Katrina as a Natech Disaster
Toxic Contamination and Long-Term Risks for Residents of New Orleans

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ABSTRACT

Hurricane Katrina's impacts have been debated and discussed as resulting from either natural forces or from the failure of man-made levees. However, both the immediate (3 years) and, most important, long-term (20 years or more) social and health consequences of Katrina must be understood in terms of natech disasters. Natech disasters combine etiological elements of both natural and technological disasters and this conceptual framework forces a recognition of the risks of toxic contamination. A review of available information on the air quality and sediment contamination in New Orleans following Katrina's destruction and subsequent flooding provides data for justifying this natech classification. Furthermore, data on the awareness of contamination for residents of Orleans parish are presented, revealing that a majority feel they have been exposed and one out of three are worried about neighborhood contamination. Suggestions for changes in risk assessment and public policy are also provided to mitigate the impacts of future natech disasters.

Disasters have traditionally been viewed as acute social crisis situations that severely disrupt the structural, organizational, and functional capacities of communities, families and people (Fritz 1961; Kreps and Drabek 1996; Freudenburg 1997). Ostensibly, disasters pose numerous risks to society by threatening human life, destroying personal resources and, in late modernity, creating toxic and hazardous environments where humans are exposed to dangerous chemicals, radiation, infectious disease and other biotechnological threats (Beck 1992, 1999; Quarantelli, Lagadec, and Boin 2006; Gunter and Kroll-Smith 2007; Marshall and Picou 2008).

Hurricane Katrina's catastrophic landfall East of New Orleans and along the gulf coast of Louisiana, Mississippi, and Alabama has stimulated disaster researchers to re-imagine the sociological study of such events (Picou and Marshall 2007). The destructive wind speeds (145 mph sustained and gusts to 200 mph) and storm surge (20–32 feet) that were generated over the extremely warm water temperatures of the Gulf of Mexico suggests that Katrina was "a worst-case event"(Clarke 2005, 2006; Picou and Marshall 2007; Marshall and Picou 2008). Katrina's economic impacts may approach hundreds of billions of dollars, while insurance costs may add an additional 40 billion, making this storm the most costly "natural disaster" in United States history (Picou and Marshall 2007). The death of over 1, 800 people, the evacuation of approximately 400, 000 individuals and the geographical displacement of over a million residents resulted in a modern diaspora (Weisler, Barbee, and Townsend 2006; Brunsma, Overfelt, and Picou 2007; Miller and Rivera 2008). The human suffering presented to the world by the mass media also etched horrific mental images that will remain as catastrophic visions throughout history (Gabe et al. 2005).

Most important, the fact that the potential dire consequences of a category 4 or 5 hurricane for New Orleans were repeatedly predicted by sociologists, engineers, emergency management specialists and other scientists over the last 25 years adds to academic and public concern and fosters a sense of preventive urgency for protecting vulnerable populations from future catastrophic hurricanes (Laska 2004). These early forecasts, made repeatedly by disaster experts, also provided predictions of the complete response failure that occurred after Katrina's deadly assault on New Orleans and the central gulf coast. Hurricane Katrina introduced the sociological community to a relatively new form of disaster, the *natech disaster*, which requires a reconsideration of disaster typologies and their health and social impacts in the modern world (Sholwalter and Myers 1994; Steinberg and Cruz 2004; Young, Balluz, and Maililay 2004; Picou and Marshall 2006, 2007).

Natech disasters also require a reorientation of emergency response systems and procedures for responding to and mitigating the social impacts of future destructive natech events in the twenty-first century (Steinberg, Sengul, and Cruz 2008; Cruz and Okada 2008). Recently addressed in the engineering literature, natech disasters signal a critical need for responding to previously unknown challenges and they chronicle new and destructive types of risks for survivors (Steinberg and Cruz 2004; Cruz and Steinberg 2004; Cruz and Okada 2008; Steinberg et al. 2008). Hurricane Katrina's human impacts will require social scientists to remain vigilant researchers of this event, since the consequences of this catastrophic natech disaster will continue to threaten the physical and mental health of returning residents well into the future. Social scientists, toxicologists and epidemiologists should not abandon this important long-term research agenda (Erikson 2007).

"NATURAL" VERSUS "TECHNOLOGICAL" DISASTERS

Disaster researchers, emergency management responders and our governmental-legal system have traditionally classified disasters as either "natural" or "technological." Research by social scientists since the late 1940s documented that natural disasters (hurricanes, earthquakes and floods) were acute, life-threatening events, which primarily destroyed the "built" and "modified" environments, while simultaneously generating the acute disruption of social systems (Quarantelli et al. 2006). Prevention of this type of destruction has focused on revising and improving architectural and engineering codes, developing sophisticated warning technologies in meteorology and seismology, while concomitantly developing emergency response plans and evacuation systems that are timely and effective (Drabek 1986; Steinberg et al. 2008). Disaster researchers have often described this response to natural disasters as actually producing an "amplified rebound" (Drabek 1986). That is, for natural disasters, engineering and technological improvements are often introduced in the post-disaster context to reduce the risk of impacts of future disastrous events. Furthermore, for the "traditional natural disaster," there is political and social consensus that: (1) a disaster occurred; (2) there are legitimate victims; (3) rescue, restoration and recovery should be "automatically" supported by the federal, state and local government, as well as by voluntary relief organizations; and (4) an "all clear" signal sounds that alerts survivors that the disaster has ended (Erikson 1976, 1994; Picou, Marshall, and Gill 2004).

