Toxic and Contaminant Concerns Generated by Hurricane Katrina

Danny D. Reible[1], Charles N. Haas[2], John H. Pardue[3], William J. Walsh[4]

When Hurricane Katrina flooded the city of New Orleans, among the many concerns left in its wake was that of the contaminants that were released or exposed. Several chemical plants or petroleum refining facilities and contaminated sites, including superfund sites, lay within the area covered by floodwaters. As with any city, hundreds of commercial establishments such as service stations to pest control businesses to dry cleaners use potentially hazardous chemicals that may have been released into the environment by the floodwaters. Figure 1 shows the potential petroleum-related release points including refineries, oil and gas wells, and service stations near the city. Figure 2 shows the major hazardous material storage locations, Superfund sites and Toxic Release Inventory reporting facilities. Adding to these potential sources of toxics and environmental contaminants are the metal-contaminated soils typically associated with old urban areas, and construction lumber preserved in the semi-tropical climate with such chemicals as creosote, pentachlorphenol and arsenic. Compounding these concerns are the variety of common hazardous chemicals stored in flooded households and the fuel and motor oil in approximately 400,000 flooded automobiles. Further contributing to the pollutant burden in the city were uncontrolled biological wastes from both human and animal sources.

[1] Danny Reible is the Bettie Margaret Smith Chair of Environmental Health Engineering in the Department of Civil, Architectural and Environmental Engineering at the University of Texas at Austin
[2] Charles N. Haas is the LD Betz Professor of Environmental Engineering and Head of the Department of Civil, Architectural and Environmental Engineering at Drexel University in Philadelphia
[3] John H. Pardue is the Elizabeth Howell Stewart Professor of Civil & Environmental Engineering and Director of the Louisiana Water Resources Research Institute, Louisiana State University, Baton Rouge
[4] William Walsh is a lawyer with Pepper Hamilton, LLP, Washington DC

The presence of these potential sources of toxics, pathogens and other contaminants led to immediate concerns for acute exposure to aid workers, stranded flood victims, and immediately after flooding, to returning residents. In addition, however, lingering questions remain about chronic exposure to these contaminants and the long-term effects of such exposure. It is toward an evaluation of both the acute and chronic exposures that this summary is directed.

In the confusion immediately after the flooding event, it was unclear to what extent the potential contaminant release was realized. There was clear evidence of at least some environmental releases with the observation of oil slicks near some service stations and flooded automobiles and wastes floating or suspended in floodwaters. A 250,000 barrel above ground storage tank at the Murphy Oil USA Meraux Refinery in St. Bernard Parish southeast of the downtown area was dislodged and lifted by the floodwaters. Approximately 25, 000 barrels (> 1 million gallons) of crude oil was released, impacting an area of 1 square mile containing approximately 1700 homes[5].

Several monitoring efforts were undertaken during and subsequent to the flooding to quantitatively evaluate the extent of chemical and biological contamination and assess the exposure and risk to these toxics and contaminants. Federal agencies, including the Environmental Protection Agency (EPA) and the National Oceanographic and Atmospheric Administration (NOAA), collected environmental samples both within New Orleans and throughout the surrounding area impacted by Hurricane Katrina. Initial concerns within the city were focused on acute exposure concerns for stranded residents and relief workers. Subsequent efforts have focused on acute exposure concerns for

[5] http://www.epa.gov/katrina/testresults/murphy/index.html

returning residents and the initial assessments of chronic exposures. Additional independent sampling has also been conducted, including that reported by Pardue et al. (2005), Presley et al. (2006) and those reported by the National Resources Defense Council[6]. The concentration of chemical and biological constituents reported by the various studies to-date have generally painted a consistent picture of contamination in the air, water and soils and sediments of New Orleans both during and after the flood. Together these studies provide a reasonable characterization of the general quality of the floodwaters and the soils and sediments that remain after the floodwater receded. They represent a relatively sparse data set, however, and therefore may not fully characterize localized problems. Typically, regulatory agencies assess risk on the basis of 95% upper confidence limits in concentrations of media to which exposure occurs, but for simplicity and because of the difficulty in characterizing the statistics of sparse data sets, we will generally focus on maximum observed concentrations. Our goal here is to summarize key results from the available data in order to assess the general character of the toxics and contaminant exposure faced during and after the flooding and to provide a perspective on the significance of those findings as we move forward in the rebuilding of New Orleans.

