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Assessment of Pathogens and Toxicants in New Orleans, LA Following Hurricane Katrina

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Storm surge associated with Hurricane Katrina and the breach of levees protecting New Orleans, Louisiana allowed floodwaters from Lake Pontchartrain to inundate 80% of the city. Environmental samples were collected during September 16−18, 2005 to determine immediate human and wildlife health hazards from pathogens and toxicants in the floodwaters. Baseline information on potential long-term environmental damage resulting from contaminants in water and sediments pumped into Lake Pontchartrain was also collected. Concentrations of aldrin, arsenic, lead, and seven semivolatile organic compounds in sediments/soils exceeded one or more United States Environmental Protection Agency (USEPA) thresholds for human health soil screening levels and high priority bright line screening levels. High numbers of *Aeromonas* spp., pathogenic *Vibrio* spp., and other coliform bacteria were found in floodwater samples. Alligator and snake tissues did not contain excessive toxicant concentrations. Initial findings suggest numerous environmental contaminants are present in New Orleans and support the need for further evaluation of the extent of those threats.

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Introduction

On August 29, 2005, Hurricane Katrina caused unprecedented devastation throughout the Alabama, Louisiana, and Mississippi region of the U.S. Gulf Coast. As a result of the 3−3.5-m storm surge associated with the storm and the breach of several protective levees, floodwaters from Lake Pontchartrain inundated 80% of the city of New Orleans, Louisiana (*1*). Additionally, widespread catastrophic wind damage from the Saffir−Simpson scale Category 4 hurricane destroyed residential, commercial, and industrial buildings, and disabled critical infrastructure components such as electrical transmission, water, and sewage services, and the city's floodwater removal pumping capabilities. Immediate concern was raised regarding the probable release and dispersion of biological and chemical contaminants in the floodwaters. Recognizing the potential for immediate human health hazards through exposure to pathogens and toxicants in floodwater, and the long-term negative environmental impact that could result from contaminated water pumped into the fragile Lake Pontchartrain ecosystem, it was determined that environmental samples taken early in the event were essential to assess public health risks and environmental threats.

The Greater New Orleans metropolitan area is bounded by Lake Pontchartrain to the north, the Mississippi River to the south, and wetlands of the Lake Pontchartrain estuarine system to the west and east (*2*). Lake Pontchartrain and its surrounding wetlands support a diverse assemblage of wildlife, including invertebrates, fishes, reptiles, amphibians, and birds which may be affected by the pumping of contaminated floodwater from New Orleans into the lake (*3*−*7*). McFall and others (*8*) reported in 1985 that water column samples from Lake Pontchartrain contained numerous USEPA priority pollutants at parts-per-billion concentrations. Pollutants detected included aldehydes, aliphatic and aromatic hydrocarbons, alcohols, amines, carboxylic acids, fatty acids, herbicides, pesticides, phenols, phthalates, and quinolines.

In this study we report our efforts to collect environmental samples and specimens, and conduct a preliminary assessment of the immediate public health and potential long-term environmental impact of Hurricane Katrina in and around the city of New Orleans. Pardue and others (*1*) collected and analyzed floodwater samples from New Orleans within a week of Hurricane Katrina and reported elevated concentrations of several metals, but, with the exception of lead in several of the samples, concentrations were not alarmingly high. Our sampling strategies and efforts focused upon obtaining sediment/soil samples and critical tissues from wildlife in addition to water samples, from which to determine what, if any, biological and chemical contaminants were present. This paper reports the results of chemical and microbiological analyses of environmental samples collected during September 16−18, 2005 in the city of New Orleans and the Louisiana parishes of Orleans and St. Charles, and provides an assessment of the immediate public health hazards and long-term environmental threat implications of those findings. Our findings may be useful in the establishment of baseline estimates of the biological and chemical contaminants entering Lake Pontchartrain and potential for mosquito-vectored diseases.

Materials and Methods

To effectively and efficiently accomplish the mission of collecting relevant and representative samples and specimens

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TABLE 1. Sampling Site Locations and Associated Sample Identification Designators

sample location designator[a]	descriptive location sample collected	sample site GPS coordinates
BC	Bonnet Carré Spillway	29°58′43.20″N/90°19′48.49″W
CH	Charity Hospital area	29°57′17.04″N/90°04′41.84″W
E1	Esplanade Avenue (southeast end)	29°58′11.82″N/90°04′09.13″W
E2	Esplanade Avenue	29°58′27.84″N/90°04′32.66″W
E3	Esplanade Avenue	29°58′44.47″N/90°04′55.49″W
E4	Intersection Esplanade Ave. & Wisner Blvd.	29°58′59.60″N/90°05′18.77″W
E5	Wisner Boulevard	29°59′43.42″N/90°05′09.93″W
E6	Wisner Boulevard	30°00′15.48″N/90°05′10.22″W
E7	Wisner Boulevard	30°00′44.67″N/90°05′09.20″W
E8	Wisner Boulevard	30°01′12.68″N/90°05′01.68″W
E9	Wisner Boulevard/ Lake Pontchartrain	30°01′37.40″N/90°05′03.79″W
IC	Industrial Canal	29°58′55.29″N/90°01′43.60″W
MC	Maxent Canal area	30°02′53.50″N/89°52′39.32″W
SD	Superdome area	29°57′05.43″N/90°04′40.11″W

