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## **AC 2011-32: FAMILIARIZING THE UNKNOWN: THREE UNUSUAL ENGINEERING CASES**

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# Familiarizing the Unknown: Three Unusual Engineering Cases

## Introduction

Anyone who has taught engineering ethics is familiar with the litany of disasters typically included in a class: the Challenger space shuttle explosion, the Bhopal gas leak, the Exxon Valdez oil spill, the Hyatt Regency walkways collapse; more recently, the Columbia disaster, the Twin Towers collapse, and the newest entry, the BP Gulf oil leak.

While studying such “big” disasters certainly has its virtues, for the instructor integrating ethics in a technical class, events with a smaller scope might prove more useful. To that end, this paper gives snapshots of three lesser known, but very intriguing, incidents appropriate for an integrative approach: the Donora “death fog,” a weather anomaly that, combined with heavy pollution, resulted in the deaths of at least 20 persons and affected thousands more; the demise of Louisiana’s Lake Peigneur, caused by a math error, when Texaco oil personnel drilled into a salt mine, draining the lake and radically transforming the environment; and the collapse of Seoul’s Sampoong Superstore, which killed more than 500 customers and injured an additional 900.

All three of these incidents were due to engineering error and poor decision-making practices, attributed to a number of factors. This paper describes the events, explores selected engineering problems and ethical issues, and offers suggestions for classroom usage.

## Rationale

Small cases offer several advantages in a classroom setting. First, they save valuable time. High-profile cases such as the Bhopal gas leak are certainly enlightening and worthy of study; however, the complexity of the incident and sheer volume of pertinent information necessitate allocating significant class time, which may be prohibitive for those technical instructors who take an integrated approach. Small cases are much more contained: “By their nature,” Lynch and Klein note, “small cases can never be presented in full ethnographic detail. . . .”<sup>1</sup> “All else equal,” suggests Michael Davis of Illinois Institute of Technology’s Center for the Study of Ethics in the Professions, “the shorter the case, the better.”<sup>2</sup>

Second, small cases allow students to more fully exercise their moral imagination, the ability to examine an ethical problem from multiple perspectives. Even very small cases, remarks David Jonassen, exhibit “myriad perspectives.”<sup>3</sup> Indeed, as Harvard faculty member Kenneth Winston explains, “students are forced to reflect . . . on the environment of decision making.”<sup>4</sup> Doing so allows students to exercise critical thinking and ethical decision-making abilities. Because small cases are so limited, instructors can spend more time focusing on these skill sets, as well as ethical problem identification and moral deliberation.

Finally, a consideration of our students’ career paths indicates that small cases may be more relevant. Engineers, of course, have been involved in high-profile cases, but chances are that our students will probably face ethical challenges of the more mundane, garden variety. Furthermore,

engineering ethicist Michael Pritchard explains that emphasizing the role of engineers in “big” cases may actually be misleading: “While important and instructive, these cases focus on extraordinary rather than ordinary situations facing engineers. Exclusive concentration on such cases may give students a distorted picture of ethical concerns in engineering practice,” as students may assume that engineering ethics simply consists of avoiding such situations.<sup>5</sup> In reality, most of our students will face challenges of lesser significance than whether or not to blow the whistle on corporate wrong-doing.

## **The Cases**

Students can learn a great deal from small, low-profile cases: those that have vanished in the mists of time, have been banished by a type of collective amnesia, or have been deliberately obscured. The three cases detailed below exhibit all of these characteristics and are “small” enough to easily integrate into technical classes.

### *Donora Death Fog*

The week prior to Halloween, 1948, began as usual in the small community of Donora, Pennsylvania, home to 14,000 residents, a number of steel mills, and the giant U.S. Steel Donora Zinc Works. Before week’s end, however, some 20 people would be dead and thousands affected as a result of a temperature inversion that trapped suffocating toxic fumes in the valley for five days before being disseminated by a refreshing rain.

Donora sits on a sharp bend in the Monongahela River, in a narrow valley bordered by the steep 400-foot cliffs of the Alleghany Mountains. It is a natural bowl that regularly collects fog, pollution from river and rail traffic, and noxious emissions from the steel mills. Residents of Donora and the tiny town of Webster, located across the river, lived in a soup of industrial pollution that was accepted as a fact of life,<sup>6</sup> the air redolent with the distinct scent of sulphur.

Western Pennsylvania has a long history of significant smoke pollution; nicknamed “The Smoky City,”<sup>7</sup> Pittsburgh and its surroundings have hosted the steel industry ever since Andrew Carnegie founded his first mill in 1875.<sup>8</sup> Located just 30 miles from Pittsburgh, Donora was the recipient of all pollution headed downriver, in addition to mill emissions in the town itself. In fact, Donora was founded to support the steel industry, and the riverfront was obscured by steel and rod mills, an acid factory, the giant American Steel and Wire factory, and the behemoth 40-acre Zinc Works, the world’s largest smelter.<sup>9</sup> Built in 1915, it ran 24 hours a day<sup>11</sup> and was fed by coal, transported by train or barge. By 1948, the plant was approaching obsolescence and had never updated its technology,<sup>10</sup> spewing forth a toxic brew of sulphuric acid, fluorine, carbon monoxide/dioxide, and cadmium, in addition to heavy metals dust and a variety of other gases.<sup>11</sup>

Mill emissions denuded hills of vegetation, skinned paint off of houses, pitted metal, and killed livestock and poultry.<sup>12</sup> Residents noticed that household furnishings, such as curtains, were eaten as if by acid,<sup>13</sup> and the cemetery grounds were so barren that a heavy rain would even expose the coffins.<sup>14</sup> Clothing was especially susceptible to discoloration; Scott Beveridge, a journalist who was raised in post-fog Webster, recalls his mother’s experience: “The slip under

my mother's dress would go from white to charcoal gray by the time she walked across the Donora-Webster Bridge to her job as an office clerk in 1948."<sup>15</sup>