Exposures during flooding

Floodwaters were present in the city from the passage of the storm on August 29, 2005 until the city was declared dewatered by the US Army Corps of Engineers on October 11. Sampling of these floodwaters showed elevated levels of a variety of inorganic and organic contaminants and biological constituents including pathogens.

[6] http://www.nrdc.org/health/effects/katrinadata/contents.asp

Inorganic contaminants in floodwaters were generally low, even when compared to drinking water standards. Presley et al. (2006) observed no floodwater samples that exhibited concentrations in excess of drinking water or acute and chronic threshold concentrations. Pardue et al. (2005) noted consistent exceedances of drinking water standards for arsenic in the floodwaters (mean of 30 μg/L compared to a maximum contaminant level in drinking water of 10 μg/L). Drinking water standards, however, are, in general, an inappropriate indicator of water quality for floodwaters because they are based on the assumption that the public is drinking two liters of the water every day of the year for 70 years and the actual ingestion and dermal exposure to flood waters is much less than to drinking water. Organic constituents were also detected in floodwaters at relatively low concentrations. This observation was initially met with some surprise since oil and hydrocarbon fuel spills were evident in many locations. More soluble petroleum oils and fuels constituents, such as benzene, however, are typically also volatile leading to rapid release to the air. Less soluble constituents would partition to sediments left behind by the floodwaters. EPA concluded that inorganic and organic chemical concentrations in floodwater were generally below levels of concern for short term (90 days) dermal contact and incidental ingestion[7].

Bacterial contamination in the floodwaters was a source of greater concern. Median concentrations of fecal coliform of approximately 10^4 MPN/100 mL were detected in the floodwaters (Pardue et al., 2005). This can be compared to a water quality standard for primary contact of 200 MPN/100 mL. Potentially of greater concern was the detection of human pathogens, such as the detection of *Aeromonas* spp. at

[7] http://www.epa.gov/katrina/testresults/katrina_env_assessment_summary.htm

concentrations of the order of 10^7 CFU/mL at two locations in the downtown area (Presley et al., 2006). Members of the genus *Aeromonas* have been associated with diarrhea and wound infections in humans (Janda and Duffey, 1988), however they are also frequently isolated from soils and freshwaters.

In addition to concerns about exposures of stranded residents and relief workers to the floodwaters, the immediate and long-term impact of discharge of the floodwaters to Lake Pontchartrain was also of concern. Between September 6 and October 11, these floodwaters were discharged to Lake Pontchartrain, to the north of the city and the source of much of the floodwaters. Lake Pontchartrain is a brackish, shallow lake with a surface area of approximately 1630 km^2 and an average depth of about 4 m and contains an active commercial fishery. Low levels of dissolved oxygen were detected in floodwaters and in discharged water by Pardue et al. (2005). This likely resulted in low oxygen levels in the immediate vicinity of the discharge point but minimal impact on the lake as a whole. Similarly the generally low levels of inorganic and organic contaminants in the floodwaters were unlikely to lead to significant impacts on Lake Pontchartrain. The sediments at the mouth of the discharge canals already contained levels of some contaminants prior to the flooding due to normal wastewater and stormwater discharges from the city. The Katrina floodwaters were characterized as similar in character, although significantly larger in volume, to the normal storm waters discharged into the lake[8]. Bacterial contamination of the discharge waters was typically an order of magnitude higher than values found in the lake prior to discharge (as measured by fecal coliform concentration, Pardue et al., 2005) but EPA collected more than 100 samples in

[8] *Ibid.*

September and October and found that bacterial levels in the lake were always within recreational limits[9].

In summary, direct exposure to floodwaters either within the city or in Lake Pontchartrain appeared likely to result in minimal toxic and contaminant impacts with the possible exception of biological pathogens.