[a] Sample location designators are indicated on maps included as Figures 1–3.

from within New Orleans, as well as the wetlands through which Lake Pontchartrain drains, the following sample/specimen collection strategy was used: (1) collect samples along a transect bisecting the city and extending through the flooded areas; (2) collect samples from an industrial center drainage canal, near a primary facility pumping floodwater into Lake Pontchartrain; and (3) collect samples from sites in wetlands through which Lake Pontchartrain drains into Lake Borgne and the Gulf of Mexico. Water samples for microbiological screening and toxicant assay, sediment/soil samples, and mosquito larval surveys were collected from all sites along the transect described above, the industrial canal, and the Superdome area (CH, E1–E9, IC, SD; Table 1). Water samples for microbiological and chemical analyses were also collected from the Bonne Carrè Spillway and Maxent Canal sites (BC, MC; Table 1). The top 5 cm of sediment and soil were collected with no attempt to differentiate sediment from soil components; all samples are identified as sediment/soil samples. In addition to the above sample collections, wildlife tissues (snakes and an alligator) and adult mosquito specimens were collected from wetlands sites. Samples and specimens were collected, processed, stored, and transported in a manner consistent with accepted protocols and procedures relevant to the bioassays and chemical analyses to be performed. Samples and specimens were immediately placed on ice and transported to a central laboratory at The Institute of Environmental and Human Health (TIEHH) and disseminated to appropriate laboratories for analyses.

Sample collection sites were established to encompass areas that ranged from highest to lowest elevation (i.e., least to greatest depth of floodwater). A sampling transect was established that began on Esplanade Avenue northwest of Interstate 10, turned northward at Wisner Boulevard, and continued to Lake Pontchartrain (Figure 1). Water samples collected along Esplanade Avenue were from remaining floodwater. Water and sediment/soil samples along Wisner Boulevard were collected randomly from either Bayou St. John or standing floodwater in City Park. Table 1 provides sample identification designators, more detailed location descriptions, and global positioning system (GPS) coordinate for each site where environmental samples were collected.

In addition to the sampling transect described above, samples were collected at strategic outlying locations in Orleans and St. Charles parishes. In the east-central area of New Orleans, sediment/soil and water samples for toxicant

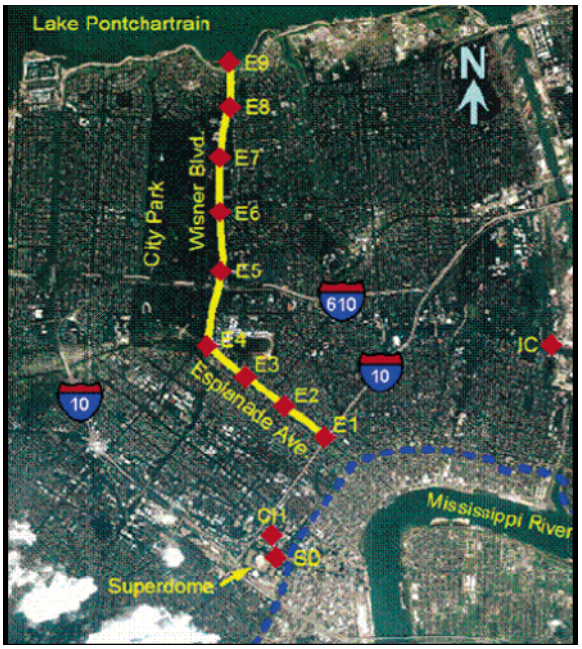

FIGURE 1. Sampling site locations within New Orleans, LA indicated by red diamonds. Blue broken line indicates southern boundaries of flooded area of city. (Digital image provided courtesy of DigitalGlobe.)

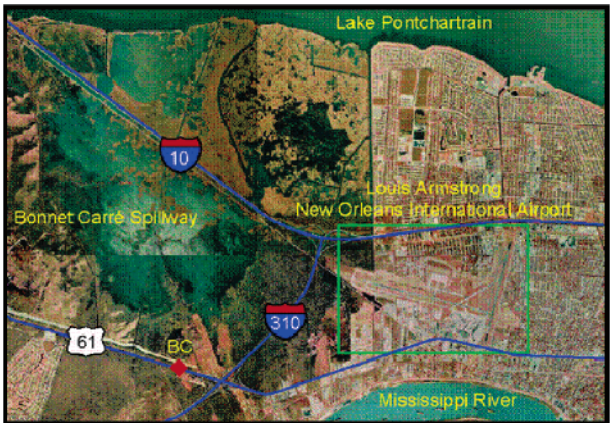

FIGURE 2. Sampling site location in Bonnet Carre Spillway, St. Charles Parish, LA indicated by red diamond. (Color infrared orthophoto provided courtesy of Louisiana Oil Spill Coordinator's Office.)

analysis were collected approximately 560 m west of Pumping Station No. 19 from the industrial canal (IC) that runs parallel to Florida Avenue. Pumping Station No. 19 is one of approximately 22 pumping stations used to move floodwater from New Orleans into Lake Pontchartrain. Additionally, water samples were collected from remaining pools of floodwater in the streets just northeast of the Superdome (SD) and near the emergency entrance of Charity Hospital (CH).