By 1917, just two years after the Zinc Works opened, people began feeling the effects, complaining of headaches, nausea, and an inability to breathe,<sup>13</sup> and area residents sued the company in 1918; the court found in favor of the plaintiffs. In the 1920s, local farmers sued again, claiming livestock, poultry, and crop damage.<sup>11</sup>

Despite these obvious signs of environmental degradation and human suffering, the Zinc Works continued to operate, belching forth noxious fumes 24 hours a day, seven days a week, week after week. The plant was vital for the economic well-being of the town's residents, primarily immigrants from Russia, Germany, and Central Europe, all of whom worked for one of the mills dotting the landscape.<sup>6, 17</sup> Indeed, U.S. Steel held an economic stranglehold on the region,<sup>11</sup> and residents tolerated the smoky air because they felt they had to: "Things were tough back then," recalls fog survivor Duane Patterson, "and you knew the mines and the mills were unsafe. But they put bread on the table, bread and butter."<sup>18</sup>

The inversion that spawned what would later be called the Donora "death fog," also dubbed the "death-dealing smog" or the "fluoride gas fog," began on Tuesday, October 26, and continued to Halloween Sunday. On Tuesday and Wednesday, few noticed the different quality of this fog, as residents had become accustomed to breathing foul air and were used to driving midday with car headlights on. By Thursday, however, the air turned yellow and noticeably more viscous. Arnold Hirsh, standing at the corner of Seventh Street and McKean, watched smoke billowing from a train on the railroad tracks below. The plume ascended for six feet and then simply stopped, as if held in place by an invisible barrier.<sup>17</sup> The air, epidemiologist and former Donora resident Devra Davis explains, was "a motionless clot of smoke."<sup>10</sup>

By Friday, wheezing residents began crowding into Donora's hospital, most coughing up blood and some faintly cyanotic. The fog was so dense that high school student Jerome Campa got lost on his way to school: "I stepped off a curb and gave myself a jolt [because he couldn't see the street]. Then when I got to the school, I walked right past it. That's how dense the fog was."<sup>19</sup> The Halloween parade continued as scheduled, but observers could hardly see the participants; they appeared as ghostly specters, fading in and out of view, "just shadows moving through the gloom," recalls former nurse Eileen Loftus.<sup>14</sup> The first victim succumbed that evening: a man who was walking home started coughing violently, sat down on the curb, fell over, and died.<sup>20</sup>

By Saturday, the situation was reaching a crisis. While attendance for the much-touted football game with arch-rival high school Monongahela was standing room only, no one could actually see what was happening on the field, cued to cheer only by referees' whistles; they would yell "kick" to alert the other team. Several footballs were, in fact, lost in the fog. Fireman Bill Schempp recalls, "If you chewed [the air] hard enough, you could swallow it."<sup>21</sup>

And people started dying; the local funeral parlor soon ran out of caskets, and the community center was transformed into a temporary mortuary.<sup>10</sup> Through it all, the Zinc Works continued normal operations. By early Sunday morning, the smelter was finally dead-fired to reduce

emissions.<sup>17</sup> But by then, the death toll had doubled, and thousands were sickened by the fetid air. Mercifully, a rainstorm ended the inversion.

The final toll from five days of lethal fog was 20 dead, all 52-85 years of age with prior respiratory conditions; within the next month, another 50 died.<sup>17</sup> Altogether, nearly half of the town's 14,000 residents were affected. Had the fog continued for another day, analysts speculate, deaths would have numbered in the thousands. Clarence Mills, head of the Department of Experimental Medicine at University of Cincinnati's School of Medicine, declared: "A slightly higher poison concentration in the air or a few hours longer time and the whole community might have been left almost devoid of life."<sup>22</sup>

A week after the fog, business resumed as usual: the mills returned to their operating capacities, although with limited production, and the residents of Donora continued to breathe foul air, albeit a less viscous variety than during the fog. Some community activists demanded action, and the U.S. Public Health Service finally conducted a study consisting of air sampling, interviews with residents, and weather modeling.<sup>11</sup> The PHS issued an inconclusive "preliminary report," which became the final report, noting that "no single substance" was responsible for the adverse health effects experienced by Donora residents. Of the 10 recommendations offered, nine dealt with reducing emissions, although the report does not indicate target percentages; the final recommendation called for the implementation of "a program of weather forecasts to alert the community of impending adverse conditions. . . ."<sup>23</sup> Overall, the report was anti-climactic and resolved nothing.

U.S. Steel, in the meantime, had been busy declaring the problem an "Act of God"<sup>11</sup> and refusing to take any responsibility for the filth its mills poured into the air. Instead, the company blamed the curious topography of the area that trapped pollution in the valley. After a number of lawsuits, the company settled for a paltry \$250,000 (about \$2.2 million in 2009 dollars), to be split, after deducting legal expenses, among the 80 families that filed suit.<sup>18</sup> U.S. Steel closed the Zinc Works in 1957 due to a number of factors, including "environmental degradation and negative effects on human health . . . new laws limiting plant emissions, and potential new legislation. . . ."<sup>24</sup> By 1967, all of the remaining mills closed, and the population of Donora has plummeted to 5,000.<sup>17</sup>

### *Lake Peigneur*

November 19, 1980, was a beautiful day at Lake Peigneur in southern Louisiana. Located near New Iberia, the lake boasted fine fishing in a bucolic setting; Jefferson Island offered a peaceful stroll through Live Oak Gardens, a botanical reserve,<sup>25</sup> and a tour through an historic home built in 1870 by noted American actor, Joseph Jefferson.<sup>26</sup> By November 20, all of that would be history, sucked down a swirling vortex created when a Texaco drilling rig punched through a salt dome into a mine located beneath the lake.