On the other hand, technological disasters, i.e., human-caused toxic events, have traditionally been viewed as involving the breakdown of technological processes and systems, which in turn, generates chronic impacts for vulnerable human populations (Erikson 1976, 1994; Baum and Fleming 1993; Freudenberg 1997; Perrow 1999). Technological disasters often leave the "built" and "modified" environments intact, but severely, and oftentimes permanently, contaminate the "biophysical environment." This toxic impact pattern creates serious long-term risks to the biophysical environment and the physical and mental health of survivors (Kroll-Smith and Couch 1993; Ott 2005, 2008; Gunter and Kroll-Smith 2007). The contamination of the biophysical environment may ultimately result in uninhabitable communities (Chernobyl) or the creation of irreparable damage to ecological resources that disconnect communities from the biophysical environment (Picou and Gill 1996). Catastrophic technological failure and massive contamination of the biophysical environment produces a series of interacting and cascading social processes that plague victims and families for decades (Erikson 1976, 1994; Freudenburg 1997; Kroll-Smith and Couch 1993; Gunter and Kroll-Smith 2007). These toxic disasters become "contested events," resulting in community conflict, uncertainly and a lack of timely community recovery (Kroll-Smith and Couch 1993; Picou et al. 2004; Gunter and Kroll-Smith 2007).

A meta-analysis of 130 disasters in the United States documented that, in contrast to natural disasters, technological disasters result in more severe long-term social and mental health impacts for survivors (Norris et al. 2001). Furthermore, in numerous qualitative and quantitative studies of technological disasters, it is irrefutably apparent that anger, social conflict, post-traumatic stress, depression, litigation and even suicide plague many survivors for decades (Picou 1996; Erikson 1994; Freudenburg 1997; Picou et al. 2004; Gunter and Kroll-Smith 2007). Many of these contested disasters are characterized by "principle responsible parties" who are the perpetrators of massive ecological contamination (Picou 1996; Picou et al. 2004; Gunter and Kroll-Smith 2007). As victims of these contamination events suffer, a legal discourse emerges, restoration and recovery are postponed and the payment of damage claims are deferred through the "advantages" that corporations and government agencies leverage in the American legal system.

In summary, technological disasters produce: (1) a contested discourse and social conflict; (2) chronic community fragmentation, physical health problems, long-term mental health deterioration and resource loss-spirals; (3) a lack of timely restoration and recovery for contaminated and economically disenfranchised communities; and (4) chronic uncertainty regarding future social well-being. (Arata et al. 2000; Picou et al. 2004; Ott 2005; Picou and Marshall 2007; Bevc, Marshall, and Picou 2007; Gunter and Kroll-Smith 2007). Given this brief review of these two traditional "types" of disasters, it is apparent that a natural disaster that directly produces and exacerbates technological failure and ecological contamination is a "worst-case disaster scenario." In short, Hurricane Katrina was clearly such a worst-case event (Clarke 2005, 2007). The etiological origins of this storm may make for interesting discussion, e.g., was Katrina a "natural" or "man-made" disaster? However, it provides little understanding of past and present risks that have been generated for returning residents.

THE SOCIOLOGICAL SIGNIFICANCE OF NATECH DISASTERS

First and foremost, natech disasters are systemic events that chronically permeate and contaminate both the ecological and social environments. These consequences are generated through the synergestic interaction of natural forces with engineering, production and technological systems of industry and government (Showalter and Meyers 1994; Cruz and Steinberg 2006; Cruz, Steinberg, and Veter-Arellano 2006). Natech disasters may take many forms and their actual ecological, social, medical and psychological consequences are not immediately identifiable. In fact, the impacts of natech disasters, similar to technological disasters, are often masked by latent health risks due to toxic exposure and slowly evolving patterns of collective stress, anger, anxiety and depression (Erikson 1976, 1994; Kroll-Smith and Couch 1993; Freudenburg 1997).

The empirical recognition of the potential destruction and risk posed by natech disasters has been noted in the engineering literature for the 1999 Kocaeli earthquake in Turkey and in the sociological literature for the 1994 Northridge earthquake (Lindell and Perry 1997; Steinberg and Cruz 2004). Numerous hazmat releases occurred for the Kocaeli earthquake, which killed more than 15,000 people and left over 250, 000 homeless (Steinberg and Cruz, 2004). As for all natech disasters, the series of releases of toxic and hazardous chemicals that occurred were both *directly* and *indirectly* associated with the massive physical damage to the built and modified environments inflicted by the earthquake. Steinberg and Cruz (2005:122–125) have documented that for this "natural disaster" a wide variety of toxic releases were set in motion, which in turn, generated health risks for survivors. These hazmat releases included the following:

1. Approximately 6.5 million kg of hazardous anhydrous ammonia was released into the air, water and soil from ruptured tanks at an industrial chemical facility.
2. Over 50,000 kg of diesel fuel leaked into a local waterway (Izmit Bay) from a petrochemical storage facility.
3. Over 1.2 million kg of liquid oxygen from impacted storage tanks at a gas company was released into the environment.
4. A series of fires in a petrochemical tank farm and several chemical storage facilities released 350,000 m? of crude oil and naphtha into the atmosphere.
5. The intentional release of 200,000 kg of hazardous anhydrous ammonia at a fertilizer plant occurred to avoid massive over pressurization of storage tanks (Steinberg and Cruz 2004).