To establish baseline information on potential long-term environmental damage in the wetlands of Lake Pontchartrain, water and wildlife samples were collected. To the west of New Orleans in St. Charles Parish, water samples were also collected in the Bonnet Carré Spillway (BC) at a location 1.1 km west of Interstate 310 on U. S. Highway 61 (Figure 2). East of New Orleans in Orleans Parish, water samples and wildlife tissue specimens were collected along Maxent Canal on the south side of U. S. Highway 90, adjacent to Bayou Sauvage National Wildlife Refuge (NWR) (Figure 3). Additionally, adult mosquitoes were trapped using CO_2-baited

FIGURE 3. Sampling site locations near Maxent Canal, Orleans Parish, LA indicated by red diamond. (Color infrared orthophoto provided courtesy of Louisiana Oil Spill coordinator's Office.)

lighttraps positioned along Maxent Canal on the north side of U. S. Highway 90. Mosquito specimens were transported back to TIEHH where they were identified and assayed for West Nile virus (WNV) and Saint Louis encephalitis (SLE) using antigen capture assay (VecTest; MAS Inc., Camarillo, CA) and reverse transcriptase polymerase chain reaction assay as previously described (*9, 10*).

Sediment/soil and water samples for toxicant analysis were collected in glass jars that met EPA specifications for metals, semivolatiles, pesticides, and PCB analysis. All sediment/soil samples were collected in 250-mL jars and water samples were collected in both 60- and 250-mL jars. A replicate sample was collected at each collection site. At random sampling locations an empty collection jar was included as a reference for toxicant analysis. Water samples for biological analysis were collected in 50-mL polypropylene centrifuge tubes with a replicate sample collected at each site.

Microbial Methods. Water samples were evaluated for the presence of coliforms and members of the genera *Aeromonas* and *Vibrio* as indicators of potentially pathogenic bacteria. Several species of *Aeromonas* are considered to be emerging microbial threats to human health, while members of *Vibrio*, such as *V. cholerae* and *V. parahaemolyticus*, are confirmed health threats. The water samples were serially diluted in sterile 0.85% NaCl and plated in triplicate onto selective and differential microbiological growth media. Eosin methylene blue agar was inoculated and incubated at 37 °C overnight to isolate fecal coliforms and to differentiate *E. coli* from other Gram-negative bacteria isolated. Colonies of fecal coliforms and *E. coli* were counted and the colony-forming units per milliliter (CFU/mL) were determined for each water sample collected. A modified Rippey and Cabelli (*11*) Aeromonas agar (no ampicillin, ethanol and trehalose, containing 4 g/L soluble starch) was inoculated and incubated at 30 °C overnight to isolate *Aeromonas* spp. Colonies of *Aeromonas* spp. and *Vibrio* spp. appear light yellow and 1−3 cm in diameter on this medium and are differentiated by vibriostatic agent 0129 (Oxoid Ltd., Basingstoke, England).

Identification of presumptive *Aeromonas* spp. isolates was accomplished using Biolog MicroStation System Release 3.50 (Biolog Inc., Hayward, CA).

Wildlife Collections. Eight snakes and one alligator (*Alligator mississippiensis*) were collected under permit from the Louisiana Department of Wildlife and Fisheries for analysis of metals and organochlorine (OC) pesticides in multiple tissues. Snakes collected included one green water snake (*Nerodia cyclopion*; snout−vent length [SVL] = 63.9 cm; mass = 191 g), one black-masked racer (*Coluber constrictor*; SVL = 103.2 cm; mass = 300 g) and six cottonmouths (*Agkistrodon piscivorus*; mean SVL = 58.6 ± 5.7 (SE) cm; mean mass = 365 g). Reptiles were collected along Maxent Canal adjacent to Bayou Sauvage NWR. Snakes were collected using Pillstrom tongs (Fort Smith, AR) and placed in holding bags for no longer than 2 h until transportation to a field laboratory. Snakes were then euthanized, and SVL, body mass, and sex were determined postmortem. The alligator was a freshly (<1 h) road-killed specimen collected on U. S. Highway 90 approximately 325 m west of Maxent Canal. The alligator was immediately placed on ice, transported to the field laboratory, necropsied, and liver and kidneys were collected. Whole snakes and alligator tissues were placed in individual zippered bags, placed on ice, and transported to TIEHH where they were stored at −20 °C within 48 h. Snakes were later necropsied, and tissues were collected for contaminant analyses. Livers were divided into three approximately equal aliquots; one was analyzed for a suite of metals, one was analyzed for mercury, and one was analyzed for OC pesticides. Right kidneys were collected for metals analysis, and left kidneys were collected for mercury analysis. Also, an aliquot of visceral fat was collected from each snake and analyzed for OC pesticides. All samples were labeled and stored at −20 °C until analysis.