Often described as "the world's weirdest engineering disaster,"<sup>27</sup> the disappearance of Lake Peigneur was attributed to a miscalculation. Texaco hired Wilson Brothers Corporation to drill test holes in the lake to locate oil reserves.<sup>28</sup> Early in the morning of November 20, at a depth of

1,228 feet, the drill bit got stuck and workers were unable to free it. Two hours later, the \$5 million rig began to tilt and sink into the lake.<sup>29</sup> While workers managed to escape unharmed, they watched in surprise as the entire rig disappeared into the shallow lake.<sup>30</sup> According to Michael Richard, then manager of Live Oak Gardens, “it seems that there was an engineering error in the location of the Texaco well. They used a form of triangulation for determining the location and one of the points they used . . . was an error.”<sup>25</sup> It was a big error: the rig was 400 feet off target.

As more water poured through the hole punched by the drilling rig, it dissolved the salt below and eroded the salt pillars supporting the dome; according to geologist Branford Hanson, “Water flowing through salt tends to dissolve the salt. As you increase the volume of water, you increase the volume of salt that can be dissolved.”<sup>5</sup> Miners working deep below the lake surface noticed water creeping towards them and sounded the evacuation signal. They convened at the 1,300 level and nervously waited for the eight-person elevator to creep down, standing in water that was ankle-deep. Within an hour, all 55 men were safely evacuated.<sup>30</sup>

On the lake, Leonce Viator and his nephew were fishing for catfish when they realized the boat was being pulled towards “an eye in the ground,”<sup>25</sup> a whirlpool that was increasing in size as they watched. It swallowed two barges before the fishermen were able to escape. Those on the shore gazed in amazement as everything on and by the lake was swallowed. “It looked like a lot of toys in a draining bathtub. They’d whip around, bobbing up and down, and then bloop, they’d disappear,” noted one observer.<sup>30</sup>

The ravenous whirlpool ate everything, including historic 150-foot pecan trees, docks, and eventually Jefferson Island itself. An expulsion of air as the mine was flooding blew a spectacular 400-foot geyser into the air.<sup>28</sup> In a mere three hours, some 3.5 billion gallons of water disappeared down the quarter-mile, 40-acre vortex, flooding the tunnels of the Diamond Crystal Salt Mine beneath.<sup>29, 31</sup> The pull was so strong that it affected the Delcambre Canal that flowed into the Gulf of Mexico and actually reversed the flow, ingesting 11 barges. Because the salt dome had collapsed, the lake level was lower, and the canal transformed into a 150-foot waterfall, briefly Louisiana’s highest, cascading into the swirling waters.<sup>27</sup>

It took two days for the lake to stabilize, disgorging nine of the lost barges “like corks in a bathtub.”<sup>25</sup> While there was no loss of life, the once pastoral landscape was transformed into a muddy wasteland, property was lost, nearly 300 miners were instantly unemployed, and the shallow lake was now one of the deepest in the world, extending some 1,300 feet.<sup>32</sup>

A year of legal wrangling ensued: the Diamond Crystal Salt Company filed a \$219 million lawsuit against Texaco and the State of Louisiana,<sup>33</sup> Texaco countersued, and the Live Oak Gardens filed suit for loss of property. Claims were eventually settled out of court, with Texaco and Wilson Brothers paying \$32 million to Diamond Crystal; Live Oak Gardens received \$12.8 million.<sup>34</sup>

## *Sampoong Superstore*

The Sampoong department store sat in the heart of Seoul's commercial district, a five-story structure painted bright pink, with an additional four basement levels. With roughly 40,000 shoppers daily, the store teemed with activity, an economic boon for its owners. On June 29, 1995, however, the building collapsed, pancaking downwards. More than 500 shoppers were killed and hundreds more injured. The incident has been characterized as South Korea's worst peacetime disaster and one of the largest structural disasters in the world.<sup>35</sup>

In 1987, Woosung Construction, one of Korea's largest construction firms, broke ground at the site of a former landfill to commence work on what was originally intended to be an office complex.<sup>36</sup> But after the foundation was poured and the basement levels completed, owner Lee Joon changed his mind. Instead of an office building, the structure would become a massive upscale shopping mall, offering customers a variety of goods ranging from groceries to expensive designer clothing. The new vision included the addition of a fifth floor roller-skating rink.<sup>36</sup>

Woosung engineers expressed doubt about the changes and refused to comply. Rather than change his vision, Lee simply fired the engineers and used his own firm, Sampoong Construction, to complete the building to his satisfaction. Lee had been involved in construction for more than two decades, initially doing work for the military and then branching out to commercial real estate ventures.<sup>37</sup>

In the two years of construction, several other changes occurred that affected the building's structural integrity by adding hundreds of tons of weight to the upper floor. The proposed skating rink became eight restaurants, requiring a three-foot-deep floor heating slab, to accommodate traditional Korean eating style, and heavy refrigeration units.<sup>36</sup> Restaurateurs, eager to improve the aesthetic appeal of their eateries, added "an artificial pond with a life-size watermill."<sup>35</sup> Overall, the design of the fifth floor was inconsistent with the rest of the building, with more windows and irregularly spaced support columns not located atop the columns on lower floors. Three 15-ton air-conditioning units were placed on the roof, rather than at ground level; when full of water for the hot summers, their weight doubled. To accommodate the extra weight, 10-inch concrete floor slabs were added. When area residents complained about excessive noise from the units, Lee simply had them pushed to the opposite side of the roof, causing large cracks that indicated a degree of structural damage.<sup>36, 38</sup> Altogether, these alterations to the fifth floor resulted in the building's dead load being 35% more than the designed load.<sup>37, 39</sup>

The loading problem was exacerbated by other building elements, as revealed by post-disaster investigations: the concrete for the flat-slab construction, while weak, was not substandard, but it was missing about half of the rebar required by building codes; columns ed in design plans as 31-35" in diameter were actually 24"; the span between slabs was too large; and tie-ins and connections to the slabs were inadequate.<sup>36</sup>

On the lower floors, the addition of escalators required cutting into some of the support columns, thus weakening the overall structure, and the installation of required fire shutters, to isolate

various parts of the building in case of fire, was accommodated by removing large chunks of supporting columns.<sup>36</sup>

In his zeal to maximize retail space and hence increase profits, Lee had built a structure that violated building codes<sup>35</sup> and compromised the safety of the shopping public. In fact, had no one died in the incident, the list of construction transgressions reads like a comedy of errors.

