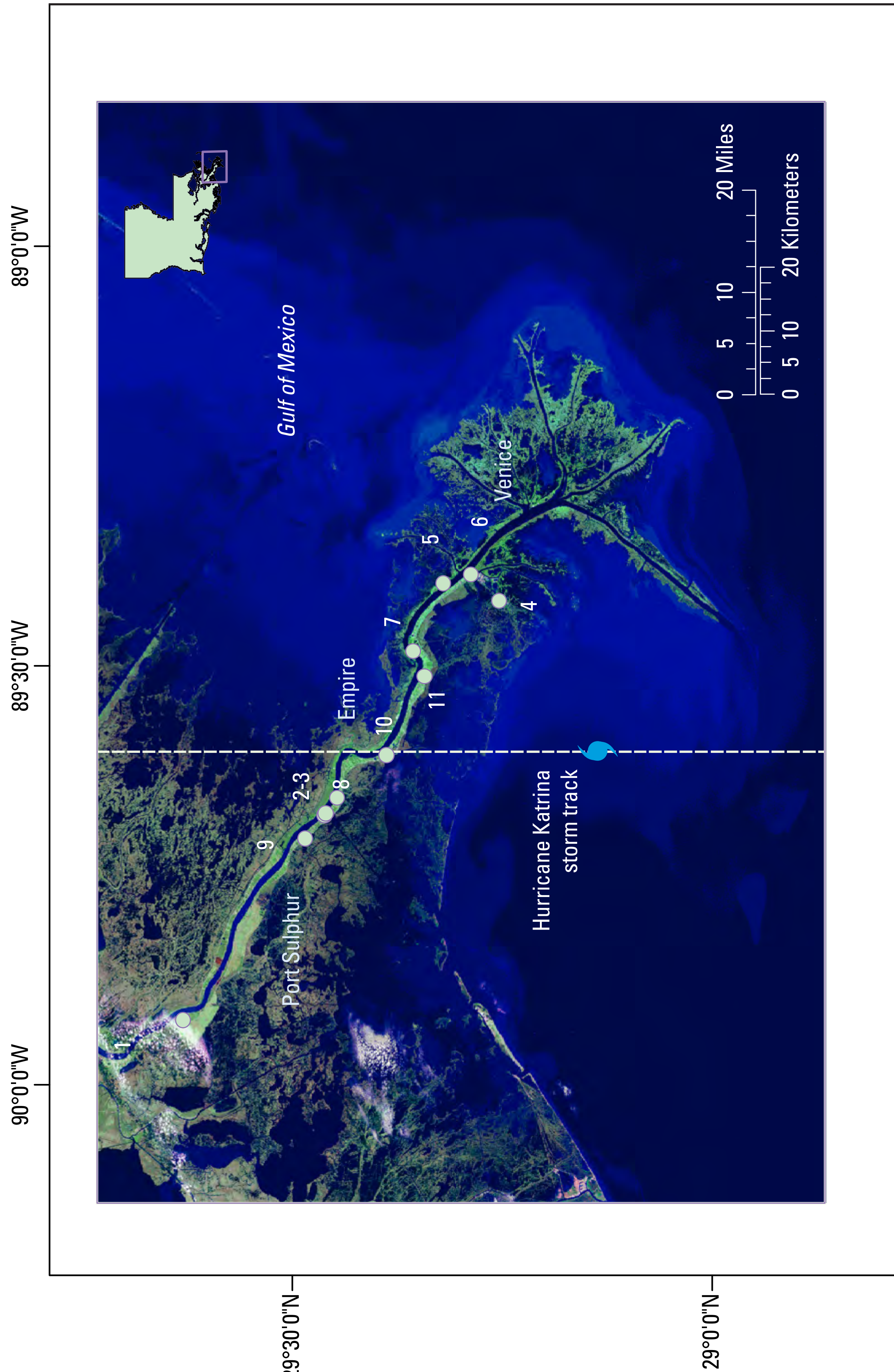

Figure 3. LandSat 7 mosaic (2002) showing the location of selected samples along the Mississippi River Delta, La.

on communities and their physical support infrastructure. These include residential areas, school playgrounds, parking lots, parks, cemeteries, and roadsides. Less emphasis was placed on obvious areas of contamination such as oil-storage facilities and refining operations associated with large areas of oil-glazed surface because several private firms were already in the area characterizing such contamination from a regulatory and site-specific cleanup perspective.