Chemical Analyses. Samples of sediment/soil, water, and biota were analyzed for inorganic and organic substances according to USEPA SW-846 protocols (*12*−*15*).

Inorganics. Aliquots of the 26 sediment/soil samples were weighed onto aluminum trays and dried to constant weight at 120 °C. An additional aliquot of each sample was weighed into a 50-mL Teflon beaker for analyte quantification. Analytes were solubilized with sequential addition of concentrated nitric acid, concentrated hydrochloric acid, and 30% hydrogen peroxide with heating after each addition (*12*). Digests were cooled and filtered before dilution to 50 mL final volume. Two field blanks, one method blank, and two standard reference materials (Canadian National Research Council) were analyzed with this batch of samples. Field blanks were empty containers that were opened on site and resealed. These samples were analyzed by rinsing the interior of the container three times with 2 mL of concentrated nitric acid, transferring the acid to a Teflon digestion beaker, and processing the sample in the same manner as all others.

Tissues were excised and weighed into polyproplylene centrifuge tubes for storage. Each tissue was predigested in its storage container using 3−30 mL of nitric acid, depending on sample weight. Each sample was then transferred to a Teflon beaker and processed as described for sediment /soil samples (vide supra).

Analyses for metals in sediment/soil, tissue, and water were performed according to SW 846 method 6010B (*13*) with slight modifications that followed USEPA 200.7. This method determines an array of inorganic elements by inductively coupled plasma−atomic emission spectrometry (ICP−AES). The wavelength used to determine element concentrations matched method 6010 as closely as possible, but interferences required use of alternate wavelengths for several elements as allowed by USEPA method 200.7 (*14, 15*). Fourteen analytes were spiked in a laboratory control sample (aluminum [Al], arsenic [As], cadmium [Cd], cobalt [Co], chromium [Cr], copper [Cu], iron [Fe], lead [Pb], manganese [Mn], nickel [Ni], selenium [Se], silver [Ag], tin [Sn], and zinc [Zn]) and reported both quantitatively and qualitatively with sufficient quality control. Another 22 analytes were determined, but estimated concentrations are reported because no certified concentrations were listed in standard reference materials.

Method blanks and calibration blanks were performed and demonstrated that contamination in the instrument and extraction procedure did not exist. All samples were diluted as necessary so that analyte concentration fell within the

TABLE 2. Mean Concentrations of Metal Toxicants Determined to Exceed USEPA Region VI Human Health Specific Screening Levels in Sediment/Soil Samples

toxicant	HHSSL[a] (μg/g)	HPBLS[b] (μg/g)	mean sediment/soil concentration (μg/g)[c] E7[d]	E2[d]	IC[d]
arsenic (As)	22.0	43.0	5.7	14.5	**24.2**
iron (Fe)	23,000.0	100,000.0	**26,200.0**	18,050.0	18,850.0
lead (Pb)	400.0	400.0	341.5	**405.5**	**642.0**

[a] USEPA Region VI Human Health Specific Screening Levels. [b] USEPA High Priority Bright Line Screening Table values. [c] For all values $n = 2$, and calculated on a dry weight basis. [d] Sample location designator (see Table 1 and Figure 1).

established ICP−AES calibration curve. Data were reported through Versa LIMS (Versatile Technologies Group, Oak Brook, IL) with accompanying quality control.

Organics. Sediment/soil samples were not distinguished since all sampled materials were soggy superficial material. Each sample was weighed (~5 g), fortified with internal standard (tetrachlorometaxylene and decachlorobiphenyl) and extracted with pressurized solvent extraction (PSE) using a methylene chloride single-pass static cycle (*14*). The solvent volume was reduced by rotary evaporation. Half of each extract was designated for OC analysis by gas chromatography−electron capture detection (GC−ECD) and the other half was designated for a larger suite of base-neutral semivolatiles by GC−mass spectrometry−selected ion monitoring (GC−MS−SIM). The latter analysis was preceded by a total petroleum hydrocarbon (TPH) analysis to ensure that analytes were in a reasonable concentration range for semivolatile analysis. Petroleum hydrocarbons were detected by GC-flame ionization detection (GC-FID) using a DB-5 capillary column. The temperature program for TPH began at 40 °C, was held for 2 min, and ramped at 15 °C/min to 280 °C, which was held for 2 min.

For semivolatiles the temperature program was 40 °C for 1 min with an 8 °C/min ramp to 300 °C, which was held for 3 min. Calibration ranges were 0.4−400 μg/mL for even-numbered C8−C40 straight chain hydrocarbons as a surrogate for TPH, 0.5−100 μg/mL for 91 semivolatiles, and 0.05−500 ng/mL for 16 OCs. Continuing calibration was checked at least once during each semivolatile sequence.