The structure opened in 1990 and remained upright for five and one-half years, gaining recognition as an elite shopping area<sup>35</sup> and grossing more than \$4 million a week, nearly half a million dollars a day.<sup>40</sup> In the spring and summer of 1995, however, Lee's shoddy construction practices became apparent: in April, cracks appeared in the fifth floor ceiling.<sup>35</sup> Rather than erring on the side of caution, however, and closing the store, Lee simply had them filled and painted over. But on the evening of June 28, the ceiling over one of the restaurants collapsed, prompting the closure of the fifth floor and the movement of expensive goods to the basement.<sup>41</sup>

The next morning, Lee brought in a team of civil engineers to inspect the building; despite the engineering consensus of imminent collapse,<sup>35</sup> management refused to close the store, fearing loss of revenue. By 5 p.m. that evening, fourth floor ceilings began to visibly sink and less than an hour later, a series of sharp cracks reverberated and the building shivered. At 6:05, it collapsed, trapping some 1,500 customers and employees under hundreds of tons of concrete. In 20 seconds,<sup>42</sup> all five stories pancaked into the basement, folding into itself, "as if," said cab driver Park Min-soo, who was stopped for a traffic light in the street outside, "it was being destroyed by a demolition crew, the way you see on television."<sup>36</sup>

Rescue operations began almost immediately, but personnel were faced with enormous challenges in traversing the huge piles of wreckage. Fires broke out, releasing toxic fumes and increasing the danger to both those trapped and the rescuers. Small victories punctuated the efforts: on July 1, 24 cleaning personnel were rescued from a third-floor basement locker room. And 17 days after the collapse, the final survivor, Park Seung-Hyung, a clerk in the children's wear department, emerged from a second-floor basement room.<sup>36</sup>

Post-disaster investigations revealed a number of troubling engineering issues, as well as exposing corruption in public officials. Public anger ran high. During one memorial service, sociologist Yee Jaeyeol describes how "angry relatives of the victims chased down and beat up a government official" who represented the city ward of the Sampoong area.<sup>43</sup> Trials that December resulted in the convictions of Lee and his son, who were sentenced to 10½ and 7 years in prison, respectively. Some 25 other officials received fines and imprisonment as well.<sup>44</sup> Families of disaster victims won a \$330 million damage settlement from the company.<sup>37</sup>

The incident also left indelible scars on the psyches of those injured in the collapse. Korean psychiatrists Lee et al. interviewed 624 of the survivors two years after the event and discovered that 54.2% were still plagued by sleep disturbances, 31.8% had severe headaches, 23.3% expressed increased anger and irritability, and 24.2% experienced "intense distress over reminders."<sup>45</sup> A more recent study in 2005 indicates the prevalence of post-traumatic stress disorder among survivors, particularly in the first three months following the incident.<sup>46</sup>



## Engineering Problems and Ethical Issues

An examination of these cases through an ethics prism reveals another world, one fraught with negligence, indifference to the public welfare, and, in two of the cases, behavior approaching the criminal. Furthermore, when discussing cases such as these that involve corporations, it is important to note that engineering ethics and business ethics become intertwined. While each case individually has myriad ethical issues, the three discussed below are common threads:

### *Questionable Competence*

Each case encompasses a degree of questionable decision-making and engineering incompetence or negligence. In Donora, U.S. Steel engineers underestimated the height of the Zinc Works smokestacks. They needed to be tall enough to help propel the smoke over the steep cliffs surrounding the valley. However, the stacks only extended 150 feet, not nearly high enough to account for the thick volume of smoke produced by the massive coal-burning furnaces. As Devra Davis notes, “Each day the plant burned as much coal as did all the homes in Pittsburgh.”<sup>17</sup> The company also neglected to include smoke filters, which would have provided minimal protection, although toxic emissions would have remained problematic.

Perhaps the worst decision of all for Donora residents was to keep the factories running to capacity during the height of the fog event. Had the plants been dead-fired on Thursday, when air problems became more noticeable, perhaps fewer people would have died. Surely fewer would have been sickened.

While poor decision-making practices compounded the damage in Donora, engineering error was the sole cause of the Lake Peigneur incident. Had the engineers double- or triple-checked their calculations, the incident might not have happened. While this event is not as dramatic as that of Donora, due to no loss of life, the damage to the environment and to historical structures was appreciable. In fact, all that now stands of Joseph Jefferson’s historic mansion is the chimney, jutting out above the lake surface.<sup>25</sup>

While some may view this incident as a simple miscalculation, it underscores the importance of mathematical accuracy in engineering and the necessity of peer review, the same issues that emerged in the investigation of the circumstances behind the Hyatt Regency walkways collapse, albeit on a smaller scale. Moreover, Texaco flatly refused to accept responsibility,<sup>33</sup> suggesting that the maps being used were inaccurate. Max Herbert, a Texaco spokesperson, said, “We don’t know what shafts are down there. If someone had come to us and told us not to drill that well, we would not have drilled.”<sup>47</sup> Such comments beg the question of why Texaco did not verify the proposed drilling site before beginning work.

