ANTHONY DEPALMA

City of Dust

Illness, Arrogance, and 9/11

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Introduction

Of all the images of the September 11, 2001, attack on New York, the one that's been hardest for me to shake is not the fiery flash of impact, or the harrowing sight of desperate people leaping to their deaths, or the awesome 10.52 seconds it took for the first tower to buckle and cave in on itself in a maelstrom of concrete and ash, followed incredibly by the second tower falling just as fast, a few yards away. Terrible indeed were those images, but there was also an aspect of cinematic unreality about them that has kept me distant, as though watching a movie or playing a video game. The one picture that has left an indelible scar on my heart is an unlikely photograph that my colleague Eddie Keating took of an elegant tea set he came upon in a vacated apartment near ground zero. The matching teapots, cups, and sugar bowl, perhaps set for breakfast on that achingly clear September morning, were covered with a skintight layer of dust the color of dried bones.

That ghostly tableau has stuck with me in the years since I first saw it, not because it elicits horror or dredges up anger, but because it so strikingly symbolizes the way the event and its aftermath have clung to so many people far beyond the grim arenas of terrorism, war, and the doomed World Trade Center itself. The fancy china had no direct connection to the events of that day before the first plane struck. And yet it had been enveloped in a supple coating of death and destruction that transformed it from a treasured implement of daily life to an artifact of a moment of death. The dust infiltrated thousands of offices and apartments in the same way. It was carried back to thousands more homes by first responders, construction workers, and volunteers who helped in the days and weeks after the attack—at first to find survivors, then sadly to recover the remains of

victims and clean up the site to show the terrorists, and the world, that the great city had been hurt but not humbled. It turned New York into a city of dust.

That dust has clung to the city just as surely as it coated the tea set, transforming New York. What happened after the attack is a uniquely American tragedy, triggered by the same virtues of generosity and care that have come to be most associated with the American character. It took only seven days for Wall Street to limp back to business, showing the terrorists that their violence had not undone America. That was the essential message. There was no time for the great city to dwell on what the long-term impact of the dust might be, or even to acknowledge that there could be a lingering danger. The failure to reopen Wall Street quickly would have been a certain disaster. A distant threat that the dust might have poisoned the air and made part of the city unlivable was then not only uncertain, it was unacceptable.

So the ground was set for a tug-of-war between truth and exaggeration, between alarmism and deception, between personal safety and political expediency that turned the worst environmental disaster in New York City history into a test of our science, our laws, our precepts of governance, and even our traditional understanding of the common good. In essence, it became a test of ourselves. Although the attack exposed mortal flaws in the nation's ability to protect itself from terrorists who hoped to die in the attack, reopening Wall Street proved that America had not been defeated. But the very success of that effort, and the quick work that was made of the cleanup and recovery that followed, was laced with tragedy. In ways that would become apparent only over time, our handling of the aftermath of the attack revealed that this nation was not prepared to protect itself from itself.

The problems that arose after 9/11 have been presented as a deliberate attempt by the Bush administration, as well as the city, to cover up the danger, a vast conspiracy to put profit ahead of people's health. But it wasn't that. Many bad decisions clearly were made, but there was no venality, nor was there a conspiracy to hide the enormity of what happened, if that were even possible. Rather, a long sequence of individual decisions—some made in haste, some made with arrogance—favored the recovery of the city over the recovery of its people.

In response to this catastrophe, the men and women of science and medicine tried against enormous odds to piece together a compassionate response and to provide answers for those who desperately needed to know what had happened to them and what they could expect in the future. The word *hero* was thrown around freely, at times used when and where it was not warranted. There were genuine heroes and villains, but they did not confront each other in the direct way this conflict was portrayed once the tabloid press hijacked the disaster. Mayor Rudy Giuliani wasn't the only one who made difficult choices that seemed to put recovery ahead of precaution. Even those who were most experienced at rescue made decisions that ultimately would have tragic consequences. The heroic firefighters who searched for their fallen brethren believed that exposing themselves to hazardous material in order to recover their dead was a justified calculation. In their eyes, the living owed a debt to the dead that made self-interest intolerable.

The defining characteristic of the catastrophe is that from the morning of September 11, the dangers presented by the dust and ash were clear for everyone to see. Billowing gray dust plumes rampaged through city streets like monsters unleashed from hell. Microscopic dust was transformed into a gruesome invader, attacking the most essential of human needs—the need to breathe. It was inescapable, yet the dust became a metaphor for the blindness that descended on the city, obscuring reality and confounding decisions that would later be regretted.

Although millions of people watched in horror as the buildings disintegrated, the dust itself remained a mystery. Even with the most advanced science, we do not yet know what the wicked concoction of dust, ash, and toxic materials did when it landed deep inside the heaving lungs of responders. We don't know how it short-circuited their immune systems or toyed with their genes. And we won't know for years if it combined with other poisons to speed up or exacerbate carcinogenic attacks on the bodies of people who were coated with it, just as the tea set was coated. However, we do know that the doubts sown in the very earliest days have been long lasting. What might have been a sentinel case of emergency response that raised an entire nation from its knees instead became an endless cycle of bickering, mistrust, sickness, and uncertainty as officials tried to deflect blame, responders became crusaders for themselves, lawyers sought to make

courtroom history, and emotions that had never before been felt rose to the surface. A wounded city became a diseased city that often refused to recognize its own disabilities.