Figure 4. Photograph showing two steel-hull fishing vessels that came to rest across the base of the Highway 23 overpass near Empire, La., after Hurricane Katrina in 2005.

Results

Samples analyzed for trace elements were prepared in the laboratory to represent the concentration of leachable trace metals or were dissolved into solution under simulated acid rain conditions. Although such conditions are not typical along the Gulf Coast, they could have occurred along the Mississippi River Delta during the mixing of contaminant-laden sediment with industrial chemicals littering the area. In the short term, this method provides an assessment of how trace elements can come into contact with the resident population during the dispositioning of soils during the posthurricane rebuilding and cleanup activities. In the longer term, this method characterizes the relative leaching potential of trace elements and enables the beginning of a data set that can be used for ecosystem studies that analyze the effects of large elemental metal concentrations on wetlands, marshes, and agricultural lands. This method does not quantify the total concentration of elemental trace metals in the solid phase, which may be very large.

This cursory investigation along the Mississippi River Delta indicates the possibility of localized soil contamination. In general, concentrations of trace elements within the leachate were small, with a few exceptions (fig. 5). Lead concentrations exceeded the drinking water standard of 15 μg/L at 1 of 11 sites, and arsenic concentrations exceeded the standard of 10 μg/L at 3 of 11 sites (U.S. Environmental Protection Agency, 2003). Vanadium, copper, and chromium were present in all samples at concentrations less than the maximum contaminant level (MCL) for drinking water. Cadmium concentrations were surprisingly low. The team had expected to find substantial concentrations of cadmium associated with the soils because cadmium is inherently linked to fluid from automobiles, boats, and other machinery—all of which were damaged or destroyed during the storm.

Of the 11 samples, 7 were analyzed for mercury concentration. Mercury concentrations were substantially less than the drinking water standard of 2 μg/L for these samples (U.S. Environmental Protection Agency, 2003). The largest mercury concentration totaled 108 nanograms per liter (ng/L) and was observed in a sample from site 7 (fig. 5). It is important to note that the unit of measure reported above for mercury (ng) is one magnitude smaller than the unit for the drinking water standard (24 g/L). Comparison of these data with the drinking water standard does not imply that drinking water supplies along the delta have been or will be contaminated at the levels reported here; however, it does provide a reference point for reviewing the data in the absence of data on the concentration of soil leachate trace elements before the hurricane.

The results of organic analysis were rather sporadic and not very conclusive. Of the BTEX or petroleum-based compounds, no toluene, ethylbenzene, or xylene was detected. Benzene, however, was detected in 5 of 11 samples at concentrations slightly above the minimum detection level of 5 μg/kg of soil. The triazine pesticides simazine, atrazine, and prometon were detected at concentrations ranging from 56 to 2,580 μg/kg in 7 of 11 samples (fig. 6). The largest concentration of atrazine and prometon were observed in the sample from site 10. While the presence of row-crop farming is minimal along the southern part of the delta, the presence of triazine pesticides in the soil and sediment may have originated from flooded warehouses storing agricultural chemicals, from limited local use and storage, and from agricultural runoff transported by the Mississippi River.

Methoxychlor, a common pesticide used to kill flies, mosquitoes, cockroaches, and chiggers, was detected in samples at seven sites (Agency for Toxic Substances and Disease Registry, 1995) (fig. 6). The concentration of methoxychlor in samples at all seven sites ranged from 70.8 to 1,306 μg/kg. The largest concentration was analyzed from a sample collected at site 2. There was no obvious reason recorded for the large concentration of this pesticide at this and other sites along the delta, except that it is a commonly used chemical for insect control along the Gulf Coast.