A lack of engineering competence was also the direct cause of the Sampoong disaster. Unauthorized changes to the designs and a desire for speed in construction resulted in a building that simply could not bear the hundreds of tons of additional weight on the fifth floor, as the forensic analysis of Gardner et al. concludes.<sup>38</sup> And, sadly, this building is representative of late twentieth century construction in Seoul, an example of the “rush-to-modernization” that

characterized the building spree of the 1970s and 1980s.<sup>43</sup> At its height, 10 new skyscrapers a week were appearing on the Seoul skyline.<sup>40</sup> In fact, the report of the investigation team led by a professor of civil and structural engineering, Lan Chung, and a professor of architecture, Oan Chul Choi, both from local universities, spawned a government survey of all major buildings in the city and the conclusions were disturbing: 14% were unsafe and required rebuilding; 84% needed major repairs; and a mere 2% met building standards and considered as safe.<sup>39</sup>

The investigation of the Sampoong disaster also revealed a high level of bribery and corruption among government officials and inspectors; between 1993 and 1995, South Korea was the scene of nine major disasters, including Sampoong.<sup>43</sup> While two were attributed to terrorist acts, the other seven took more than 1,000 lives and cost billions of dollars “due to the convergence of negligence, inexperience, and corruption.”<sup>48</sup> It is clear that Lee Joon bribed at least 25 different public officials and inspectors, and that, under normal circumstances, the department store would not have opened due to egregious building code violations. However, in the construction industry of the 1980s, the abnormal (bribery) became the norm: constructing a building involved liaisons with at least 12 different ministries (for electricity, fire, environmental concerns, etc.), and they often had differing standards. Thus, “to satisfy those conflicting standards, construction companies had to buy off the government officials.”<sup>43</sup> Simply put, the inspectors never really inspected the structure; they simply pocketed the bribes and signed off. And the bribes were substantial, some amounting to \$17,000.<sup>39</sup> Because South Korea is rife with such corruption, Yee concludes that “Koreans are suffering from *routine abnormal accidents*.”<sup>43</sup>

### *Lying/Disclosure*

Lying and lack of disclosure are not uncommon after a major event and result from the responsible parties refusing to accept responsibility for the occurrence. Of the three cases examined, these two issues are most prominent in the Donora incident.

Following the inversion, several professionals stepped forward to publically oppose U.S. Steel’s claim that the incident was due to a weather anomaly. Donora doctor William Rongaus was the first to suggest the widespread effect of the pollution, which the company had downplayed by focusing on the age and health status of the victims, and fluoride expert Philip Sadtler, who was convinced that victims died of fluoride poisoning, flatly declared, “It was murder. The directors of US Steel [sic] should have gone to jail for killing people.”<sup>49</sup> Sadtler’s report, published in *Chemical and Engineering News*, was attacked by Robert Kahoe, hired by U.S. Steel specifically to discredit Sadtler.<sup>50</sup>

U.S. Steel, according to BBC journalist Chris Bryson, actively colluded with the U.S. Public Health Service to conceal the role of fluoride in the deaths of Donora residents,<sup>49</sup> and Devra Davis concludes that the PHS study was “inconclusive by design.”<sup>10</sup> PHS official James Townsend’s 1950 summary of the incident is similarly vague, although he does mention fluoride as one of the substances released into the atmosphere.<sup>51</sup> Overall, however, the article is a study in rationalization, the methodology being to divorce the pollution from its source. And a follow-up study 10 years after the event is similarly inconclusive: “although we know that an answer to this question [of whether the air pollution caused healthy people to become ill] is vital for the

understanding not only of the Donora experience, we find no way in which the analysis of the data now in our possession can provide an answer.”<sup>52</sup> Like U.S. Steel, the PHS was deliberately blind to what was clear to everyone in the area who experienced the fog: “You didn’t need science to identify the culprit. All you needed was a pair of reasonably good eyes.”<sup>53</sup>

More recent research tends to support the view that fluoride was to blame: an autopsy report of a victim exhumed for testing indicates elevated fluoride levels, 10 to 20% percentage higher than usual,<sup>54</sup> and a 2003 study of particulates confirms that overexposure to fluoride causes deep tissue damage in the lungs, findings that are consistent with the autopsy report.<sup>55</sup> While U. S. Steel, of course, was not privy to current research in 1948, surely company officials were aware of the astonishing amounts of chemicals and dust released into the air over the Zinc Works’ 43-year operating life, including 73,000 tons of zinc in dust, fumes, and gases and 72,000 tons of sulphur dioxide.<sup>24</sup> A definitive answer, however, eludes investigators, as PHS records are missing, and U.S. Steel has closed its archives to researchers.<sup>49</sup>

### *Greed*

Of all of the ethical issues apparent in these three cases, the overriding one is greed—the seductive pull of money. All of the companies involved anticipated great profits to be earned but, as it turned out, at the expense of the workers, customers, and the environment.

Working conditions in Donora’s Zinc Works were terrible: workers toiled in almost unbearable heat and, while they earned the highest wages of any Donora workers and spent less hours on the job, few lived beyond age 30.<sup>17</sup> One worker gives a disturbing rendition of his last day: “Five guys had gone before me to shovel out the finished zinc. Each one of them keeled over, real sick, kinda pale, and nearly passed out. I was the sixth one in. I couldn’t take it either. I left. Spent a week in bed and never returned.”<sup>17</sup> And, of course, the entire populace of the Monongahela Valley was forced to breathe poisonous air, a heavy price to pay for employment with U.S. Steel.