Now, long after most of the dust itself has been cleared away, many individual stories of true courage and heroism burn through this haze of doubt. There has been no end to the searing accounts of men and women who truly acted like heroes only to be laid low by diseases they cannot explain. There have been stirring examples of men and women of science who have refused to allow politics or public opinion to shade their work, and who have toiled against great odds and in the most challenging of circumstances to continue to provide care in the screening and treatment their patients needed. Heroes have abounded.

Unfortunately, the combination of our darkest traits and our most noble ones made the story of the city of dust more compelling than the truth could justify, and some have succumbed to the temptation to bend the truth to serve their needs. It will take years for the air to clear, if it ever does.

Certainty, in principle and in practice, itself became a victim. The doubters initially used principles of certitude to challenge the notion that the dust made people sick. By denying any danger in the early weeks and months after 9/11, New York City and Washington hesitated to take steps that could have reliably assessed the safety of workers and residents. By not being clear about the risks, the federal and municipal governments—in what has been called a conspiracy of purpose—sacrificed a degree of safety for the quick recovery of Wall Street. Then, by staking out a high moral ground that made it difficult to question survivors' symptoms, advocates made it easier for abuses to take place.

For four years, I covered the environmental and health consequences of ground zero for *The New York Times*. Many of my articles appeared on the front page of *The Times* and were reprinted around the world. I got to know many of the most important people involved, from the earliest attempts to identify the contents of the dust, up to the historic mass litigation that brought thousands of responders to court charging New York City with negligence. At every turn, I encountered people on both extremes of the issue—those who refused to believe that the dust had caused anyone to become sick, and those who refused to accept that the dust was not going to kill

everyone it touched. When the head of the federal Environmental Protection Agency said the air was safe to breathe, I, like so many New Yorkers, was relieved because, at that time, in the days just after the attacks, it seemed impossible to have processed more bad news. I believed because I wanted to believe. Later, as I investigated what had happened, I came to view things differently.

The city of New York at one point estimated that more than 500,000 people may have been affected by the dust in some way.[1] In addition, thousands of people from across the country came to New York at that tragic time to work on the pile. Millions watched the towers fall and sympathized with those who were injured while doing their jobs. Under most circumstances, American society celebrates the efforts of those who respond to emergencies. In New York, some of those people have been all but forgotten. The painfully slow physical rebuilding of ground zero receives far more attention than does the health of those who responded to the disaster. Even as the ranks of the sick grow, they fade farther into the background. And not just the responders were touched by the dust. Residents, workers, scientists, doctors, lawyers, and politicians all felt the dust in some way. This story of the victims of the aftermath of 9/11, told through the personal experiences of the individuals whose lives have never been the same since that day, represents an overlooked chapter of one of the most extraordinary events of our time.

The scientific, medical, political, and legal scope of the disaster has never been looked at in this comprehensive way. Because of the massive litigation against the city, many of the individuals most intimately involved in the cleanup and its aftermath have declined to speak out publicly, leaving their court testimony to speak for them. Everything about the disaster is monumental, except for the dust itself. But only when the small decisions and the individual acts of arrogance, ignorance, and courage are examined will a telling sense of the tragedy come through. In the end, it is a story of fear and a story of hope. The people of the city, like the city itself, were laid low but were not broken. And we, as a society, will not be prepared to handle the next disaster unless we fully understand what we did right—and wrong—the last time.

Endnotes

[1]"Assessing the Health Impacts of 9-11," Report of the World Trade Center Health Panel, February 13, 2007: 50.

1

All that we hold dear

Stowed among the beakers and boxes in the cold room of the Central New Jersey lab are several jars filled with elemental material that, if the need arose, could be categorized as catastrophe. The jars—standard chem-lab bottles in amber or clear glass—are labeled only with the dates September 16 and September 17. Those are the days in 2001 when Dr. Paul J. Lioy, a leading scientist at New Jersey's Environmental & Occupational Health Sciences Institute, made his way to New York City to sample fallout from the most devastating attack on American soil and the worst environmental disaster in the city's history. If the terrible calamity of the destruction of the World Trade Center could be reduced to its essence and bottled, this is what it would look like. Held at a constant 39°F since 2001, the dust now looks so benign. But at its moment of creation, it roared out of the base of the collapsing towers with uncontrolled fury. Tens of thousands of people touched it, breathed it in, swallowed it, rubbed it out of their eyes, wiped it off their clothes, and tried to brush it off their carpets and drapes, their sofas and teacups, even the teddy bears that their children hugged to sleep at night. Breathing is the most elemental yet essential part of life. Our lungs are especially sensitive to contaminants because they come in direct contact with the environment, as if the body were turned inside out. Lioy was determined to find out what that dust was made of and how dangerous it might be.