This documentation of hazmat releases from this major earthquake reveals that direct, indirect, and intentional contamination may occur from natech disasters (Young et al. 2004; Picou and Marshall 2006, 2007). Interestingly, natech disasters occur frequently, but have been overlooked by disaster sociologists. From 1990 to 2003 the number of natech disasters in the U.S. ranged from a low of 530 in 1997 to a high of 820 in 1994 (Steinberg et al. 2008:146–147). Furthermore, a variety of exposure pathways are generated by these events for vulnerable human populations, including air, water, soil, and food consumption.

A similar natech scenario characterized Hurricane Katrina for residents of New Orleans. For example, one of the largest inland oil spills in United States history occurred in the Chalmette community when approximately 1,050,000 gallons of oil was released from damages incurred throughout the Murphy Oil Refinery (Picou and Marshall 2007; Steinberg and Cruz 2008). Although a total of over eight million gallons of oil was released throughout the geographical area impacted by Hurricane Katrina (Picou and Marshall 2007), the nature and extent of the contamination that resulted goes beyond the Murphy Oil Refinery petrochemical contamination south of New Orleans. Indeed, major contamination events such as the *Exxon Valdez* oil spill are often viewed as "signal events." In other words, the contamination is highly visible and the event receives intense media and public attention. However, the contamination of the biophysical environment caused by Katrina seems to have been overlooked and the long-term health risks to returning residents of New Orleans are being ignored in the aftermath of the storm (Godsil, Huang, and Solomon 2009). The remainder of this article will review levels of air and sediment contamination measured in the post-Katrina greater New Orleans area, describe perceptions of the seriousness of post-Katrina contamination for local residents and provide suggestions for the implementation of appropriate risk assessment methods and policy initiatives for reducing the long-term health risks of Katrina and future natech disasters.

Air Pollution following Katrina

In the months following Katrina's landfall and the flooding of New Orleans, the Environmental Protection Agency (EPA) and state regulatory agencies permitted open-pit burning of hurricane waste and various types of accumulated debris. On the extremely warm days following the storm a visible and persistent haze covered the city and there were sporadic reports from residents of respiratory problems and allergies. These complaints were most pronounced for people living close to burning pits (DeFur personal communication). The massive debris removal program, which was initiated in the weeks and months following the storm, also generated dust plumes on a daily basis, providing a continuous release of toxins in the air throughout all areas of the city. The air sampling plan utilized by the EPA was acknowledged as not being designed to protect citizens. The EPA stated: "The monitoring activities described here are not specifically designed to provide all appropriate information on the exposure of workers [and residents] while they are actively occupied in clean up and recovery tasks" (cited in DeFur personal communication). Furthermore, EPA's monitoring plan did not estimate "ambient concentrations" of toxins, nor was it designed to gather air quality data from areas near the numerous open-burning sites located throughout the city. In summary, it is apparent that volatile organic compounds were heavily concentrated in the air in the greater New Orleans area following Hurricane Katrina.

The massive flooding of over 120,000 homes also posed risks for respiratory damage to returning residents. As the toxic waters slowly receded from revitalized pumping operations and evaporation processes, the aerosolization of mold spores and endotoxins occurred both inside and outside of residences. Mold spores (*filamentous microfungi*) pose a serious threat to human health because when they are released in the air and inhaled they initiate numerous toxic responses and/or produce asthmatic and allergic respiratory problems (Robbins et al. 2000). Long-term exposure to elevated levels of fungal material induces respiratory inflammation and allergic reactions in humans (Bush et al. 2006). Furthermore, exposure to air-borne endotoxins, "that is soluble lip polysaccharide fragments" that form on the cell walls of bacteria, produces cough, flu symptoms, headaches, chronic bronchitis and numerous other critical respiratory disorders (Rylander 2002; Solomon et al. 2006).

Air sampling studies conducted in New Orleans in the months following Katrina revealed that dangerous levels of mold spores and endotoxin concentrations were found in both indoor and outdoor environments (CDC 2006; Solomon et al. 2006; Godsil et al. 2009). It is important to note that concentrations of mold spores varied by location. That is, when flooded geographical areas were compared to areas that did not flood, flooded neighborhoods had significantly higher concentrations. Nonetheless, Solomon et al. (2006:6) state that "the ambient spore concentrations measured in non-flooded sections of New Orleans that were adjacent to flooded neighborhoods were also high according to NAB national benchmarks." The mold spore concentrations measured inside flooded homes revealed higher and more varied types of fungal spores than air samples taken in outdoor areas and outside non-flooded homes. Spore concentrations were also higher for dwellings in which remediation was occurring in contrast to those that were fully remediated (Solomon et al. 2006; Godsil et al. 2009).

The risk of mole spore contamination for reducing the air quality of New Orleans in the months immediately following Katrina's landfall was significant. Solomon and associates clearly substantiate this claim by stating:

> Ambient spore concentrations >50,000 spores/m? are defined as "very high" . . . and exceed the 99th percentile nationwide. Ten of the 13 samples (77%) taken within flooded areas of New Orleans exceeded 50, 000 spores/m?. In addition, because the dominant spore types . . . were different from the normal

> mix of fungi in ambient air, on which the NAB bases its guidelines, it is possible that the health effects for those with allergies or asthma may be greater . . . than would be predicted based on spore concentrations along (2006:7).