Even after U.S. Steel paid the settlement, *Time* magazine reported that the company’s profits increased nearly 13% from the year before, well outpacing that of other steel companies.<sup>56</sup>

In Seoul, the Sampoong department store was a veritable cash cow for its owners, who also profited by shortcuts in construction. It was, in fact, one of the most prestigious and prosperous retail establishments in the city,<sup>40</sup> which added to Lee Joon’s already considerable fortune.<sup>44</sup> Perhaps the most reprehensible action of management was failing to close the store after learning from the structural engineers that the possibility of collapse was very real and immediate. Interestingly, they were observed leaving the building early and hence escaped injury.<sup>36</sup>

Prosecutors at the ensuing trial characterized Lee Joon and his son as “more concerned with maximizing profits than customer safety,”<sup>44</sup> echoing the sentiment expressed in the final investigative report that attributed the collapse to “human ignorance, negligence, and greed.”<sup>36</sup> In short, Sampoong owners were willing to sacrifice the lives of nearly 1,500 employees and customers for one more day of sales revenue.

In comparison to the incidents at Donora and Seoul, the Lake Peigneur problem seems almost insignificant. However, the profit motive was equally strong for Texaco, which stood to gain enormously from the discovery of new oil reserves. Due to the drilling error, however, the landscape was devastated, damages totaled in the hundreds of millions of dollars, and the Diamond Salt Company lost a mine that had been in operation for decades.<sup>57</sup>

While Texaco did not engage in any nefarious profit-making schemes at Lake Peigneur, it did display a blatant disregard for the environmental effects that might result from drilling, a tendency noticeable in its most recent foray into Ecuador, where it illegally disposed of production water in open pits, compromising the public health as well as the surrounding environs.<sup>58</sup>

Ironically, Texaco's quest for greater revenues in Louisiana somewhat backfired as the company had to pay millions for its error. But the payout hardly made a dent in overall profits; Texaco ranked 6th on the Fortune 500 list of most profitable companies for 1980, grossing more than \$1.7 billion.<sup>59</sup>

### **Classroom Usage**

Students tend to respond well to unusual cases, and each of these provides an object lesson for budding engineers: the situation in Donora is well suited for classes in environmental sciences, as is Lake Peigneur; the Lake Peigneur debacle is also appropriate to discuss in mining and math courses; and Sampoong is a good choice to use in structural engineering classes. Specific applications include the following:

*Group projects:* Divide the class into groups and have each research a different case, the goal being to provide the rest of the class with a technical explanation of what happened and a consideration of the ethics involved.

*Class discussions:* Provide the class with background information on each case and ask them to consider various ethical ramifications, such as the wisdom of allowing corporations to self-police, the responsibility of engineers to the health and welfare of the public, the duty of engineers to protect the environment.

*Debates:* As above, provide adequate information on each case and develop a debate format, with students assigned to either pro or con perspectives. For example, using the Donora case, the issue could be corporate self-regulation: whether or not U.S. Steel should be allowed to operate independently of federal or state oversight.

*Case extensions:* Have students examine similar cases that have occurred before or after the original ones. With air pollution, for example, shortly before the Donora incident, Los Angeles experienced a period of crippling smog,<sup>60</sup> and a horrendous fog in 1952 in London killed more than 4,700 people.<sup>61</sup> Students working on the Sampoong case might note several similarities between it and other structural collapses, such as the Hyatt Regency walkways collapse, which was also attributed to engineering negligence and a lack of proper inspection. This exercise is

particularly effective if students are convinced that we learn important lessons from history, as they will discover that we do not. We tend to be historically myopic.

## Conclusions

Despite the loss of life and environmental degradation that resulted from these three cases, there were some benefits: the Donora death fog provided the initial impetus for the first Clean Air Act, passed in 1955;<sup>12</sup> fishing improved in Lake Peigneur, with the introduction of new salt water species;<sup>25</sup> and the Sampoong collapse exposed bribery and corruption in the construction industry, leading to more oversight.

Integrating small, unusual cases in technical classes is an effective methodology for fostering an awareness of ethical issues. This serves the pragmatic goal of meeting the ABET criterion regarding a knowledge of professional and ethical behavior. Hopefully, however, examining these cases will also impress upon students the need to be ever vigilant when working on projects that can adversely affect human lives or the environment. As the saying goes, “small mistakes can have huge consequences.”<sup>33</sup>

## References

1. Lynch, William T., and Ronald Kline. 2000. “Engineering Practice and Engineering Ethics.” *Science, Technology, & Human Values* 25 (2): 195-225.
2. Davis, Michael. 1999. *Ethics and the University*. New York: Routledge.
3. Jonassen, David H. 2011. *Learning to Solve Problems: A Handbook for Designing Problem-Solving Learning Environments*. New York: Routledge.
4. Winston, Kenneth. 2000. “Teaching Ethics by the Case Method.” *Journal of Policy Analysis and Management* 19 (1): 153-60.
5. Pritchard, Michael. 1992. *Teaching Engineering Ethics: A Case Study Approach*. Kalamazoo, MI: Center for the Study of Ethics in Society. Accessed January 2, 2011. <http://ethics.tamu.edu/pritchar/an-intro.htm>.
6. Huester, Gerald, Jr. 2010. “Disaster in the Skies: The Donora Death Fog.” *Harrisburg History Examiner*, July 27. Accessed November 10, 2010. <http://www.examiner.com/history-in-harrisburg/disaster-the-skies-the-donora-death-fog>.
7. McCabe, W. Michael. 1998, October 26. “Donora Disaster Was Crucible for Clean Air.” Accessed November 10, 2010. <http://donora.fire-dept.net/1948smog.htm>.
8. PBS. 1999. “Rage to Riches Timeline.” *American Experience: The Richest Man in the World*. Accessed January 4, 2011. <http://www.pbs.org/wgbh/amex/carnegie/timeline/timeline2.html>.
9. Beveridge, Scott. 2008, June 9. *The Gamble on Donora Steel, Part II: Yellow Smoke and Big Money*. Accessed December 21, 2010. <http://scottbeveridge.blogspot.com/search?q=steel+for+%2445+million>.