When he arrived at the confusion of Lower Manhattan early on September 16, a pretty Sunday morning tainted by the inescapable sense of dread, Lioy already had an inkling of what he was going to find. As each 110-story paragon of modern architecture and unbridled capitalism had disassembled in ten transfixing, confounding seconds, he had been at the quirky 120-year-old Victorian home that he

and his wife, Jeanie, lovingly restored in suburban Cranford, New Jersey, watching spellbound on TV. With his years of experience studying environmental contamination, Lioy was certain the doomed buildings contained a long list of dangerous chemicals and harmful elements that would be blown far and wide by even the gentlest breeze. He also was quite familiar with the complicated grid of Lower Manhattan that had been blanketed by the dust. He'd grown up across the Hudson from New York and had watched the towers being built. Lioy's spine had stiffened as the television screen filled with images of first one and then, 29 minutes later, a second angry thunderhead of dust roaring through the streets like a bloated tornado, blotting out the sun while engulfing everything—and everyone—in its path.

In the world of environmental health science, what looks bad often ends up being bad for people unlucky enough to live or work around the suspected hazard. That's the easy part of the science, which has existed only since the world became sensitive to environmental issues in the 1970s. The hard part is getting anyone to do anything to eliminate the hazards, or even control them. In the past, factories, shipyards, mines, and the towns around them were routinely contaminated by industrial processes, but little or nothing was done to correct things. People got sick. Many died. Even when a link between working conditions and disease was suspected, few thought anything could be changed. Fewer still were willing to do what it took to make a difference.

Environmental health had not always been Lioy's passion. He had never worked in a factory, and big industry was not a part of his family background. But it was a part of the environment in which he was raised. His father, Nicholas, an Italian immigrant, was part owner of a building in the gray industrial town of Passaic that housed a combination delicatessen and liquor store. As a teenager, Paul often worked in the deli and came to prefer being there—or playing sandlot baseball—to wasting time in the classroom. He was an indifferent student, too smart for school, too lazy or distracted to strike out on his own. His report card was regularly marked "L.A." in behavior—it stood for "lousy attitude."

But then Lioy discovered science, particularly chemistry. More important, he found out that he was good at it. He saw a problem and was challenged by the mechanics of trying to figure out the answer. And the beauty of the answers, the intricate structures of the physical world and the way elements stacked atop one another, linked in curious ways according to intractable rules, intrigued him. He studied physics and applied mathematics, and in 1975 earned his PhD in environmental science at Rutgers. One of his first jobs after graduating was a safe bureaucratic one as an engineer with the Interstate Sanitation Commission that served New York and New Jersey. One of the first projects he was thrown into there was testing a theory advanced by a colleague that ozone in the atmosphere was not produced locally, but was being transported in the air from Midwestern states. Elaborate testing gear was set up on the highest spots around, including the roof of the recently completed World Trade Center. Lioy collected and analyzed the data, eventually coming up with an answer (much of the ozone turned out not to be produced locally, but came from faraway states).

Thirty years later, Lioy was sent back to the trade center by the National Institute of Environmental Health Sciences, an arm of the federal Department of Health and Human Services and the Centers for Disease Control and Prevention. In the fear and confusion of those first days after the planes smashed into the towers, officials at the institute ignored pronouncements by Mayor Rudy Giuliani and the Environmental Protection Agency about conditions in Lower Manhattan. They were thinking about the fallout and the potential danger it represented for the people who lived and worked there, including the rapidly expanding horde of workers scraping through the top layer of the monstrous debris pile for survivors. As deputy director of the environmental institute in New Jersey (which is sponsored jointly by Rutgers and the University of Medicine and Dentistry of New Jersey), a member of the faculty at the Robert Wood Johnson Medical School, and a nationally recognized expert on air exposure, Lioy was a natural choice to lead the investigation. Lioy had excused Giuliani's optimistic outlook about the dust as political necessity, but it struck him as strange that Christie Whitman, the head of the Environmental Protection Agency and former Republican governor of New Jersey, had sounded no warning about any contaminants

other than asbestos. Just two days after the attack, Whitman's agency stated that monitoring and sampling for asbestos was "very reassuring about potential exposure of rescue crews and the public to environmental contaminants."[1]

For the firefighters and police officers working on the pile; for the news cameramen breathing in noxious gases as they flew over the superhot debris in helicopters; for the first ironworkers who scrambled over the still-smoking mound to begin the massive job of removing more than 1.5 million tons of mangled steel; and for the volunteers, office workers, and residents who all gulped the tainted air into their frightened lungs, there would be only speculation, not hard scientific facts, about what they had actually been exposed to in those first hours and days after the buildings fell.

Lioy left home before sunrise that Sunday morning, steering his black Lincoln Mark VIII up the Garden State Parkway toward the George Washington Bridge. It was hardly an emergency vehicle, or even a sensible one for such a mission. The only outward sign that this wasn't just a weekend drive was the copy of an American flag from a local newspaper that Lioy had taped to his back window. In those first hyper-patriotic days after the attacks, so many people felt the urge to fly the flag that supplies ran out. Newspapers printed their own. Lioy's aging Lincoln wasn't the only car to have sprouted one.