Results and Discussion

Analyses for 26 metals in sediment/soil resulted in the detection in three samples with concentrations exceeding the USEPA Region VI human health specific screening levels (HHSSL) for As, Fe, and/or Pb, as well as exceeding the USEPA high priority bright line screening table (HPBLS) values for Pb (Table 2) (*16, 17*). Toxicant concentration thresholds established by the HHSSL are pertinent to chronic exposure in humans, while HPBLS levels indicate remediation prioritization in USEPA Region VI. All sediment/soil toxicant concentrations were determined on a dry weight basis. Maximum concentration of As across all sediment/soil samples was 24.15 μg/g, with a minimum of 1.74 μg/g, and a mean concentration of 7.25 μg/g. Concentrations of Fe determined from sediment/soil samples across all sampling sites ranged from a maximum of 26 200 μg/g to a minimum of 6300 μg/g, with a mean of 13 700 μg/g. Sediment/soil collected at two sampling sites, E2 and IC, exceeded both HHSSL and HPBLS threshold values for Pb. The maximum Pb concentration across all sampling sites was 642 μg/g, with a minimum of 16.4 μg/g, and a mean of 190 μg/g.

A total of 26 sediment/soil samples from 12 locations were evaluated for presence of more than 90 semivolatile compounds, including many industrial pollutants and OC compounds. Each OC was detected at least once. Heptachlor and methoxychlor were the most frequently detected OCs in samples (88%), followed by DDT (81%) and DDE (69%). The highest OC concentrations were for DDT (228 ng/g) and DDE (172 ng/g), although only aldrin from one sample exceeded USEPA Region VI HHSSL (Table 3). Additionally, sediment/soil from sampling sites E4 and IC exceeded HHSSL concentrations for benzidine, benz[*a*]anthracene, benzo[*b*]-flouranthene, and benzo[*a*]pyrene. Samples from the IC site also exceeded HHSSL concentrations for *N*-nitroso-dimethylamine and *N*-nitroso-di-*n*-propylamine (Table 3).

Basic water chemistry values determined from the floodwater samples are provided in Table 4. Mean concentrations of inorganic analytes detected in floodwater samples are provided in Table 5.

None of the floodwater samples tested exceeded Safe Drinking Water Act, Maximum Contaminant Levels (SDWA MCL), or USEPA national recommended freshwater quality criteria for Criteria Maximum Concentration "acute" (CMC) and Criteria Continuous Concentration "chronic" (CCC) thresholds (*18*). Basic water chemistry parameters and inorganic analyte contaminant concentrations determined from the water samples collected on September 18, 2005 in this study were similar to the findings reported by Pardue and others (*1*) in samples collected 11−15 days earlier.

Extremely high concentrations of pathogenic bacteria were detected in water samples from the Superdome and Charity Hospital collection sites (Table 6). Of particular note are the excessively high concentrations of *Aeromonas* spp. from those sites (2.6×10^7 and 5.6×10^6 CFU/mL, respectively). Initial assessments have indicated that at least 50% of the isolates are *Aermonas hydrophila*, a known human pathogen. Comparatively, expected concentrations of *Aeromonas* spp. in polluted waters worldwide typically range from 100 to 10^7 CFU/mL.

Multiple metals and OC pesticides were detected in snake and alligator tissues collected from the Maxent Canal area. In snakes, metals detected included Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Sn, and Zn, while the OC pesticides aldrin, *p,p′*-DDE, *p,p′*-DDT, dieldrin, endosulfan, endrin, heptachlor, heptachlor epoxide, lindane, and methoxychlor were also found. In the alligator liver, Al, As, Cd, Co, Cr, Cu, Fe, Hg, Mn, Ni, Pb, Se, Sn, Zn, *p,p′*-DDE, heptachlor, and methoxychlor were detected (Tables 7 and 8). Concentrations of these contaminants were generally lower than, but in some cases similar to, those detected in conspecifics examined in previous studies (*19−24*). For example, DDE concentrations in cottonmouth fat analyzed in this study (range = non-detectable [ND] to 0.1 μg/g; $n = 6$) were predominantly lower than those recently reported for cottonmouths in eastern Texas (range = 0.1 − 14.0 μg/g; $n = 19$) (*24*). Conversely, mercury concentrations in some cottonmouth livers examined in this study (range = ND to 0.4 μg/g) fell within the range of those reported in cottonmouths from eastern Texas (range = 0.1 − 8.6 μg/g) (*24*) and northern water snakes (*Nerodia sipedon*) from eastern Tennessee (range = 0.09 − 3.98 μg/g; $n = 47$) (*23*). Cottonmouth snakes at Longhorn Army Munitions Plant in eastern Texas contained geometric mean DDE concentrations of 789 ng/g in fat and 16 ng/g in liver (*24*). Liver and kidney samples from the same population contained geometric mean Hg concentrations of 739 ng/g in liver and 211 ng/g in kidney.