10. Davis, Devra Lee. 2007, February. "Backs to the Future . . . Air Pollution Risks to Children: A Global Environmental Health Problem." *EM, The Urban Environment*: 31-7.
11. Snyder, Lynne Paige. 1994. "'The Death-Dealing Smog over Donora, Pennsylvania': Industrial Air Pollution, Public Health Policy, and the Politics of Expertise, 1948-1949." *Environmental History Review* 18 (1): 117-39.
12. Templeton, David. 1998, October 29. *Cleaner Air Is Legacy Left by Donora's Killer 1948 Smog*. Accessed November 10, 2010. <http://donora.fire-dept.net/1948smog.htm>.
13. Beveridge, Scott. 2009, January 5. *The Gamble on Donora Steel, Part III: The Mill Is Sued over Sickening Smoke*. Accessed December 21, 2010. <http://scottbeveridge.blogspot.com/2009/01/gamble-on-donora-steel.html>.
14. Kiestler, Edwin, Jr. 1999, November. "A Darkness in Donora." *Smithsonian*. Accessed November 19, 2010. [http://www.smithsonianmag.com/history-archaeology/phenom\\_nov99.html](http://www.smithsonianmag.com/history-archaeology/phenom_nov99.html).
15. Beveridge, Scott. 2007, September 2. *Dying for Fresh Air, Chapt. 5: Welcome to Nowhere*. Accessed January 5, 2011. <http://scottbeveridge.blogspot.com/2007/09/dying-for-fresh-air.html>.
16. Musser, Christine. 2009, May 24. *Worst Air Pollution Disaster in United States*. Accessed November 10, 2010. <http://www.suite101.com/content/worse-air-pollution-disaster-in-united-states-a119910>.
17. Davis, Devra. 2002. *When Smoke Ran Like Water: Tales of Environmental Deception and the Battle against Pollution*. New York: Basic Books.
18. Hopey, Dan. 2008. "Museum Remembers Donora's Deadly 1948 Smog." *Post-Gazette*, October 21. Accessed November 20, 2010. [www.post-gazette.com/pg/08295/921526-85.stm](http://www.post-gazette.com/pg/08295/921526-85.stm).
19. Rivers of Steel. n.d. "Donora Gallery." Accessed January 7, 2011. <http://www.rumorofbluesky.com/Donora/gallery.html>.
20. "Pennsylvania: Death at Donora." 1948, November 8. *Time*. Accessed November 10, 2010. <http://www.time.com/time/magazine/article/0,9171,853334,00.html>.
21. Peterman, Erin. 2009. "A Cloud with a Silver Lining: The Killer Smog in Donora, 1948." The Pennsylvania Center for the Book—Donora Smog. Accessed January 5, 2011. <http://pabook.psu.edu/palitmap/DonoraSmog.html>
22. "Donora Smog Held Near Catastrophe; Expert Asserts Slightly Higher Concentration Would Have Depopulated Community." 1948. *The New York Times*, December 25. Accessed November 10, 2010. <https://eee.uci.edu/clients/bjbecker/SpinningWeb/week9d.html>.
23. Schrenk, H. H. et al. "Air Pollution in Donora, Pa, Epidemiology of the Unusual Smog Episode of October 1948, Preliminary Report." *Public Health Bulletin No. 306*. Washington, D.C.: Public Health Service, 1949.
24. Bleiwas, Donald I., and Carl DiFrancesco. 2010. "Historical Zinc Smelting in New Jersey, Pennsylvania, Virginia, West Virginia, and Washington, D.C., with Estimates of Atmospheric Zinc Emissions and Other Materials." Open File Report 2010-1131. Washington, D.C.: U.S. Department of the Interior, U.S. Geological Survey.
25. History Channel. 2004. *Lake Peigneur: The Disappearing Lake*.
26. City of New Iberia. 2009. *Rip Van Winkle Gardens of Jefferson Island*. Accessed January 11, 2011. [http://www.cityofnewiberia.com/site\\_362.php](http://www.cityofnewiberia.com/site_362.php).