That weekend, the bridge was the only way to get a private car like Lioy's across the Hudson River from New Jersey to the city. The Lincoln and Holland tunnels both had been closed to most traffic since the 11th, and all the ferries and trains into the city had been cancelled. On his way north, Lioy stopped to pick up a colleague, Dr. Clifford Weisel, who was deputy director of Rutgers' exposure science division. Once over the bridge, they headed downtown to Canal Street, the edge of the restricted zone. There they steered east, hoping to find a way past the police barriers and into the hot zone. The closer they got, the more chaotic everything became. Police were out in force. Dazed residents wandered around, looking for a way into or out of the restricted zone. Normal routines were disrupted; the unexpected suddenly became unexceptional. Finally, Lioy pulled over to a police barricade. He showed his Rutgers ID and took out the letter he had received from the National Institute asking him to investigate

conditions at the site. With his voice of calm reason, Lioy explained his mission, then held his breath as the duty cop turned a suspicious eye toward the Lincoln. The big black coupe with the flag in the back window must have given the policeman pause, but he waved them in.

Lioy drove slowly through the familiar streets that now looked like a scene from *The Twilight Zone.* Most people had been evacuated, and nothing was moving but emergency vehicles. Cruising the abandoned streets in the Mark VIII might have seemed theatrical, even farcical, but Lioy wasn't thinking about that. From the moment he had watched the towers fall, he had been at turns angry and confused. He recognized that he was reacting emotionally, seeing things as an American who had benefited greatly from the opportunity that the nation offered and that the terrorists deplored, not as the dispassionate scientist he was trained to be. The days since that awful Tuesday morning had been interminable. Everyone who had watched the towers come apart wanted to be able to do something in response. Now Lioy had his chance to pitch in. Now he could matter.

He parked the car at the edge of the East River near the Manhattan Bridge and walked in from there, knowing that security would get tighter the nearer he and Weisel got to the debris pile. They had packed the trunk with essentials—they did not expect to find electricity for any sophisticated monitoring device. Besides, they figured that carrying around anything that looked technical might seem suspicious and get them detained, or worse. All they brought with them were notebook-sized sample bags, labels, plastic Fisher Scientific shovels, and a small camera.

It didn't take long to find what they had come for. They walked less than five minutes before they saw a light blue Chevrolet Lumina sedan parked near a cyclone fence. It clearly hadn't been moved or touched since 9/11, and an overhanging tree had shielded it from the rain on September 14. The car was about four-tenths of a mile east of ground zero, in the path of the initial dust plume as it blew over the East River into Brooklyn on the morning of the attacks. The windshield was blanketed with a thick layer, 4 to 6 inches deep, of light gray dust; the car looked like it had been left untouched after a snowstorm. With just one swipe of the Fisher shovel, Lioy filled a sample bag with nearly a pound of material. He was surprised at how light and fluffy it seemed, given its origin. He didn't yet know what the

dust contained, but he knew that it wasn't merely dust. It should have been classified as remains, the essence of bustling commerce and life itself—thousands of snuffed-out personal lives. In seconds, it all had been reduced to this most elemental form. He marked the sample bag with the time, 8:20 a.m., and the place, Cherry Street in Lower Manhattan. The date was September 16.

After sealing the first sample bag, Lioy and Weisel pressed on. A few yards away, they found more undisturbed dust, which they also bagged and recorded. They then turned back to the car and loaded the samples in the trunk without getting close enough to see ground zero for themselves. Lioy later regretted that decision and wished he had ventured into the inner circle of hell that morning. But he was a scientist, and his mission—to collect dust samples—was accomplished.

He also knew that he would be returning the next day, September 17, when Wall Street was scheduled to reopen. He had a second assignment, this one from the Port Authority of New York and New Jersey, the large bi-state agency that had built the trade center and owned the ground on which it stood. The Port Authority had asked Lioy's colleague Mark Robson to pull together a team to do an initial analysis of the environment at the 16-acre site. This time, Lioy left the Lincoln at home and drove up in a rented van with four other scientists.

With Port Authority officials escorting them, the Rutgers team easily crossed the security barriers at Canal Street and entered the restricted zone, which extended from the destroyed trade center to a ring of commercial and residential buildings that had also been damaged, some severely, in the attack. The scientists were brought to a prep station, where each was given a hard hat, white haz-mat overalls, boots, gloves, and a half-face respirator. They spent much of the rest of the day at the heart of ground zero, getting close enough to feel the infernos beneath the debris. The air around the pile was the most contaminated in the city; Lioy and the others wore their respirator masks and were puzzled to see firefighters and construction workers in the same area without theirs. As the group walked along Cortlandt Street, one block east of the trade center's foundations, Lioy grabbed another sample from a protected ledge. Because the dust did not appear to have been diluted by rain, he figured it could reveal what

had been in the air in those primal moments just after the towers came down.