These high concentrations of mold spores provided a context for significant respiratory hazards to returning residents and clean-up workers and should have been continuously monitored (Solomon et al. 2006). Because nearly 50 percent of the returning residents and 33 percent of clean-up workers did not utilize protective respiratory equipment, exposure levels were even more acute and widespread, and the long-term health consequences of this lack of precaution remains unknown (CDC 2006). Furthermore, these spore concentrations were continuously released from on-going home remediation activities, suggesting that the indoor and outdoor exposure pathways became a chronic air contamination problem for residents and workers throughout the New Orleans area. Given that over 120,000 homes were flooded and approximately 50,000 homes continue to be demolished, exposure to mold spores still remains a significant threat to the respiratory health of hundreds of thousands of returning residents (Wright and Bullard 2007).

Sediment Contamination Following Katrina

As the levees failed and the city was inundated with water, soil and debris from Lake Pontchartrain insidiously mixed with numerous toxic and hazardous chemicals from industrial and residential locations, producing the most massive contamination event in the history of the United States. This toxic disaster has been ignored by local, state and federal government officials and agencies, but the long-term risks to human health posed by this natech disaster are real and deserve long-term sociological and toxicological monitoring. Once the contaminated floodwaters receded, through intentional pumping to other bodies of water, namely Lake Pontchartrain, Lake Borgne, and eventually the Gulf of Mexico, "a caked layer of muck" covered the vast area that was flooded (Solomon and Rotkin-Ellman 2006:3). Although the EPA collected hundreds of samples of this toxic sediment, they failed to provide any analysis and simply posted their results on their website for public review (http://oaspub.epa.gov/storetkp/dw_home). The Natural Resources Defense Council (NRDC) has provided a secondary analysis of these published sediment samples and selected portions of their analysis will be reviewed for three primary contaminants—arsenic, diesel fuel, and benzo(a)pyrene.

Arsenic: Arsenic is a naturally occurring element that is found in the biophysical environment in extremely small concentrations. It is often located in the soil and can be transferred to air and water by wind and hydrological run-off. Arsenic is a highly toxic substance for humans and exposure poses a variety of serious health risks, including stomach and intestinal damage, skin eruptions, damage to red and white blood cells, and, most important, liver, lung, and lymphatic cancer. Once arsenic permeates the biophysical environment it cannot be destroyed and readily accumulates in plants, fish, and birds. This lethal contaminant is a long-term threat to health unless it is carefully removed from the environmental context it occupies (Lenntech 2008).

Prior to Hurricane Katrina's impacts, it is highly probable that some level of arsenic contamination characterized the greater New Orleans area due to pesticide use, various incineration activities and chronic industrial pollution (Solomon and Rotkin-Ellman 2006). Nonetheless, the technological failure of the levees and subsequent flooding of the city resulted in the movement of this indestructible carcinogen to the soil surface which subsequently produced a multiplicity of exposure pathways to humans. Table 1 provides the National Resource Defense Council's evaluation of the EPA's arsenic samples for the New Orleans area (Solomon and Rotkin-Ellman 2006). Of the 389 samples analyzed, 95 percent were found to exceed EPA screening levels, 56 percent exceeded

Louisiana arsenic background levels, and 30 percent were above the Louisiana Department of Environmental Quality (LDEQ) guidelines for requiring a cleanup operation (Table 1). The data presented for Orleans parish were found to be similarly high in arsenic deposits with 37 percent exceeding LDEQ cleanup guidelines. These findings indicate that following Katrina, an extremely large geographical area was encapsulated in an arsenic shell.

Arsenic samples taken in New Orleans East, Lakeview, the Lower Ninth Ward, Bywater, Gentilly, the Central City Garden District, and Chalmette contained the largest proportion of samples that exceeded the EPA screening levels (Table 1). Indeed, New Orleans East, Lakeview, Bywater, and Mid-City are all areas where LDEQ cleanup guidelines were found to have been significantly exceeded, and cleanup and soil removal projects should have been initiated. Solomon and Rotkin-Ellman (2006:4) state that "there are serious hot spots of arsenic contamination in several neighborhoods, including Lakeview, Gentilly, Mid-City, and New Orleans East." The Gert-Town neighborhood in Mid-City contained arsenic concentrations "200 times higher" than the EPA "concern level" for arsenic soil contamination (Solomon and Rotkin-Ellman 2006:4). Because no amount of arsenic exposure is safe for human health, this secondary arsenic contamination produced by Katrina poses a significant long-term health risk to residents of Orleans parish and the greater New Orleans area. Two years after Katrina, tests conducted by the NRDC revealed that approximately 25 percent of the schoolyards in New Orleans contained levels of arsenic that require immediate soil removal (Godsil et al. 2009:123). This fact expands the risk of arsenic poisoning to children, who are highly vulnerable to toxic and hazardous exposure (Powers 2007).