Exposures to soil and sediment post-flooding

Although floodwaters were removed from the city by October 11, 2005, their legacy of contaminated soils, sediments, debris and houses remains. In addition to the existing soils and debris, sediment mobilized from storm surge through Lake Pontchartrain and the Mississippi River Gulf Outlet/Industrial Canal was deposited in the city Additional sampling has been conducted to assess the concentrations of chemical and biological contaminants in these media and to evaluate the impacts thereof. Presley et al. (2006) found several inorganic constituents (arsenic, iron and lead) and organic constituents (mostly PAHs) in sediments from New Orleans that exceeded EPA Region VI Human Health Specific Screening Levels for soils. The Region 6 Superfund Human Health Screening Levels are used for evaluate the

> "relative environmental concern for a site or set of environmental data. The values are not regulatory, but are derived using equations from EPA guidance and commonly used defaults." [10]

The Screening Levels are "not generated to represent action levels or cleanup levels but rather as a technical tool."[11] Screening Levels are "chemical concentrations that

---

[9] *Ibi.*
[10] Region 6, Medium-Specific Risk-Based Human Health Screening Values at 2(November 2005), available at: <http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/r6screenbackground.pdf> at 3 of 37 (Region 6 Screening Value Guidance)..
[11] Updated EPA Region 6 internet version of Risk-Based Human Health Screening Values, available at: < http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/screen.htm>.

correspond to fixed levels of risk (i.e., either a one-in-one million [10^{-6}] cancer risk or a non-carcinogenic hazard quotient of one, whichever occurs at a lower concentration) in soil, air, and water," using assumptions of life time exposures to generally, but not uniformly, exposure values that are the upper end of the range of possible exposures. [12]

EPA collected 430 sediment samples between September 10 and October 14 and identified a number of sediment samples that exceeded screening criteria of the local regulatory authority, the Louisiana Department of Environmental Quality (LDEQ Risk Evaluation/Corrective Action Program or RECAP)[13]. These screening criteria were developed to meet objectives similar to the EPA Region VI Human Health Specific Screening Levels and are derived similarly. The constituents most often found to exceed the RECAP screening criteria were arsenic, lead, several PAHs including benzo[a]pyrene, and diesel range organics.

EPA resampled areas on November 19 and 20 where previous sampling had indicated contaminant concentrations in excess of screening criteria and where sediment depth equaled or exceeded 0.5 inches[14]. Only 14 of the 145 potential sediment sampling locations exhibited sufficient sediment depth. Due to the complex nature of the storm surge and associated levee breaches and overtoppings, the amount of sediment deposited in flooded areas varied widely. Three samples showed arsenic concentrations above 12 mg/kg (14.4-17.6 mg/kg) , one sample showed benzo[a]pyrene concentration of 0.77 mg/kg and one sample contained diesel range organics at 2100 mg/kg. Other samples were below applicable screening values.

---

[12] Region 6 Screening Value Guidance, available at: <http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/r6screenbackground.pdf> at 3 of 37..
[13] http://deq.louisiana.gov/portal/tabid/131/Default.aspx
[14] http://www.epa.gov/katrina/testresults/katrina_env_assessment_summary.htm.

Samples were also collected at several specific sites where known or potential leaks of hazardous materials might be found. Elevated concentrations of total petroleum hydrocarbons and a variety of crude oil associated contaminants were observed in the vicinity of the Murphy Oil crude oil tank failure and spill. Because the latter contamination had a clearly identifiable source and is easily differentiated from the general flooding related contamination, this area is being managed separately from the rest of the flooded area and will not be considered further here. EPA also collected 74 soil samples at the site of the Agriculture Street Landfill, a closed Superfund site that was flooded by Katrina. All samples were analyzed for lead, which was the contaminant of concern that defined the cleanup. The samples were collected immediately above the geotextile liner (12-24" below ground surface) which was installed as part of the site remedy. No samples exhibited concentrations that exceeded the lead cleanup standard or EPA screening standards for lead, and EPA concluded that the flooding did not impact the effectiveness of the remedy[15]. The NRDC analyzed for other contaminants at this site and found arsenic at levels similar to other New Orleans sites and a variety of high molecular weight PAHs at somewhat elevated levels[16]. They ascribed the presence of the high molecular weight PAHs to leachate from the landfill although the hydrophobic nature of these compounds would be such that they would more likely be transported by resuspended soil from the site or elsewhere. Further assessment of this area might be warranted.

The conclusion from this sampling is that there was no general contamination of New Orleans to clearly unacceptable levels – especially with respect to acute exposures.

---

[15] http://www.epa.gov/katrina/superfund-summary.html#2
[16] http://www.nrdc.org/health/effects/katrinadata/bywater.asp

There appear to be some areas where concentrations exceed applicable screening values and some specific areas impacted by particular events, such as the failure of the crude oil storage tank in St. Bernard Parish.