At the time Lioy began his investigation, the dust was not considered a priority. With Wall Street reopening and the reeling nation trying to get back on its feet, most people were desperate to hear some positive news. And while most took nervous comfort in official pronouncements that the air seemed safe, men like Lioy knew from experience that heavy exposure to such a broad range of contaminants would likely harm the respiratory systems of the men and women who worked there. As someone who had already spent years studying environmental exposures, Lioy was aware that the twin towers, built in the early 1970s, contained tons of asbestos fireproofing that had probably been ripped from the steel beams it was intended to protect. Once loose, the asbestos fibers had spread over Lower Manhattan in the towering dust plume.

"The first order of business was to test for asbestos, but in retrospect, I think it was a mistake," Lioy recalled. "We had a situation where people swallowed gobs and gobs of this stuff. We should have been thinking about ways to characterize it so we could look for acute respiratory disease"—that is, the kinds of reactions that would befall responders within days, not the decades that asbestos can take to do its work. But since asbestos was the hazard that every New Yorker knew about, "at that moment, people just grabbed for asbestos."

Within days of the attacks, nearly all of the city's firefighters, and many other men and women working on the pile, started to cough. Some of them took time away from the desperate search to see their own doctors and complain that, since 9/11, they couldn't stop coughing and had not felt themselves. Most kept searching.

Millions had watched New York's tallest buildings disintegrate, and then, from different angles and perspectives shown on television, they saw them come apart again and again in the days following the attacks. What people didn't know then was what engineers subsequently determined about exactly what happened to bring down the towers that had once seemed indestructible. The jets had smashed into each building at around 500 miles per hour, severing steel columns designed to work together to hold up the colossal structures.

The remaining columns were strong enough to support the weight of the floors above for a short time after the impacts. But as fires fueled by the thousands of gallons of jet fuel raged, the high-strength steel began to weaken and eventually buckle on the floors nearest the impact zone. Stirrups holding the lightweight floor trusses to the exterior skeleton were deformed by the heat and soon pulled apart. The entire block of upper floors above the area where the planes had smashed into the buildings twisted almost imperceptibly, then tilted and collapsed with tremendous force, as though one building were dropped on top of another. What happened next was unprecedented. Engineers who studied the collapse extensively believe the first collapsing floor traveled the 3.7-meter distance from ceiling to floor in 0.87 seconds. Subsequent floors fell even faster,. The ocean of air in the building was compressed by the collapsing floors and had nowhere else to go but downward, then out. The dust cloud unleashed by the destruction was powerful enough to blow responders who weren't killed immediately right off their feet. The collapses poured an estimated 100,000 micrograms of particles into every cubic meter of air,[2] a whirlwind of dust so dense that it nearly solidified the air and turned it into a blinding black curtain for several minutes. Years later, when workmen undertook the laborious task of tearing down the badly damaged Deutsche Bank Building on Liberty Street, at the southern end of ground zero, they found that the pulverized construction material had been blown into the building with such force that it raced through the elevator shafts and then blew out through the narrow spaces around the closed doors on each floor, leaving halos of dust.

Although Americans were deluged with the sobering images of destruction, little was known with certainty about the composition of the dust and the effect it might have on those who were breathing it. Even less was known about the extremely toxic smoke and gases rising from the burning pile in those first days. No air monitors capable of capturing the toxic emissions were functioning, nor could they be brought to Lower Manhattan quickly enough to record the crucial data.

Common sense would dictate that there was danger. Common sense would say that there had to be asbestos in the dust because the trade center was one of the last buildings in New York to have asbestos fireproofing. Common sense would make it clear that

anyone working on or near the pile would be exposed to an immense amount of dust and other health hazards. But emotions ruled those days, not common sense, and it was widely accepted that wearing a dust mask when thousands of victims could have been lying beneath the rubble was not only unnecessary, it was unpatriotic.

Lioy did not wear a dust mask when he collected his first samples. But he did have one on the following day when he participated in the Port Authority task force. Still, even he didn't keep the respirator on all day—it was just too hot, too uncomfortable and too difficult to communicate while wearing it. He wore it religiously anywhere near the pile, even though few of the firefighters and responders did so. For the rest of the time, it was just hanging around his neck.

For days after he returned to the laboratories at Rutgers' Piscataway campus, those days stretching into weeks and months and, eventually, years, Lioy and his colleagues delved into the intimate makeup of the dust, studying the tiniest particles as they tried to understand this almost unfathomable event. They began by dividing the big plastic bags of dust into smaller samples, putting some in chem-lab jars and keeping the rest in plastic pouches.

The dust was deceptively normal—what it mostly looked like was the inside of a vacuum cleaner bag, fluffy and gray, the color of dirty New York snow. At first the dust had an odd pinkish tint, a blush that was as curious as it was repulsive because it suggested blood and human remains. It was probably caused by some chemical reaction, and it did not last long. Eventually, the dust took on the more neutral color of dry bone. When Lioy and his colleagues put the dust under a scanning electron microscope or subjected it to polarized light microscopy, it began to reveal some of its secrets. They could see the awesome destructive force of the collapse. It was as though the buildings and everything they contained had been put through a gigantic wood chipper, and then those remnants passed through a coffee grinder, were thrown into a gigantic mortar, and were smashed with a pestle until all that was left were indistinguishable particles, a powder of the past. Lioy theorizes that the initial plume that was released as the towers came crashing to the ground was made up of larger, lighter, material that traveled farther. People caught in the plume described it as being swallowed by night.