Diesel Fuel: Hurricane Katrina caused a multitude of oil, gasoline and diesel fuel spills. The high wind velocity and the flooding of New Orleans combined to cause releases from abandoned vehicles, holding tanks, waste sites and other sources in a variety of concentrations that collectively contaminated the sediment throughout the city. Specifically, diesel fuel is a complex combination of chemicals that include formaldehyde, benzene, sulphur compounds, and a wide variety of other volatile organic compounds. Solomon and Rothkin-Ellman (2006:7) state that both the EPA and the CDC have concluded that "Even brief skin contact with sediment contaminated by fuel oil can cause itchy, red, sore and peeling skin. Breathing dust contaminated with these chemicals . . . can also cause illness." Long-term inhalation of diesel dust/vapors can raise blood pressure, induce headaches, damage kidneys and produce dizziness, nausea, and loss of coordination (http: webstuff\H&Sfactsheets\HazardsofDieselFuelandFumes.doc). Long-term human exposure also elevates the risk of lung and prostate cancer, while toxic ecological impacts will also be evident well into the future.

Table 2 provides the NRDC's analysis of the EPA's diesel fuel sampling in the greater New Orleans area. According to guidelines established by the LDEQ, approximately 59 percent of the samples in the greater New Orleans area and 91 percent of the samples collected in Orleans parish were found to have concentrations of diesel fuel that require a soil clean-up program (Solomon and Rotkin-Ellman 2006:7). All nineteen samples taken in the Central City/Garden District and Uptown/Carollton area exceeded LDEQ screening levels (Table 2). High levels of diesel fuel were also found in the Mid-City, Lakeview, and Bywater districts. Solomon and Rotkin (2006:7) also point out that "there are serious hot spots of diesel fuel contamination in several neighborhoods, including Chalmette, Bywater, Lakeview, Central City, and Mid-city." Combined with other carcinogens, such as arsenic, it is apparent that sediment contamination poses a serious health risk to residents throughout New Orleans and the surrounding area.

Benzo(a)pyrene: Benzo(a)pyrene is part of larger class of chemicals called polycyclic aromatic hydrocarbons, or PAHs. They are compound mixtures whose long-term health impacts can be fatal to humans. Evidence exists that this compound produces skin, lung and bladder cancer in humans and it is also listed as an immunotoxicant, liver toxicant, and respiratory toxicant (Park and Holliday

Table 1. Summary of EPA Arsenic Sampling in Greater New Orleans Area

District	# Samples	# Samples per Square Mile	Average (mg/kg)	Upper 95% Confidence Interval	Maximum (mg/kg)	Exceed EPA Screening Level (%)	Exceed Louisiana Background (%)	Exceed LDEQ Cleanup Guideline (%)
Central City/ Garden District	8	1.8	7.4	10.0	12.1	100%	63%	13%
Uptown/Carrollton	22	2.9	3.1	4.7	17.0	69%	0%	0%
Mid-City	21	3.0	15.9	24.4	78.0	95%	48%	43%
Lakeview	21	2.8	17.2	23.4	53.3	100%	71%	52%
Gentilly	28	3.5	13.7	19.1	61.2	100%	64%	39%
Bywater	31	5.3	13.0	15.9	28.9	100%	68%	52%
Lower Ninth Ward	23	10.1	9.2	10.7	15.8	100%	70%	17%
N.O. East	44	3.1	16.0	18.8	45.5	100%	82%	68%
Arabi	22	10.4	8.7	10.6	20.3	100%	41%	23%
Chalmette	52	6.6	8.0	9.2	21.4	100%	58%	15%
Meraux	17	3.6	5.4	6.4	11.5	100%	18%	0%
Greater New Orleans Area	389		10.6	11.7	78.0	95%	56%	30%
Orleans Parish	228		11.8	13.3	78.0	95%	59%	37%

Source: Solomon and Rotkin-Ellman 2006:6.

Table 2. Summary of EPA Diesel Fuel Sampling in Greater New Orleans Area

District	# Samples Diesel Fuel Detected	# Samples per Square Mile	Average (mg/kg)	Upper 95% Confidence Interval (mg/kg)	Maximum (mg/kg)	Exceed LDEQ Screening (%)	Exceed LDEQ RECAP MO-1(%)
Central City/ Garden District	5	1.1	2533.0	5823.5	9140	100%	60%
Uptown/Carrollton	14	1.9	617.3	1060.5	2610	100%	21%
Mid-City	21	3.0	1317.7	2176.1	8250	95%	38%
Lakeview	20	2.7	1220.3	2131.0	9160	85%	35%
Gentilly	28	3.5	765.2	991.9	2050	96%	46%
Bywater	32	5.5	1116.1	1989.7	14200	94%	28%
Lower Ninth Ward	19	8.4	148.0	197.2	481	53%	0%
N.O. East	42	3.0	773.1	1057.1	5565	93%	48%
Arabi	22	10.4	239.7	361.5	1230	91%	9%
Chalmette	430	54.2	343.6	460.0	17400	43%	10%
Meraux	20	4.2	239.9	643.4	4150	15%	5%
Greater New Orleans Area	679	9.5	524.1	630.0	17400	59%	17%
Orleans Parish	207	3.7	956.8	1193.0	14200	91%	35%

Source: Solomon and Rotkin-Ellman 2006.

1999). Benzo(a)pyrene is viewed as one of the highest ranked hazardous compounds to ecosystems and human health known in modern chemistry (Scorecard.com 2008). Human exposure can occur through a variety of pathways, including breathing air, skin contact, eating, and drinking.