Conclusion

Katrina devastated the Mississippi River Delta to the degree that nearly every structure will need to be rebuilt

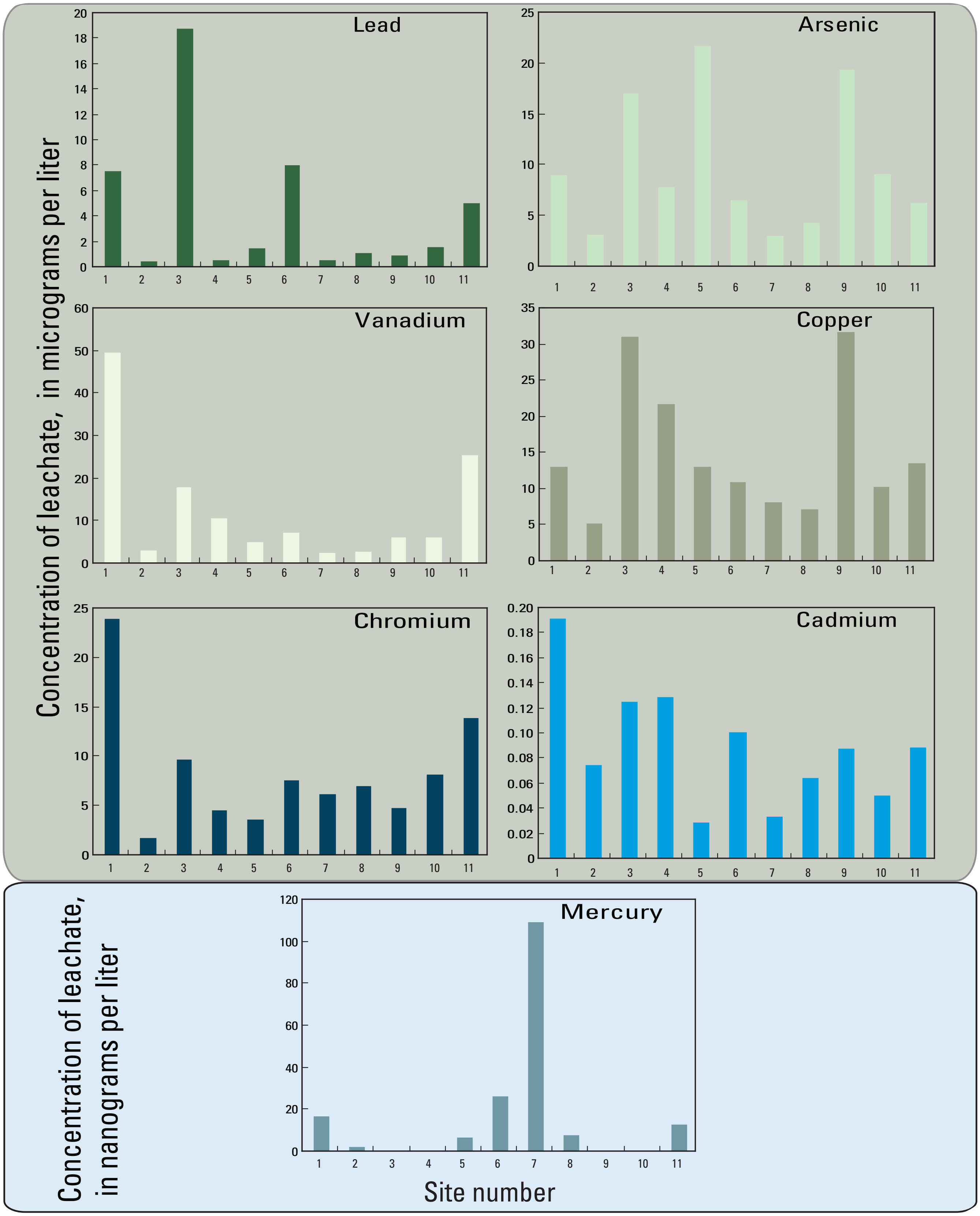

Figure 5. Elemental trace-metal leachate concentration in samples from the Mississippi River Delta, La., after Hurricane Katrina in 2005.