Much of the dust was composed of cement particles, the minute remnants of the towers' 110 floors—each the size of a football field and 4 inches thick. In seconds, the hardened concrete had been ground into bits smaller than any controlled demolition ever created. Because of the way the floors had crashed on top of each other in rapid succession, the concrete had literally been pulverized. When the scientists subjected it to chemical analysis, they found that the dust had a surprisingly high pH value because of the cement dust, which made it very alkaline and caustic, significantly increasing its ability to harm the delicate nasal passages and throats of workers on the pile. Cement is ubiquitous in cities, but its standard form is solid. After the twin towers came apart, an extraordinary transformation took place. The rock-solid concrete in the towers was turned into windborne specks. The air above and around ground zero was literally filled with cement. Lioy found that the pH was highest in the coarse particles, which the body generally can filter out before they travel too deeply into the respiratory system. The smaller particles, which can easily slip in and, therefore, are more dangerous, were not so caustic because acid particles in the smoke, with their low pH values, acted to neutralize them. Two researchers at New York University, George Thurston and Lung Chi Chen, came to a similar conclusion about different pH values for coarse and fine particles after analyzing dust samples that had been collected around ground zero. They predicted that health effects caused by the dust would be severe in the short run because the dust was so caustic, but that the body's natural defenses would trap most of the material before it could reach deeply into the lungs, minimizing long-term impacts. Their thesis would be severely tested in the coming months.

To determine how irritating the dust was, Stephen H. Gavett, a scientist at the EPA's National Health and Environmental Effects Research Laboratory in North Carolina, exposed mice to it.[3] Gavett isolated the fine particles of less than 2.5 micrometers in the dust and blew them into the lungs of the mice at high concentrations, equivalent to what might have been in the air right after the towers came down. The dust caused mild to moderate lung inflammation, but importantly, it left the mice hypersensitive to things that could trigger asthmalike restrictions in the lungs. For most people with the same

level of sensitivity, cold air and cigarette smoke can trigger an asthmatic attack. Lioy worked with scientists at the National Toxicology Program on a test to replicate the effects of the dust, exposing lab animals to both fine and large particles. They came up with similar results that persisted in the lab animals somewhat longer than they had in the EPA study. But the scientific journal they sent the results to found fault with the study, and it was never published. The experience showed Lioy that national health authorities might not be as interested in the fallout from 9/11 as he was. Even so, it was becoming increasingly clear to him that ground zero dust did not conform to the typical pattern with which aerosols move into and out of human lungs. The dust was full of surprises.

Lioy first presented some of his findings to residents of Lower Manhattan on October 18, 2001, at a meeting on NYU's Washington Square campus that was organized by the scientific community. But the data on the caustic nature of the dust was largely overlooked because the hundreds of residents of Lower Manhattan who attended the meeting were fixated on other elements that seemed scarier—namely, lead and asbestos. Mixed in with the caustic particles of cement were the asbestos fibers that Lioy had feared he would find.

Asbestos is an incredible mineral, made up of long, thin strands that can withstand heat and pressure. Man has used asbestos for thousands of years, and it became widely industrialized in the latter half of the nineteenth century. Asbestos becomes most dangerous when the fibers break loose and can be breathed in. They can become lodged in lower airways, where they cause irritation that can lead to debilitating diseases like asbestosis, as well as fatal ailments like lung cancer and a rare disease of the thin lining of the lungs called mesothelioma. The asbestos fibers are normally long, tough, and thin—so thin that 100 of them laid side by side are no wider than a single strand of human hair. Once they get inside the lungs, they are almost impossible to get out. Although considered nearly indestructible, the asbestos fibers in the trade center dust had broken into smaller pieces because of the force of the collapse. Some had attached to fibrous mats of other elements and compounds, making them even more insidious.

The actual amount of asbestos in two of Lioy's dust samples was relatively small—.8 percent chrysotile asbestos—but still significant. The dust he had scooped up on Market Street contained 3 percent asbestos. Even small amounts can cause lasting damage after many years, but asbestos could not account for the cough workers had started experiencing almost immediately.

Lioy, who had investigated toxic exposures for over 30 years, had never seen anything like the trade center dust. Neither had anyone else. It contained an unprecedented variety of materials, a tragic mixture whose toxicity was yet unknown. In time, he and his colleagues identified more than 150 different elements and compounds in the dust. They found common construction debris that included particles of plaster, glass, synthetic foam, vermiculite, and charred wood. They identified dead skin cells, the type typically found in household or office dust. They also found plenty of exotic elements, including titanium, from the white paint used in the towers' offices. Most worrisome were the benzene, lead, and dioxin that were released when miles of PVC pipe in the twin towers went up in flames. Lioy classified the ground zero disaster as a "dual nature event," the first phase being the collapse of both towers and the second the fires that raged at over 1,000° for days and then smoldered at lower temperatures for months, leading to incomplete combustion that released dangerous soot. Using transmission electron microscopy, the scientists found polycyclic aromatic hydrocarbons and were able to isolate individual fibers of asbestos. When they tested for inorganics, they found gold, lead, and the mercury from thousands of fluorescent light bulbs.