Complicating the assessment of these concentrations in soils and sediments is the presence of a pre-Katrina background of contamination. For example, the background of arsenic is of the order of 10 mg/kg throughout the Mississippi River Delta region of south Louisiana (Gustavsson et al., 2001) and LDEQ has reported a background arsenic concentration of 7 mg/kg. Pre-Katrina concentrations of arsenic could be higher in residential areas due to the presence of arsenic in a variety of lawn fertilizers.[17] Lead has also long been a concern in inner city New Orleans with H. Mielke reporting that 40% of nearly 5000 soil samples showed lead levels in excess of 400 mg/kg (Pelley, 2006). Presley (2006) found 2 of 12 sediment samples with lead in excess of 400 mg/kg (405 and 642 mg/kg), consistent with the pre-Katrina observations of Mielke. Mielke et al. (2004) also showed elevated levels of PAHs in pre-Katrina soils of New Orleans and showed that PAH levels and metal contamination were positively correlated. With only 12 sediment samples collected by Presley et al., 14 meeting depth and previously detected contamination criteria by EPA in their November 19 and 20 sampling, and smaller numbers of samples reported in other analyses efforts, it is impossible to statistically differentiate the current observations from pre-Katrina contamination levels.

Current Risks

Regardless of whether current levels of contamination were present pre-Katrina or due to the destructive effects of the storm, the question before residents attempting to

[17] Washington State Department of Agriculture, 2001. Pesticide Management Database, http://www.app2.wa.gov/agr.

return to the city is the level of risk and need for remediation prior to return. Complicating the assessment of the need for remedial activities is the uniqueness of the short-term exposure pathways for residents returning to New Orleans. Homeowners returning to flooded homes have been faced with removal of both wet and dry sediment from the home and yard. Generation and exposure to airborne dusts from these sediments has also occurred and is exacerbated by demolition or home "gutting" activities occurring across the region. The evaluation of the risk to human health associated with the contaminant levels observed in the post-Katrina soils and sediments is further complicated by the lack of clearly applicable standards. Clear standards can typically be defined for atmospheric contaminants on the basis of risk of inhalation. Water standards have also been developed and have a clear scientific basis when linked to use (e.g drinking water vs. recreational use water) . Soil and sediment concentrations, however, are not clearly linked to exposure and risk. Pathways of exposure may be incomplete (e.g. direct exposure to buried soil not subject to significant erosion) or quite variable (e.g. soil in a park versus residential soil) or contaminants may be present in forms that are largely unavailable for uptake and risk (e.g. metals largely associated with low solubility metal sulfides). It is for these reasons that screening or threshold values are used to assess the need for soil and sediment remediation and to help guide the selection of cleanup standards. Under the Louisiana RECAP standards, a site which exhibits concentrations below levels defined on the basis of default lifetime exposure assumptions and without the use of site-specific exposure or availability data can be considered safe and no remedial action is necessary. As is typical under such approaches, however, exceeding the concentrations defined by default assumptions may not require cleanup. In order to interpret exceedances of screening values, it would be appropriate to consider factors that EPA Region 6 normally considers “to prevent misuse of screening levels,” including “[a]pplying screening levels to a site without adequately developing a conceptual site model that identifies relevant exposure pathways and exposure scenarios,” “[n]ot considering background concentrations when choosing screening levels, “[u]se of screening levels as cleanup levels without the consideration of other relevant [remedy selection] criteria,” and “[u]se of screening levels as cleanup levels without verifying numbers with a toxicologist/risk assessor,”[18]. As a result, a review of the arsenic soil cleanup levels selected at Superfund or state sites indicate a wide range of concentrations (ranging from background levels to hundreds of parts of per million, depending upon site specific conditions).[19]

Under RECAP, two management options (management options 2 and 3 in addition to the use of a tabulated screening level, management option 1) exist for the definition of alternative concentration standards that might apply to a particular site. One allows use of site-specific information with specified analytical fate and transport models and default exposure assumptions to define concentration standards different from screening values and the other allows site-specific exposure and environmental fate and transport data to be employed. All site screening approaches have a similar structure and allow modifications to allow site-specific information to be used to refine estimates of exposure and risk and inform remedial planning. LDEQ policy is that a total lifetime

[18] Region 6 Screening Value Guidance at 33, available at: <http://www.epa.gov/earth1r6/6pd/rcra_c/pd-n/r6screenbackground.pdf> at 34 of 37..