The numerous industrial spills of petroleum products directly caused by Hurricane Katrina, as well as historic conditions of contamination in the city, resulted in floodwaters that were infused with high concentrations of PAHs. After the water traversed throughout the city, benzo(a)pyrene settled into the soil where the potential for human exposure became long-term. Table 3 reveals that in 43 percent of all EPA sediment samples collected in the greater New Orleans area exceeded LDEQ guidelines for cleanup. Furthermore, 57 percent of the samples taken in Orleans Parish were also contaminated with levels of benzo(a)pyrene that were beyond LDEQ levels that require the initiation of clean-up operations. Average levels of this dangerous chemical in the Central City/Garden district, Uptown Carollton area, Mid-City area, Gentilly, and New Orleans East were also found to be prominent enough to require cleanup.

The geographical contamination pattern for benzo(a)pyrene was highly correlated with the pattern observed for diesel fuel. Solomon and Rotkin-Ellman (2006) note that one exception to this pattern did occur. The Bywater district had "Some of the highest levels of benzo(a)pyrene—in some instances more than 50 times the LDEQ soil cleanup level—were found around the former Agricultural Street Landfill" (Solomon and Rotkin-Ellman 2006:10). These sediment samples clearly reveal unacceptable levels of a highly carcinogenic compound and identifies serious long-term health risks exists for returning residents in numerous areas throughout the greater New Orleans area. Furthermore, research on the Exxon Valdez oil spill has revealed that the PAHs remain highly toxic for decades and pose serious health risks to both the ecology and humans (Ott 2005; O'Neill 2003; Peterson et al. 2003).

Perceptions of Contamination in Orleans Parish

Given the documentation of air and sediment contamination in Orleans Parish and the greater New Orleans area from the analysis provided by the NRDC, the question arises as to whether or not local residents are aware of and concerned about personal exposure and the existence of dangerous chemicals in their neighborhoods? Data taken from a larger study of Hurricane Katrina survivors in Louisiana and Mississippi afford an opportunity to evaluate this question (Picou and Bevc 2009).[1]

Table 4 reveals that a majority of residents of Orleans Parish believe that either family members or themselves were exposed to dangerous chemicals because of Hurricane Katrina. When compared to Jefferson Parish, an area that also flooded which is contiguous to Orleans Parish, and St. Tammany Parish, an area north of Lake Pontchartrain which was not flooded, it is apparent that there are significant exposure concerns among residents of the greater New Orleans area that are not shared by residents of neighboring parishes.

Furthermore, Table 4 also shows that one out of three residents in Orleans Parish worry about the existence of dangerous chemicals in their neighborhoods. This proportion is higher than responses observed for residents of Jefferson and St. Tammany parishes. These descriptive results, coupled with the data on air and soil contamination, reveal that residents are aware of their exposure and are concerned about the existence of toxic chemicals such as arsenic, diesel fuel and benzo(a)pyre in their neighborhoods. However, Orleans parish residents may not understand the nature and scope of the health risks that currently exists. Furthermore, on-going home remediated will continue to release mold spores and endotoxins in specific areas of New Orleans, at times producing spontaneous and sporadic health risks to residents and contractors. Nonetheless, there remains

Table 3. Summary of EPA Benzo(a)pyrene Sampling in Greater New Orleans

District	# Samples B(a)P Detected	# Samples per Square Mile	Average (ug/kg)	Upper 95% Confidence Interval (ug/kg)	Maximum (ug/kg)	Exceed LDEQ Cleanup Guideline (%)
Central City/ Garden District	5	1.1	908.8	1736.7	2530	80%
Uptown/Carrollton	15	2.0	478.5	823.7	2870	47%
Mid-City	8	1.2	974.9	1889.0	4160	63%
Lakeview	9	1.2	463.8	645.3	1020	78%
Gentilly	12	1.5	656.5	895.7	1680	75%
Bywater	15	2.6	3218.2	6121.3	17700	53%
Lower Ninth Ward	5	2.2	219.2	372.9	519	20%
N.O. East	16	1.1	365.3	493.1	1120	44%
Arabi	10	4.7	149.8	242.4	533	10%
Chalmette	37	4.7	225.0	321.8	1580	16%
Meraux	1	0.2	166.0	—	166	0%
Greater New Orleans Area	144	2.0	975.7	1557.8	35500	43%
Orleans Parish	96	1.7	1359.6	2223.1	35500	57%

Source: Solomon and Rotkin-Ellman 2006, 11.

Table 4. Perceptions and Concerns of Toxic Contamination in Orleans, Jefferson and St. Tammany Parishes, Louisiana

Question	Parish		
	Orleans % Agreeing	Jefferson % Agreeing	St. Tammany % Agreeing
"I believe that either myself or my family members have been exposed to dangerous chemicals because of Hurricane Katrina."	53 (*N* = 534)	36 (*N* = 533)	27 (*N* = 241)
"I worry that there are dangerous chemicals in my neighborhood."	34 (*N* = 533)	22 (*N* = 546)	13 (*N* = 248)

a lack of public awareness concerning these risks and no active clean-up programs for risk reduction have been proposed or initiated.

CONCLUSIONS

As a meteorological event, Hurricane Katrina was extremely destructive and the geographical location where landfall occurred was highly vulnerable to storm surges and flooding. This vulnerability went beyond geography, it also included historically developed industrial production systems, industrial waste facilitates, oil refineries and numerous chemical holding facilities. When viewed as a natech disaster, Katrina was clearly a catastrophic contamination event which severely impacted the biophysical environment of New Orleans and presently poses serious risks to the health and social well-being of residents.