The list would have contained much more than the 150 elements and compounds if the scientists had continued to classify the material that appeared in ever smaller quantities. Had they carried on this work, they would eventually have had to list human DNA from the vaporized victims, although in infinitesimally small amounts (1 in one sextillion, or 10 to the minus 20) because even 3,000 human souls made up only a miniscule percentage of the overall mass of the trade center. The New York City fireman who had shouted "We're breathing dead people" was correct, in a scientific sense. But Lioy knew that even if he had continued to categorize the dust into smaller and smaller amounts that could separate out human DNA, he would not

have come up with enough to link the genetic material to any of the victims, at least not with currently available methods and equipment.

Though the Institute's scientists could not carry their investigation that far, they did find strands of what they easily identified as human hair. Whereas the super-hard concrete of the buildings' floors had been ground to dust, the hairs had survived intact. Lioy was not prepared to subject these remains to DNA analysis, either. He believed the hair probably came from the carpets of the office towers, the accumulated human detritus of 40 years of daily commerce. The hair and cells caught in the carpets could have come from the thousands of victims. Or they could have come from anyone—including him—who had ever worked in the buildings or visited long enough to drop a single strand of hair. Perhaps in decades to come science would be able to reliably match DNA from such samples. But not now.

Even without the genetic stamping, the material in Lioy's lab jars clearly constituted the sum of countless individual lives and the passage of those lives inside the walls of the doomed buildings. The minute particles of gold Lioy found might have started as a wedding band or an earring given as a birthday gift. The tiny strands of black polyester may have come from the back cover of a picture frame that once held the photo of a beloved parent or a childhood friend. And some of the ubiquitous cellulose in the dust may have originated in the desks where men and women whiled away countless hours in their high-rise offices. Or it may have come from the memos those people wrote while they were daydreaming of the beach, or from the pages of the calendars on which they noted the ordinary milestones of daily living—the dentist appointments, birthdays, and special anniversaries that could not be missed.

Lioy spent as much time studying the dust as anyone in the scientific community. His growing intimacy with the material eventually led him to see it not just in scientific terms, but in a humanistic way as well. Those two sides of his personality had been wrestling since September 11, and occasionally the personal side burned through without him being aware. At a 2005 conference, Lioy summed up the tragedy before an audience of students and faculty at Montclair State University in New Jersey. He narrated a short list of the chemicals, minerals, and compounds that had been detected in the dust, making clear that the entire list was extremely long and all-inclusive. Finally,

he abandoned the language of the laboratory all together. "The trade center dust contains everything we hold dear." The words were uncharacteristically emotive for a traditional scientist like Lioy, who hadn't even realized what he'd said until it was brought to his attention. It astonished him to think that he had dropped his professional detachment so fully. But it's clear that those sentiments must have come from a deep emotional well that usually is off-limits in his scientific work.

This time emotion prevailed, at least temporarily.

On the same day that Lioy and Weisel collected their dust samples with shovels and plastic bags, the U.S. Geological Survey (USGS) sent one of its most sophisticated imaging spectrometers over ground zero.[4] Mounted on a Canadian-built de Havilland Twin Otter airplane, the Airborne Visible/Infrared Imaging Spectrometer (AVIRIS) is capable of detecting heat and identifying chemical bonds in molecules based on how they absorb infrared light. The spectrum of colors in the resulting images can reveal the presence of different minerals, including asbestos. As the AVIRIS flew over ground zero, it picked up more than three dozen hot spots. Some measured 800°F; a couple were a blistering 1,300°F. (Most were gone or greatly reduced by September 23, when the AVIRIS again flew over the area.) The imaging also picked up trace amounts of what was believed to be asbestos. On Monday, September 17, a two-person USGS ground crew began gathering dust samples. They collected material from 35 different spots within half a mile of ground zero and managed to get much closer to the debris pile than Lioy had on his first expedition. They took two samples from the coating on steel beams that had just been removed from the pile. Two other samples came from indoor spaces that presumably had not been diluted by rain. It took the crew two days to grab everything. All the samples were sent to USGS laboratories in Denver, where they went through a battery of tests. The results were in line with what Lioy's team was finding. Trace amounts of asbestos showed up in most of the outdoor samples. But the material taken from the steel beams confirmed that asbestos that had been used as insulation on at least some portions of the buildings was still there on 9/11. These samples were laden with asbestos fibers—as much as 20 percent chrysotile asbestos, a known carcinogen.