[19] See EPA’s Record of Decision database (available at: < http://www.epa.gov/superfund/sites/rods/index.htm>), which can be word searched for arsenic soil cleanup levels.

cumulative carcinogenic risk level above 10^{-6} may be acceptable, as long the cumulative risks associated with residual constituent concentrations following corrective action is at or below 10^{-4}.[20] Even using the conservative default exposure assumptions, an arsenic concentration of approximately 40 ppm may be deemed acceptable if arsenic is the overwhelmingly predominate contaminant present.

Thus the need for remedial activities at any particular site in New Orleans as a result of residual contamination post-Katrina must be assessed on the basis of an evaluation of that site for 1) average concentrations within an area in which a resident or work might be regularly exposed exceeding screening values and 2) pathways and attenuation along routes of exposure that lead to unacceptable risk.

It should be noted that even screening values based upon generally conservative default assumptions may not be fully protective in all cases. More generally, EPA, states, and the general scientific community are regularly re-assessing whether the methodologies utilized in the risk assessment process are adequate to protect children or other sensitive populations, even when default exposure values are utilized. Currently, this question is supposed to be addressed on a case-by-case assessment.

The difficulty with a site-specific assessment and evaluation approach is the cost of sampling and analysis. On the other hand, use of screening levels as remedial goals could add significant cost to any remedial efforts undertaken without assurance that there would be commensurate significant reduction in risk, thereby diverting limited resources to address minor risks. Individual homeowners could assess the contamination

[20] LDEQ Risk Evaluation/Corrective Action Program at 65, available at: < http://deq.louisiana.gov/portal/Portals/0/technology/recap/2003/RECAP%202003%20Text%20-%20final.pdf> at 75 of 129

concerns on their own property but in the absence of government support for both the testing and the cleanup, the impact would fall disproportionately on the poor. The response would naturally be avoidance of testing. Any generic response to potential contamination concerns, however, would undoubtedly lead to destruction of property that did not pose excessive risks and further slow the return of people to their homes and the rebuilding of their lives.

A further concern for returning residents is the presence of mold and airborne mold spores in homes. Unlike air, water and soil contamination, there exists little scientific basis to evaluate the potential effects of mold on human health, and in particular to develop risk based action or cleanup levels. Mold counts of 50,000 spores/m^3 are considered very high and yet spore counts of up to 650,000 spores/m^3 were observed by NRDC in a home in mid-city New Orleans [21]. No standards exist to which these mold counts can be compared and there is no clear regulatory responsibility for indoor air among federal agencies. The high mold counts are causes for concern and both NRDC and EPA recommend caution among returning residents, use of respiratory protection, and complete cleanup of flooded homes including removal of all porous construction materials including carpets and drywall.

Outlook

The flooding of New Orleans in the wake of Hurricane Katrina resulted in the potential for exposure to toxics and contaminants that was unparalleled by other natural disasters. Initial concerns about the generation of a “toxic gumbo”, however, have not

---

[21] http://www.nrdc.org/health/effects/katrinadata/mold.asp

been supported by the sampling and analyses conducted to-date. Floodwaters did contain significant short-term biological hazards that posed risks to stranded residents and relief workers. These floodwaters did not contain chemical toxicants at levels that are expected to lead to long-term impacts on the surroundings beyond that which would be expected of a similar volume of stormwaters from the city. The floodwaters undoubtedly redistributed some contaminants in the city, but the contaminant burden in the soils and sediments appear to generate few concerns for acute exposure and risk. Although acute generalized hazards have not been identified, the population of New Orleans faces localized areas where contamination was more serious, such as the neighborhoods impacted by a crude oil tank failure in St. Bernard Parish.

The most serious short-term contaminant and toxic issue that faces residents outside of the areas facing acute chemical contamination is the presence of high concentrations of mold and airborne mold spores. Reconstruction that involves the complete removal of mold-contaminated construction materials with respiratory protection for reconstruction workers offers hope of mitigating this problem.