There was minimal adult mosquito activity observed at all sampling sites, as well as at the staging site within urban New Orleans. To further confirm that observation, only one pool of standing water was found to harbor mosquito larvae (near Site E1) and 47 adult mosquitoes were collected in the four CO_2-baited lighttraps during one night at the Maxent Canal site. Dried mosquito specimens were identified to genus, and trap catch composition included 34 *Aedes* spp.,

TABLE 3. Mean Concentrations of Semivolatile Toxicants Determined to Exceed USEPA Region VI Human Health Specific Screening Levels in Sediment/Soil Samples

toxicant	HHSSL[a] (μg/g)	mean sediment/soil concentration (μg/g)[b] E3[c]	E4[c]	E5[c]	E8[c]	IC[c]
aldrin	0.029	0.001	**0.043**	ND	ND	ND
benzidine	0.0021	0.05	**0.01**	0.00	0.00	**0.69**
benz[*a*]anthracene	0.62	0.00	**1.64**	0.03	0.00	**1.16**
benzo[*b*]fluoranthene	0.62	0.01	**1.88**	0.01	0.00	**1.21**
benzo[*a*]pyrene	0.062	0.01	**1.26**	0.00	0.00	**0.81**
N-nitroso dimethylamine	0.0095	0.00	0.00	0.01	0.00	**0.21**
N-nitroso di-*n*-propylamine	0.069	0.00	0.00	0.00	0.02	**0.41**

[a] USEPA Region VI Human Health Specific Screening Levels. [b] For all values $n = 2$, and calculated on a dry weight basis. [c] Sample location designator (see Table 1 and Figure 1).

TABLE 4. Water Quality Parameters for Floodwater Collected in New Orleans, LA September 18, 2005

parameter	floodwater sampling site designation BC ($n = 2$)	CH ($n = 2$)	E4 ($n = 2$)	E6[a] ($n = 4$)	E8 ($n = 2$)	MC ($n = 2$)	SD ($n = 2$)
pH	7.6	8.2	7.5	7.5	7.5	7.5	7.6
dissolved oxygen (mg/L)	8.77	7.73	7.64	8.07	8.42	8.83	6.95
conductivity (uS/cm)	1276	2404	4615	4040	4635	ND[b]	ND
salinity (ppt)	0.5	1.3	3.3	3.3	2.5	0.1	0.1
NH3−N (mg/L)	0.97	1.19	0.66	1.09	0.52	1.21	2.74
reactive phosphorus (mg/L PO_4)	3.12	0.75	2.06	5.05	1.40	0.52	4.77

[a] Water collected from City Park on west side of Wisner Boulevard. [b] No data due to insufficient volume of sample.

TABLE 5. Mean Concentrations of Inorganic Analytes in Floodwater Collected in New Orleans, LA September 18, 2005

toxicant	analyte concentrations by sampling site (μg/mL)[a] BC ($n = 2$)	CH ($n = 2$)	E4 ($n = 2$)	E6[b] ($n = 4$)	E8 ($n = 2$)	MC ($n = 2$)	SD ($n = 2$)
Al	0.40	0.40	0.17	0.49	0.32	**1.64**	1.09
Ba[c]	0.24	0.17	0.19	0.32	0.17	**0.34**	0.21
Be[c]	**0.018**	0.015	0.016	0.016	0.017	0.015	0.015
B[c]	0.12	0.28	**0.72**	0.57	0.69	0.61	0.14
Cr	0.018	0.009	**0.069**	0.011	0.012	<0.008	0.023
Cu	0.024	<0.013	<0.013	0.017	<0.013	<0.013	**0.140**
Fe	1.89	2.34	0.21	4.79	0.46	3.44	**4.92**
Mn	1.52	0.29	0.45	0.92	0.45	**4.97**	1.58
P[c]	1.57	0.85	0.72	2.55	0.73	0.87	**3.76**
Sb[c]	0.026	0.027	0.013	0.016	0.030	**0.043**	0.011
Sr[c]	0.64	1.21	**1.76**	1.64	1.69	1.72	0.60
Zn	0.036	0.716	0.039	0.062	0.274	0.069	**1.64**

[a] The following analytes were determined from all samples to be below the detection limits (μg/mL) indicated: Ag (0.003); As (0.04); Cd (0.005); Co (0.03); Mo (0.03); Ni (0.03); Pb (0.04); Se (0.05); Sn (0.05); V (0.01); Ti (0.025). [b] Water collected from City Park on west side of Wisner Boulevard. [c] No standard reference material (SRM) data available for these analytes.

6 *Culex* spp., and 7 unidentifiable specimens. All mosquitoes tested negative for the presence of WNV and SLE.

The highlighted data for Pb in Table 2 exceed the HHSSL and HPBLS threshold values for adverse health effects and for bright line prioritization of hazard cleanup. Although these concentrations are not the highest reported for Pb in urban New Orleans (*25*), Pb concentrations in post-Katrina samples may pose a significant health risk particularly to children returning to highly contaminated areas. Published studies by Mielke and Reagan (*26*), and Johnson and Bretsch (*27*) suggest that physiology and behavior of children naturally predisposes them to exposure to Pb in soil. Detected concentrations for As and Fe exceed HHSSL, but not HPBLS. We present adverse human health benchmarks (i.e., HHSSL) in our tabulation, since that is the science-based value, whereas the waste site prioritization (i.e., HPBLS) incorporates scientific and other metrics to guide remediation policy. For example, hazard quotients range from 3 to 10 for different toxicants within USEPA's HPBLS values.