In the weeks and months following Katrina's assault on New Orleans, returning residents and clean-up workers were exposed to smoke from burning pits which contained a combination of toxic substances, mold, bacteria, asbestos and just about any configuration of chemical compounds that one can imagine. Air samples from both flooded and non-flooded areas revealed extremely high concentrations of mold spores and to a lesser extent endotoxins (Godsil et al. 2009). Dangerous spore concentrations are being continuously released as residents slowly return and home remediation progresses. Sediment samples collected several years after Katrina document extremely high-levels of arsenic, diesel fuel and benzo(a)pyrene throughout the greater New Orleans area. Furthermore, given that toxic contamination and exposure to dangerous chemicals is never uniform (Bevc et al. 2007), various "hotspots" have also been identified and these contamination zones pose serious health risks to people who reside near or travel through these areas.

In many ways the greater New Orleans area and Orleans parish can be viewed as a "toxic time bomb." However, federal, local and state agencies have not initiated a comprehensive testing and clean-up operation. In fact, the toxic contamination resulting from direct, indirect and purposeful chemical and hazmat releases caused by Hurricane Katrina seems to have been forgotten, or "swept under the rug." There are many reasons for this dire situation. For example, it has been noted that LDEQ officials feel that they are not responsible and argue that the toxic contamination measured post-Katrina was actually there before the storm struck. The failure of the EPA to act is understandable, given that this agency never intended to protect residents when they collected sediment samples throughout the greater New Orleans area (Godsil et al. 2009). The lack of concern for the serious health and social risks of Katrina's toxic legacy is also directly related to how we conceptualize and establish a public discourse on "types" of disasters and the risks that different "types" of disasters present to the public.

Hurricane Katrina was not a "natural" disaster nor was it a "technological" disaster. Katrina was a "natech disaster," that is, a different species of catastrophe that poses serious long-term physical and mental health risks to survivors (Erikson 1994). The lethal and continuing damage inflicted by Katrina is more akin to the 9-11 terrorist attack than Hurricane Andrew or Love Canal. Following 9-11, the EPA's lead administrator Christine Todd Whitman stated that it was safe for people to return, giving a false "all clear" signal that has been viewed by many as being inaccurate and criminal (Marshall, Picou, and Gill 2003; Godsil et al. 2009:131–132).[2]

When viewed as a natech event, academicians, politicians, leaders of federal, state and local agencies, as well as the general public, are "forced" to address the risks posed by Katrina's contamination. This massive contamination situation could emerge as a chronic health plague to residents of New Orleans as they attempt to reclaim and rebuild their city. Natech disasters overwhelm local responders for a number of documented reasons. First, their vast geographic range overwhelms victims and responders; second, the heavily damaged built environment delays emergency response; third, response plans of industrial facilities simultaneously fail and produce multiple sources of contamination that is unnoticed by survivors and fourth, funds to clean-up environmental contamination may not be available (Steinberg et al. 2008:145–146). Natech disasters need to be prominently recognized by disaster and environmental sociologists and immediate attention needs to be given to the long-term protection of survivors.

As the growing literature on technological disasters reveals, toxic contamination of the biophysical environment creates chronic uncertainty, economic loss, social disruption and severe psychological problems for survivors (Kroll-Smith and Couch 1993; Erikson 1994; Freudenburg 1997; Arata et al. 2000; Bevc et al. 2007). Given that health risks of Katrina's contamination may eventually come to the attention of public officials and survivors, one can predict that fragmented social collectivities will subsequently emerge, producing anger, uncertainty, social conflict, and litigation (Freudenburg 1997; Arata et al. 2000; Marshall, Picou, and Schlichtmann 2004; Picou et al. 2004).[3] For example, data collected one month after Hurricane Katrina revealed that African-Americans were more stressed at the time of the survey and anticipated more future stress than whites (Eliott and Pais 2006). Given that patterns of chronic stress are linked to loss of trust in government institutions, the deterioration of coping skills, litigation, and continuing loss of economic and personal resources, residents who return to New Orleans appear highly vulnerable to future mental health problems, as well as physical health isssues (Freudenburg 1997; Arata et al. 2000; Picou et al. 2004; Bevc et al. 2007).

These chronic impacts will certainly continue to have dire consequences for those who were more vulnerable to Katrina's initial onslaught, particularly residents who lack medical insurance as well as lower-socioeconomic residents of the city (Bullard and Wright 2009). Recognizing that natech disasters pose new and deadly risks to survivors well after the natural disaster has "ended" is the first step toward achieving recovery from this deadly form of catastrophe. As Erikson (2007:xviii) has insightfully stated:

> The story of Katrina is what those winds and surges did to the persons and communities caught in their path, and the dimensions of that occurrence are only now emerging in enough detail to begin the process of understanding. "Katrina" exploded into being in August 2005, but it does not have a defined location in the flow of time . . . what we mean by Katrina began long before the storm, and it will be an ongoing event for a long time to come. The storm is not over.