The long-term chronic exposure concerns for New Orleans residents, however, remain uncertain. There are areas where chemical contamination has been found to exceed screening guidelines for chronic exposure. Outside of specific known areas of concern, however, apparently elevated levels of contaminants can be found in nearly all samples for some constituents (such as arsenic) or less frequently although commonly for other constituents (such as PAHs or other hydrocarbons). Are these problems of a nature that they pose a significant future risk to the residents of New Orleans? Exceedences of screening values do not in themselves confirm such risk. Should reconstruction be delayed pending a more complete assessment? It is unlikely that either the public or the local government would brook further delays in attempting to rebuild their city and their lives. Complicating the assessment of these problems is that the frequency and distribution of such exceedances may not differ from pre-Katrina conditions in the city. Would individuals be willing to delay their return to the city and support decisions as to which neighborhoods might be rebuilt as a result of contamination that might not be different from pre-Katrina conditions? Can the cleanup after Katrina be viewed as an opportunity to reduce the exposure to toxics and other contaminants regardless of whether the contamination was there pre-Katrina or whether the contamination is indistinguishable from any large city? Such efforts would undoubtedly require the support of the citizenry who would be forced to accept a diversion of reconstruction funds to environmental cleanup. Could contamination concerns be used to help decide which neighborhoods might move from residential use to lower exposure parklands or other uses? What is the appropriate balancing of expenditures for environmental restoration versus restoring and enhancing flood protection? If individuals or neighborhoods were unhappy with such decisions, what administrative or legal mechanisms exist for government to make such decisions? What role might government condemnation play in making such decisions?

Unfortunately, the currently available data do not identify a sufficiently serious contamination problem to drive government and public action toward answering these questions. In the absence of a clear driver for government or public action in response to contamination, the decisions about rebuilding are being based upon more clearly defined risks, such as the potential for reflooding. These decisions are largely being made by individuals and third parties such as insurers, banks, mortgage companies, and, eventually, courts in condemnation proceedings, while governmental entities are trying to build a public consensus around governmental proposals.

Because some areas exhibit contaminants that are present in concentrations that exceed adopted screening standards, Louisiana RECAP standards call for further assessment and evaluation. Normally (i.e., absence a massive catastrophic event, such as Hurricane Katrina), the existing institutions (local government, insurers, banks, etc.) could adequately handle the volume of site-specific assessments. However, the shear volume of assessments in the case of Hurricane Katrina (and by analogy other similar large scale disasters, whether caused by nature, an industrial accident or terrorism) suggests that there is a societal need for some degree of uniformity and equity in such decision making.

While it is beyond the scope of this article to provide definitive guidance as to how these assessments should be used in making decisions about the reconstruction of New Orleans, it is worthwhile to consider some guiding principles.

First, it should be recognized that the scale of decision making needed in this case (and the number of people impacted by such decisions) is of a scale not previously experienced. Thus, there are no models that can be taken off the shelf and simply used as is.

Second, there should be rules by which these decisions are made and they should be uniform, transparent, and consistent with existing hazardous waste and natural disaster clearnup criteria. History suggests that if a consensus is reached (at least among governmental entities) implementation will be easier. While the scale is difference in this situation, the tools exist and have been used in the past to make habitability decisions (e.g., Love Canal, Times Beach, World Trade Center, and prior Hurricane recovery efforts).

Third, any approach must balance the cost of an approach that maximizes equity by making a truly case-by-case determination and the need to make a large number of decisions in a relatively short period of time. There are many questions that will need to be answered. In the absence of rapid decisions and answers to the many questions, individuals will define the future of New Orleans based upon their own circumstances and desires and uniformity and equity are likely to suffer. Some might prefer that individuals or local governments to be able to call upon reconstruction funds to conduct a property owner-by-property owner assessment and to use the conclusions in decisions about the need for remedial efforts or in reconstruction planning. Others may argue that representative sampling should be used by government to make community decisions and individual property owners might seek independent sampling only to demonstrate the inappropriateness of the community decision as applied to that property.

Finally, a system for performing checks and balances on such decisions should be created because the re-development process may result in the government taking an individual's property.[22] To the extent feasible, such a system should rely upon existing methodologies, such as scientific peer review, public involvement processes, cooperative efforts between local, state, and federal agencies and/or public-private partnership. The

---

[22] The U.S. Constitution Takings Clause states: "Nor shall private property be taken for public use without just compensation." Thus, there may be legal proceedings at some point that takes the property of New Orlean's residents in exchange for "just compensation." Many of the issues in such a proceeding may be technical and they are likely to be effected by the policies adopted by the government and private sector concerning the risk associated with each property.

critical test of a legal process is not whether the agency chooses the alternative preferred by the public, but that the public perceives the process as fair.