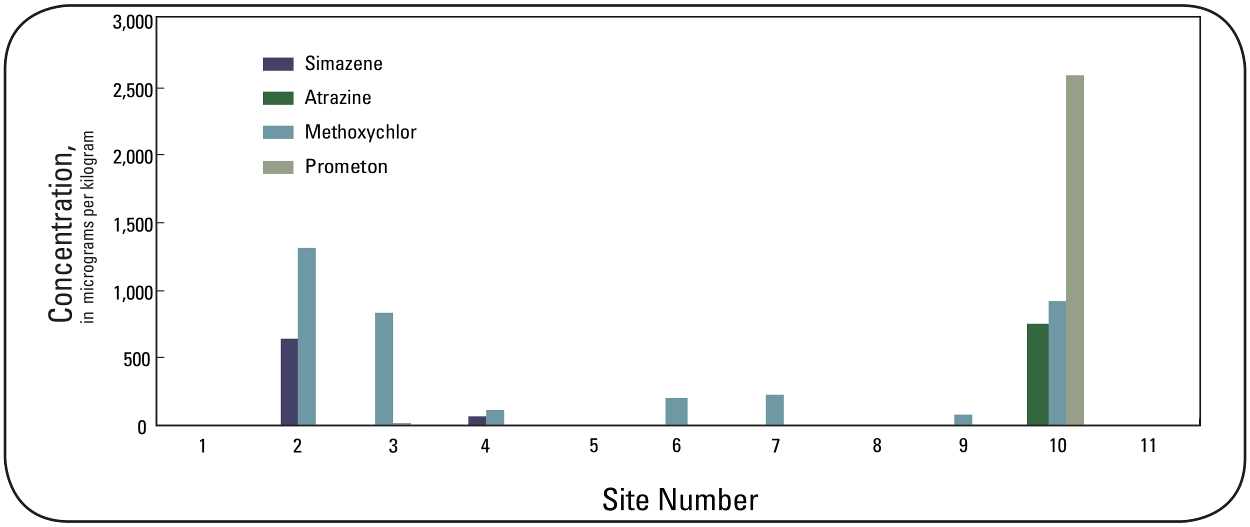

Figure 6. Concentration of pesticides found in selected samples from the Mississippi River Delta, La., after Hurricane Katrina in 2005.

to support the business and population of the region. Understanding the distribution and level of soil contamination will be necessary to determine if the region constitutes a hazard to human health or to the fishing industry. This information is a critical consideration when planning rebuilding activities. Unfortunately, the data collection associated with the present study and the results presented here are inadequate for answering the contamination question. They do, however, suggest that some level of contamination exists and that it could be widely distributed throughout the delta. To address concerns about post-Katrina environmental quality, a systematic study based on more extensive sampling for a broader suite of potential contaminants is required. Such an effort would require substantial investment and commitment on the part of the Government.

References

Agency for Toxic Substance and Disease Registry, 1995, Toxicological profile for methoxychlor: Atlanta, Ga., U.S. Department of Health and Human Services, 2 p.

U.S. Census Bureau, 2000, Quick facts Web site, *http://quickfacts.census.gov/*.

U.S. Environmental Protection Agency, 1994, Synthetic precipitation leaching procedure, method 1312, in SW-846—test methods for evaluating solid waste. Physical/chemical methods.

U.S. Environmental Protection Agency, 2002, Mercury in water by oxidation, purge and trap, and cold vapor atomic fluorescence spectrometry, method 1631, revision E.

U.S. Environmental Protection Agency, 2003, National primary drinking water standards, EPA 816-F-03-016, *www.epa.gov/safewater*

Contact Information

Emitt C. Witt III, Director, Mid-Continent Geographic Science Center (*ecwitt@usgs.gov*); and David K. Shaver, Geographer (*dshaver@usgs.gov*)

U.S. Department of the Interior

U.S. Geological Survey

Mid-Continent Geographic Science Center

1400 Independence Rd. MS 200

Rolla, MO 65401

Craig Adams, Director, Environmental Research Center (*adams@umr.edu*)

John and Susan Mathes Chair of Environmental Engineering

Professor, Civil, Architectural, and Environmental Engineering

Professor, Chemical and Biological Engineering

University of Missouri-Rolla

220 Butler-Carlton Hall

Rolla, MO 65409-0030

Jianmin Wang, Assistant Professor (*wangjia@umr.edu*); and Youssef Filali-Meknassi, Assistant Professor

Department of Civil, Architectural, and Environmental Engineering

University of Missouri-Rolla (UMR)

223 Butler Carlton Hall

1870 Miner Circle

Rolla, MO 65409