Members of the genus *Aeromonas* are ubiquitous Gram-negative rods found in almost every aquatic environment including chlorinated drinking water, raw sewage, groundwater, and both polluted and unpolluted rivers and streams. Several studies have shown that aeromonads are the major causative agents of fish infections and have been associated with human diarrheal disease and opportunistic wound infections (*28*), and are considered an emerging human health threat (*29*). Recently published information describes more than 500 skin and soft tissue infections among tsunami survivors in southern Thailand reports that *Aeromonas* spp. were isolated from 22.6% of the infected wounds (*30*). Of those *Aeromonas* spp. isolated, some degree of antibiotic resistance was also detected (*30*).

Opportunistic wound infections with *Aeromonas* spp. occur as a result of exposure to contaminated water, such as through swimming and boating accidents, and fishing-hook accidents. Cellulitis, myonecrosis, and ecthyma gangrenosum can result from wound infections and have to be treated with antibiotic therapy. There is a clear lack of information concerning environmental conditions that perpetuate opportunistic *Aeromonas* spp. infections, or on population levels required to cause such infection in humans. It is well documented that environmental contamination with antibiotics and other pollutants, particularly metals, contributes to the maintenance and spread of antibiotic resistance genes in pathogenic bacteria (*31, 32*).

Although aeromonads are widespread in aquatic ecosystems and have been designated an emerging threat to human health, little is known about the antibiotic and metal resistance profiles of aeromonads from freshwater systems. Studies conducted in freshwater playa lakes around the Lubbock, TX region have found that at least 6% of the *Aeromonas* spp. isolates display resistance to co-trimoxazole, tetracycline, and cerfuroxime (*33*). The antimicrobial resistance patterns for *Aeromonas* spp. from these studies have been generally comparable to other published investigations.

TABLE 6. Bacterial Densities from Water Samples

sample location designator[a]	mean total coliforms on EMB[b] (CFU/mL)			mean total colonies on mA[c] (CFU/mL)	
	DAY 0	DAY +1	total *E. coli*	total	presumptive *Aeromonas*/*Vibrio*
BC ($n = 2$)	4,300	1,700	50	90,000	270
CH ($n = 2$)	259,000	32,000	ND[d]	5,596,000	3,700
E4 ($n = 2$)	51,200	51,200	ND	49,000	170
E5 ($n = 2$)	91,700	20,500	1,800	202,000	8,300
E8 ($n = 2$)	9,500	6,000	20	28,800	320
MC ($n = 2$)	18,000	8,300	ND	11,700	ND
SD ($n = 2$)	8,083,000	2,133,000	300,000	26,600,000	1,716,700

[a] Sample location designators (see Table 1 and Figure 1). [b] EMB = Eosin-methylene blue. [c] mA = modified Rippey and Cabelli *Aeromonas* medium. [d] ND = not detected.

TABLE 7. Concentrations of Metals Detected in Tissues of Wildlife Collected near Maxent Canal, East New Orleans, Louisiana September 17, 2005

	concentrations in animal tissue samples (μg/g, wet weight)							
	AM[a]		AP[b]		CC[c]		NC[d]	
metal	liver	kidney	liver	kidney	liver	kidney	liver	kidney
Al	0.37	3.17	2.62	5.81	12.70	2.34	6.65	12.20
As	0.06	0.16	0.17	0.11	0.58	0.15	0.25	<0.13
Cd	<0.02	<0.01	0.01	0.03	0.29	0.07	<0.01	<0.04
Co	<0.01	0.02	0.05	0.07	0.16	<0.07	<0.03	0.09
Cr	0.01	0.06	0.08	0.14	0.09	0.10	0.10	0.17
Cu	0.34	1.58	5.35	2.36	4.43	1.72	2.99	2.46
Fe	142.00	48.50	458.50	65.85	983.00	67.10	170.00	51.00
Hg	0.01	0.00	0.13	0.05	0.15	0.11	0.04	0.07
Mn	0.10	2.83	0.62	1.61	1.00	1.78	0.95	2.01
Ni	<0.01	0.04	0.03	0.14	0.14	<0.09	<0.39	<0.13
Pb	0.11	0.23	0.14	0.97	0.14	0.39	<0.11	0.73
Se	<0.02	0.39	0.10	0.57	<0.10	0.78	<0.13	0.47
Sn	0.31	0.07	0.12	1.41	0.24	0.66	<0.10	0.84
Zn	1.10	11.00	19.85	13.73	30.40	24.10	9.40	18.40

[a] AM = *Alligator mississippiensis* (American alligator); $n = 1$. [b] AP = *Agkistrodon piscivorus* (cottonmouth); $n = 6$. [c] CC = *Coluber constrictor* (black-masked racer); $n = 1$. [d] NC = *Nerodia cyclopion* (green water snake); $n = 1$.