Ultimately, the lessons learned (or missed) from Katrina need to be crystallized in a generic form so that the country is better prepared for the next natural disaster (whether a hurricane or other natural event), a major industrial accident or act of terrorism. This may mean making extraordinary efforts to put aside partisan concerns and solve real, significant problems in the way we process information in emergencies, and make cleanup/habitability decisions in response to the inevitable murky aftermath. Because existing institutions were largely unprepared for a disaster of the scale of Katrina, it may not be possible to implement the above principles in responding to the toxic and contaminant concerns generated by the storm and its aftermath. It is sincerely hoped, however, that we can learn from the disaster and provide more fundamentally sound responses to future catastrophic events.

References

Janda, J.M and P.S. Duffey. 1988. Mesophilic aermonads in human disease: current taxonomy, laboratory identification and infectious disease spectrum. *Rev. Infect. Dis, 10*, 980-997.

Gustavsson, N., B. Bølviken, D.B. Smith, and R.C. Severson. 2001. *Geochemical Landscapes of the Conterminous United States— New Map Presentations for 22 Elements*, U.S. Geological Survey Professional Paper 1648.

Mielke, H.W, G. Wang, C.R. Gonzales, E.T. Powell, B. Le, V. N. Quach. 2004. PAHs and metals in the soils of inner-city and suburban New Orleans, Louisiana, USA, *Environmental Toxicology and Pharmacology, 18* 243-247.

NIEHS. 2005. Katrina/Rita Response Portal, National Institutes of Environmental Health Sciences, http://cleek.ucsd.edu:8080/gridsphere/gridsphere?cid=gisimages.

Pardue, J.H, W.M. Moe, D. McInis, L.J. Thibodeaux, K.T. Valsaraj, E. Maciasz, I. Van Heerden, N. Korevec and Q.Z. Yuan. 2005. Chemical and microbiological parameters in New Orleans floodwater following hurricane Katrina, *Environ. Sci. Technol. 39*, 22, 8591-8599.

Pelley, J. 2006. Environmental News- Lead a hazard in post-Katrina sludge, *Environ. Sci. Technol., 40* 413-414.

Presley, S.M, T.R. Rainwater, G.P. Austin, S.G. Platt, J.C. Zak, G.P Cobb, E.J. Marsland, K. Tian, B. Zhang, T.A. Anderson, S.B. Cox, M.T. Abel, B.D. Leftwich, J.R. Huddleston, R.M. Jeter, and R.J. Kendall. 2006. Assessment of pathogens and toxicants in New Orleans, LA following Hurricane Katrina, *Environ. Sci. Technol. 40*, 468-474.