The Denver lab also found that the calcium sulfate in the concrete made the dust highly alkaline. As with Lioy's samples, the USGS discovered pH values as high as 10, which made it as strong as ammonia. The pH of indoor samples that had not been diluted by the September 14 rain were even higher, hovering around 12. At that level, the dust was about as caustic as drain cleaner. This crucial information was posted September 27 on a USGS website that was accessible only to the EPA and other government agencies. Even though Lioy and the NYU researchers had independently come to the same conclusion about the corrosive nature of the dust, many clinicians and ground zero workers didn't find out about it until an out-of-town newspaper reported the results, along with startling headlines, five months later.[5]

At the Institute, Lioy and his colleagues continued their multifaceted investigation. One group studied the dust plumes and created a computer simulation of their movements.[6] Using motion graphics like those on TV weather reports, the physicists showed that the ominous clouds rose on updrafts caused by warm temperatures and then were buffeted by September winds. Over several days, the winds pushed the plume around so that it snaked across the metropolitan region, slashing over Brooklyn, twisting back again over Manhattan north of Canal Street, and then sweeping across the Hudson to New Jersey before blanketing the harbor again. The animation indicated that a broad swathe of the metropolitan area, not just Manhattan's financial district, had been touched by the airborne dust, which eventually settled in those areas as well, although less densely because of the distance from ground zero.

As the energy that carried the plume up and out eventually dissipated, the dust drifted back down to Earth, coming to rest on hundreds of buildings, seeping underneath thousands of windows, sucked into countless air-conditioning ducts, and infiltrating every surface. Much of it would quickly be washed away, mopped up, or swept into the trash. But the tiniest of particles would remain for years and would rise like unwelcome ghosts every time something disturbed them.

Since 2001, Paul Lioy has given away over half of the dust he collected to scientists from all over the world who have asked to study the material. He finally stopped sharing it when he feared that the composition of the dust had changed so much with time that testing would no longer produce reliable results.

Still, requests come in, and Lioy sometimes makes the long walk from his office down the hallway of the Institute, around a corner, and into the cold room.

"Like a police evidence room," he says, pulling open the heavy metal door. The refrigerated chamber, about 12 feet by 12 feet, is lined with five open metal shelves that go from floor to ceiling, front to back. On a shelf on the left side of the room is a pair of ordinary plastic storage bins, clear with blue lids. They are marked "Dr. Lioy's WTC samples—Please do not touch." No one does.

Lioy hauls one bin back to his office. As time has passed, he's moved on to other issues and eventually immersed himself in a huge national children's study with Dr. Philip J. Landrigan of the Mount Sinai Medical Center. But he can never get far from the dust. He has written more than a dozen scientific papers about his investigations into the exposure risks at ground zero, and he is often asked to weigh in on issues involving health and environmental issues related to the disaster. In 2009, the National Society of the Daughters of the American Revolution gave him a patriotism award for his work on 9/11 dust. On a bookcase in his office he keeps the hard hat, respirator, and gloves he wore at ground zero. And on the wall is a photograph he took while he was there. The debris pile looms over several workers who are pitching in with the rescue and recovery operation. One of them wears a respirator mask. One has a mask hanging around his neck. A third doesn't wear any respiratory protection at all. It is a preview of an unfolding disaster.

Since those first bleak days after 9/11, Lioy has confronted the same kind of intricate, many-layered problem that originally drew him into science. How does everything fit together? How does one element affect others? What was there to fear—the dust itself, or the pattern of exposure, or the way the government responded to the disaster, or the responders' own failure to protect themselves? Would emerging fears turn out to be overblown or underestimated? Who

was telling the truth? Who was shading the truth? Could anything be known with certainty?

Lioy was determined to be guided by science, not emotion. He had felt himself slip over from cold analysis to the warm emotions of anger, fear, and awe, and he did not want to be there again. His instruments and graphs would tell the story. He feared that the frenzy over asbestos was overshadowing the dust's more immediate threats. Moreover, no one knew what was in the gasses and smoke that belched from the pile in the first few days of utter chaos. And that worried him, because he believed that all the responders who were exposed to that material immediately after the collapses probably breathed in a dangerous combination of toxins that could interact in ways that might not be clear for decades. People who had been exposed were frightened and wanted answers, and they wanted them right away.

Through it all, Lioy harbored a painful over-riding doubt. He knew better than most that certainty about the real danger of the dust may not come for a long time. Some workers who were exposed to asbestos mixed with the gases from the burning rubble might not become ill until 30 years after they left ground zero. But many are already sick, far sicker than the results of tests of lab animals would have suggested. Something else clearly was going on, but what? Certainty won't come for decades, but if the dust—combined with the gases and smoke—truly was toxic, waiting that long could cost lives. If the threat that the dust could cause cancer and other fatal diseases could not be discounted outright, waiting could cause tremendous pain and endless anguish. Uncertainty and fear could make victims of those who escaped becoming victims on 9/11.

Clearly, there wasn't time to wait, especially not after so many men and women started complaining of respiratory problems they shouldn't have had if the air had truly been safe to breathe. Nor was there an easy explanation for why the workers who were digging in the rubble for remains weren't wearing the masks that would have kept them from being hurt by the air that so obviously was filled with danger. There was a troubling disconnect between what was expected and what was actually happening. Even after the dust plumes had started to dissipate, it was as if the dust continued to cling to the air, blinding reason, obscuring truth, and distorting belief.

Endnotes

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