Returning residents should not be placed "in harms way" as they engage in reclaiming, rebuilding and revitalizing New Orleans. By conceptualizing Katrina as a natech disaster and assessing the types and levels of contamination that resulted from the storm, scholars, researchers, scientists, political officials and, most important, the general public will become more informed and responsive to the new risks that returning residents will face for decades.[3]

When viewed as a natech disaster, the contamination generated by Hurricane Katrina has important implications for the management of vulnerable industrial facilities and the assessment of disaster risks. In particular, petrochemical facilities, such as oil refineries, metal processing operations, mining-waste disposal facilities (dams), chemical storage and distribution facilities and chemical manufacturing plants (including pharmaceuticals, pesticides and fertilizers) pose significant risks to ecological and human health (Krausmann and Mushtaq 2008:184–186). Minimally, such production facilities should be protected by a variety of secondary containment systems, such as dikes and retaining walls (Krausmann and Mushtaq 2008). In addition to flooding, natech events can result in explosions and fires that result from the acute release of flammable liquids, liquefied gases and rapid chemical interactions that become exposed to electrical system failures or lightening. Toxic and hazardous chemicals can be released into the air through fires as flood waters and storm surges simultaneously move such material across large geographical areas. Indeed, the intensity of natural hazard vulnerability, as well as the type and quantity of toxic industrial facilities, needs to be factored into risk assessment calculations to refocus emergency response and clean-up operations to alternative dangers posed by natech events (Cruz and Okada 2008; Galderisi et al. 2008).

Natural and technological hazards have traditionally been viewed as separate risk domains and, accordingly, risk assessments rarely calculate combined probabilities. When conceptualized as a natech disaster, the impacts of natural hazards become magnified, more complex and elevated risks are generated for the biophysical environment and the human community. The reduction of the risks posed by natech disasters is first and foremost dependent on the conceptual and empirical acknowledgment that natech disasters exist and are common in the modern world (Steinberg et al. 2008). Natech risk assessments require "a comprehensive analysis approach . . . that takes into account the interactions between the natural hazards a region is subject to and the industrial facilities present in the region" (Steinberg et al. 2008:147). A dynamic system of risk assessment must incorporate information on interactive chains of causality that identify domino effects, systemic outcomes and emergency response modifications that would be required to minimize the risks of future natech events (Menomi 2001).

Several recent advances have been made in the area of natech risk assessment, and although a detailed explication of these efforts goes beyond the scope of the present research, important suggestions are available in the literature. The conjoint impacts of natech catastrophes requires a sensitivity to low probability-high consequence events, or worst-case events (Clarke 2007). Cruz and Okada (2008:200) have developed a methodology for conducting "preliminary, rapid assessments of natech risks in urban areas." This approach requires community participation, the collection of data on natural hazards, the identification of hazmat facilities and their locations, community resources, community demographic profiles and spatial and geographical mapping of all of this information (Cruz and Okada, 2008). Natech risk inventories (NRI) are calculated from these data, , and although limited, these values provide a screening tool for estimating degrees of risk for communities that may be vulnerable to natech disasters. Furthermore, qualitative natech damage scales are available for floods and a multi-attribute decision model, which has GIS compatibility, has been developed for land-use planning mitigation strategies for seismic events (Krausmann and Mushtaq

2008; Galderisi et al. 2008). These initial attempts to evaluate and prepare for natech disasters need to become a focal point for emergency response planning and disaster policy in the post-Katrina world of disaster management.

In conclusion, traditional disaster typologies need to be reconsidered for Hurricane Katrina. A reconceptualization of Katrina as a natech disaster reframes the long-term risks of this event for environmental sociologists, disaster researchers and, most important, for the public (Picou 2008). Viewing Katrina as a natech disaster forces a consideration of the synergestic contamination consequences overlooked by traditional "natural" and "man-made" classifications, allows for the expansion of disaster impacts to include long-term medical and mental health risks and allows need for government agencies, national NGO's, community groups, scientific organizations and the media to address the mitigation of these risks for returning residents. Minimally, federal and state agencies, such as the EPA and LDEQ, should reconsider the available data on the contamination of New Orleans and initiate the organization of sediment removal programs in all areas where contamination levels exceed established guidelines for required site clean-ups (Godsil et al. 2009: 117–121). Given the perception of exposure and concerns regarding neighborhood contamination held by residents of Orleans Parish, the removal of dangerous toxic chemicals released by Hurricane Katrina would be an important and necessary step toward community recovery. Finally, natech risk inventories and other comprehensive natech risk methodologies need to be developed for the greater New Orleans area and the central gulf coast in anticipation of emergency response activities needed for future hurricanes that will invariably result in the toxic contamination of this region.

NOTES

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1. Data were collected from April to August from residents in the seven parishes/counties in Mississippi and Louisiana that received the most damage from Hurricane Katrina. Random digit-dialing telephone interviews were conducted for 2,548 respondents. The data for Orleans, Jefferson and St. Tammany Parishes are presented. For more information, see Picou and Bevc (2009).

2. Research indicates that residents near the World Trade Center are characterized by an increased incidence of new-onset respiratory symptoms and bronchial problems (Reibman et al. 2005). Estimates suggest that 16,000 responders and 2,700 community residents are ill and currently are receiving treatment. Over 40,000 responders are under medical monitoring (911listserv@googlegroups.com.September 29, 2008).

3. Litigation is currently a characteristic of the post-Katrina social context. Murphy Oil settled with residents of 1, 800 homes for 330 million dollars (McConnaughey 2007) and on-going litigation against the U.S. Corps of Engineers could reach 100 billion dollars for government liability.

4. It should be noted that in addition to the data reviewed in this article, New Orleans residents have been exposed to chemicals in contaminated FEMA trailers, poor drinking water quality, lead contamination, and other toxic and hazardous materials.

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