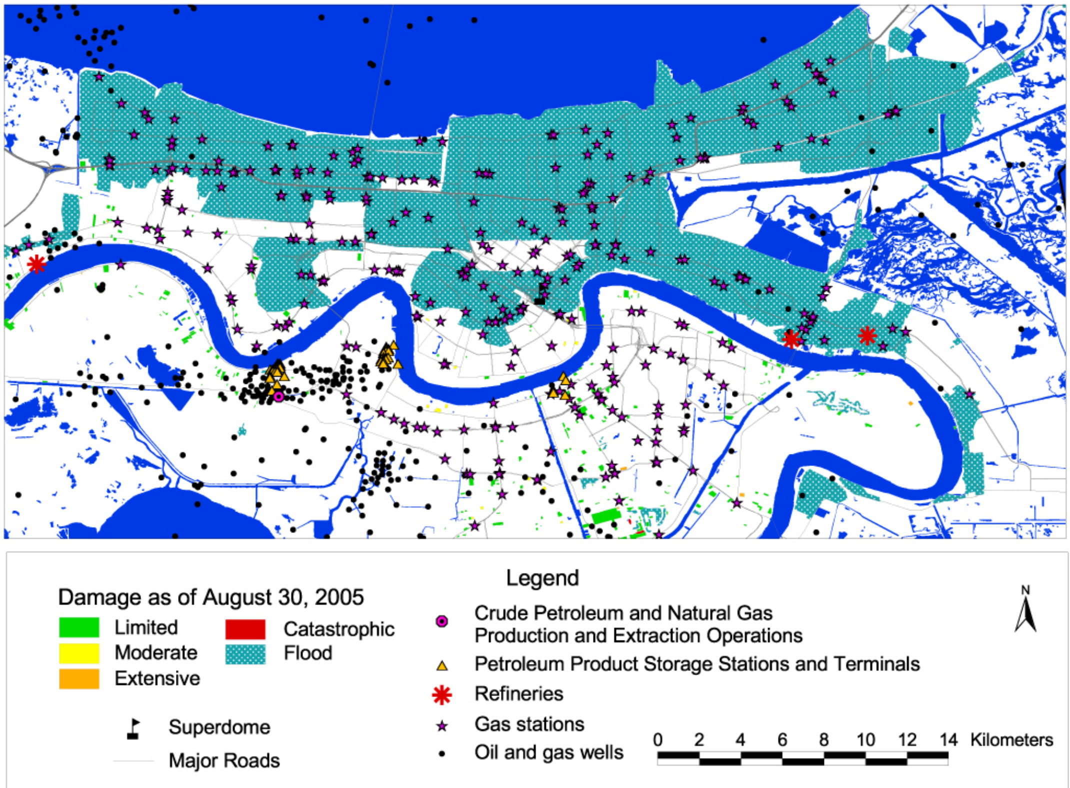

Figure 1 Map of New Orleans showing flooded area and petroleum and natural gas extraction, refining and distribution facilities (NIEHS, 2005)

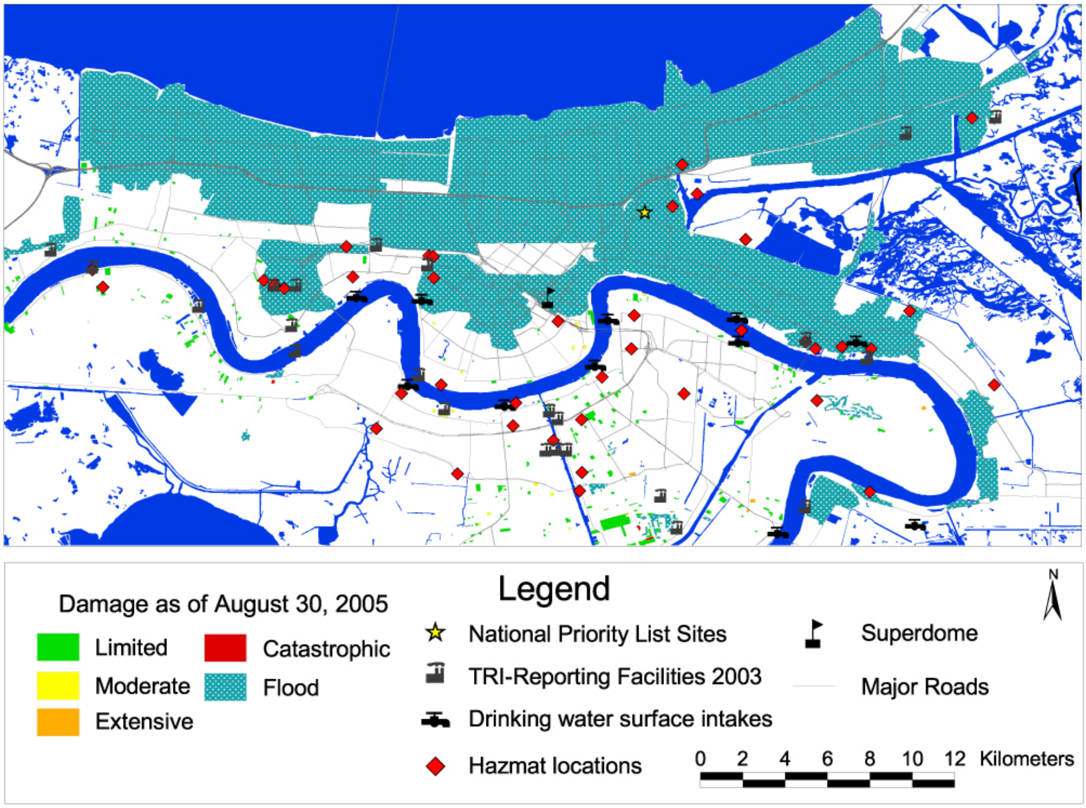

Figure 2 Map of New Orleans showing flooded areas and hazardous material release, storage and disposal areas (NIEHS, 2005)