TABLE 8. Concentrations of Organochlorine Pesticides Detected in Tissues of Wildlife Collected near Maxent Canal, East New Orleans, Louisiana September 17, 2005

	concentrations in animal tissue samples (μg/g, wet weight)						
	AM[a]	AP[b]		CC[c]		NC[d]	
OC	liver	liver	fat	liver	fat	liver	fat
aldrin	ND[e]	0.004	0.016	0.006	ND	0.032	0.020
dieldrin	ND	0.004	ND	0.027	ND	ND	ND
heptachlor	0.001	ND	0.001	ND	ND	ND	ND
lindane	ND	0.013	0.001	ND	ND	0.012	ND
methoxychlor	0.034	0.227	0.071	0.653	ND	0.254	0.092
p,p′−DDE	ND	0.001	0.041	ND	ND	ND	0.032
p,p′−DDT	0.006	0.067	0.068	0.135	0.107	0.070	0.144

[a] AM = *Alligator mississippiensis* (American alligator); $n = 1$. Fat samples were not analyzed. [b] AP = *Agkistrodon piscivorus* (cottonmouth); $n = 6$. [c] CC = *Coluber constrictor* (black-masked racer); $n = 1$. [d] NC = *Nerodia cyclopion* (green water snake); $n = 1$. [e] ND = not detected.

A survey of 217 *Aeromonas* strains, representing all currently recognized genomic species and including both clinical and environmental isolates, found that 10% were resistant to tetracycline and 1.4% were resistant to cefuroxime (*34*). Given the extremely high numbers of aeromonads detected from several locations in the New Orleans area the potential for contact and opportunistic infection of children and adults with skin abrasions and cuts is high.

Detection of multiple metals and OC pesticides in snake and alligator tissues from the Maxent Canal area indicate the pollution of wetlands associated with New Orleans and demonstrate the propensity of these animals to accumulate a variety of environmental contaminants. However, due to the brief period (ca. 20 days) between the flooding of New Orleans as a result of Hurricane Katrina and the collection of reptile tissues for analysis, it is unlikely that contaminants detected in these tissues were the result of hurricane-related pollution. Rather, these concentrations likely reflect chronic exposure to low concentrations of contaminants. Thus, data derived from this study provide valuable baseline information on pre-Hurricane Katrina contaminant burdens in wildlife to which data from future wildlife sampling in the New Orleans and Lake Pontchartrain area can be compared. Numerous animal carcasses were observed during sampling in the Maxent Canal area, including three alligators, two feral hogs (*Sus scrofa*), one armadillo (*Dasypus novemcinctus*), one green water snake, one nutria (*Mycastor coypus*), one raccoon (*Procyon lotor*), and one white-tailed deer (*Odocoileus virginanus*). Although exposure to environmental contaminants may have been a contributing factor, flooding, strong winds, and killing by humans have been previously reported as causes of wildlife mortality associated with hurricanes in Louisiana (*35*, *36*) and were likely the primary factors after Hurricane Katrina.

In addition to the findings reported above, there were four significant on-site observations recorded by the team while sampling that must be considered for further investigation. (1) Fine, powdery dust was aerosolized or resuspended via vehicular traffic disrupting sediments on previously flooded roadways and other hard surfaces (an inhalational hazard). (2) The lack of larval and adult mosquitoes and filth flies in the city, as well as in the wetlands, may be a result of aerial applications of insecticides (i.e., Dibrom/Naled, an organophosphate) by the United States Air Force, or may be a result of contaminants in mosquito and muscoid fly breeding sites. (3) Numerous dead fish were observed along banks of canals and shores of Lake Pontchartrain, as well as in rafts in the marginal waters of the lake. (4) Clearly delineated high waterline were noted on trees, with discolored and apparently dead foliage in areas below waterline. These observations combined with the findings reported here of microbiological, metal, and semivolatile contaminants in some areas of the city, suggest further research is needed to determine environmental and human health hazards.

The findings of this initial microbiological and chemical contaminant assessment will serve as baseline information for ongoing follow-on studies to monitor existing and emerging public health risks to residents of New Orleans and potential long-term environmental impacts upon the wildlife and wetlands associated with Lake Pontchartrain and Lake Borgne. The determination of microbiological and chemical toxicants in the sediment/soil exceeding HHSSL

and HPBLS thresholds should be carefully considered in the planning and execution of cleanup and rebuilding operations, particularly in the protection of construction workers, waste handlers, and residents. Additional emerging public health concerns that may develop within New Orleans include arboviral diseases due to infrastructure deficiencies, enteric diseases resulting from contaminated food and water systems, mycotoxin exposures resulting from excessive black mold (*Stachybotrys chartarum*) and other molds, and respiratory disease resulting from inhalation of other aerosolized pathogenic microorganisms and chemical toxicants.

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