27. Odds n Ends. 2008, February 25. *The World's Weirdest Engineering Disaster*. Accessed January 2, 2011. <http://oddoroma.com/2008/2/25/the-worlds-weirdest-engineering-disaster/>.
28. "Lake Peigneur." n.d. *Oil Rig Disasters*. Accessed January 11, 2011. [http://home.versatel.nl/the\\_sims/rig/lakepeigneur.html](http://home.versatel.nl/the_sims/rig/lakepeigneur.html).
29. Bellows, Alan. 2005, September 5. *Lake Peigneur: The Swirling Vortex of Doom*. Accessed January 6, 2011. <http://www.damninteresting.com/lake-peigneur-the-swirling-vortex-of-doom>.
30. Bradshaw, Jim. 1997, November 27. "Peaceful Lake Peigneur Turned into Maelstrom." *Daily Advertiser*. Accessed January 6, 2011. [http://www.carencrohighschool.org/LA\\_Studies/ParishSeries/IberiaParish/LakePeigneur.htm](http://www.carencrohighschool.org/LA_Studies/ParishSeries/IberiaParish/LakePeigneur.htm).
31. Berest, Pierre, Benoit Brouard, and Bernard Feoga. 2004. "Dry Mine Abandonment." *Proceedings of the SMRI 2004 Conference*, April 18-20, 2004, Wichita, Kansas.
32. Worthington, Peter. 2001. "Down the Drain: The Day the Earth Swallowed Lake Peigneur Whole." *The Toronto Sun*, October 28: C4.
33. "Cave-In Suit: \$219 Million." 1981. *The New York Times*, November 24. Accessed January 11, 2011. <http://query.nytimes.com/gst/fullpage.html?res=9B04E5DA1638F937A15751A967948260>.
34. Silverman, Steve. 2001. *Einstein's Refrigerator: And Other Stories from the Flip Side of History*. Kansas City: Andrews McMeel.
35. Lankov, Andrei. 2004. "[The Dawn of Modern Korea] (233). Collapse of the Sampoong Department Store." *The Korea Times*, October 14. Accessed January 6, 2011. [http://web.archive.org/web/20070314002032/http://times.hankooki.com/lpage/opinion/200410/kt20041014\\_18510554130.htm](http://web.archive.org/web/20070314002032/http://times.hankooki.com/lpage/opinion/200410/kt20041014_18510554130.htm).
36. Wearne, Phillip. 1999. *Collapse: When Buildings Fall Down*. New York: TV Books.
37. Park Hye-min. 2003. "Lee Joon, 81, Convicted in Sampoong Deaths." *JoongAng Daily*, October 6. Accessed December 9, 2010. <http://joongangdaily.joins.com/article/view.asp?aid=2040664>.
38. Gardner, N. J., Jungsuck Huh, and Lan Chung. 2002. "Lessons from the Sampoong Department Store Collapse." *Concrete & Concrete Composites* 24: 523-9.
39. Delatte, Norbert J. 2009. *Beyond Failure: Forensic Case Studies for Civil Engineers*. Reston, VA: ASCE.
40. National Geographic. 2006, September 20. *Seconds from Disaster—Department Store Collapse*. Iain Riddick, producer.
41. "Disaster City." 1995, July 8. *Economist* 336 (7922): 31.
42. Swift, Bill. 2005, September 13. "Explorer: Collapse." *National Geographic*. Accessed January 6, 2011. [http://911research.wtc7.net/cache/wtc/analysis/compare/ngexplorer\\_collapse.html](http://911research.wtc7.net/cache/wtc/analysis/compare/ngexplorer_collapse.html).
43. Yee, Jaeyeol. 1998. "Rick Society as a System Failure: Sociological Analysis of Accidents in Korea." *Korea Journal* 38 (1): 83-101.
44. CNN. 1995. *Korean Store Owner, Son Sentenced for Role in Collapse*, December 27. Accessed January 8, 2011. [http://edition.cnn.com/WORLD/9512/skorea\\_store/sentencing/index.html](http://edition.cnn.com/WORLD/9512/skorea_store/sentencing/index.html).

45. Lee, M. S., C. S. Han, D. I. Kwak, and J. S. Lee. 1997. "Psychiatric Symptoms in Survivors of the Sampoong Incident." *Journal of the Korean Neuropsychiatric Association* 36 (5): 841-9.
46. Kim, Jung Bum, Seol Young Ryu, and Hyunnie Ahn. 2005. "A Review of Korean Mental Health Studies Related to Trauma and Disasters." *Psychiatry Investigations* 2 (2): 22-30.
47. "The Lake That Vanished." 1981, December 1. *Newsweek*: 42.
48. Nichols, Philip M. 2000. "The Myth of Anti-Bribery Laws as Transnational Intrusion." *Cornell International Law Journal* 33: 627-55.
49. Bryson, Chris. 1998. "The Donora Fluoride Fog: A Secret History of America's Worst Air Pollution Disaster." 13 (3). *Earth Island Journal*. Accessed November 10, 2010. <http://www.fluoridation.com/donora.htm>.
50. Beveridge, Scott, and Amanda Gillooly. 2008. "Donora: The Truth Was Concealed." *Observer-Reporter*, October 19. Accessed November 10, 2010. <http://www2.fluoridealert.org/Pollution/Miscellaneous/Donora-THE-TRUTH-WAS-CONCEALED>.
51. Townsend, James G. 1950. "Investigation of the Smog Incident in Donora, Pa., and Vicinity." *American Journal of Public Health* 40: 183-9.
52. Ciocco, Antonio, and Donovan J. Thompson. 1961. "A Follow-Up of Donora Ten Years After: Methodology and Findings." *American Journal of Public Health* 51 (2): 155-62.
53. "Historical Markers." n.d. Accessed November 10, 2010. <http://explorepahistory.com/hmarker.php?markerId=532>.
54. Hamill, Sean D. 2008, November 1. "Unveiling a Museum, a Pennsylvania Town Remembers the Smog That Killed 20." Accessed November 19, 2010. <http://woodsmokenuisance.wordpress.com/2009/02/20/2008-1948video-pa-donora-smog-museum-opens-on-60th-anniversary/>.
55. Bell, Michelle L., Jonathan M. Samert, and Francesca Dominici. 2003. "Time Series Studies of Particulate Matter." Johns Hopkins University, Department of Biostatistics Working Papers, Paper 10.
56. "Full of Steam." 1948, November 7. *Time*. Accessed January 12, 2011. <http://www.time.com/time/magazine/article/0,9171,801107,00.html>.
57. Autin, Whitney J. 2002. "Landscape Evolution of the Five Islands of South Louisiana: Scientific Policy and Salt Dome Utilization and Management." *Geomorphology* 47: 227-44.
58. Jacques, Ecuador-Kristi. n.d. *Environmental Justice Case Study: Texaco's Oil Production in the Ecuadorian Rainforest*. Accessed March 9, 2011. <http://www.umich.edu/~snre492/Jones/texaco.htm>.
59. "1980 Profits 1-100." 2011. *Fortune 500*. Accessed January 12, 2011. [http://money.cnn.com/magazines/fortune/fortune500\\_archive/profits/1980/](http://money.cnn.com/magazines/fortune/fortune500_archive/profits/1980/).
60. Bachmann, John. 2007. "Will the Circle Be Unbroken: A History of the U.S. National Ambient Air Quality Standards." *Journal of the Air and Waste Management Association* 57: 652-97.
61. Trivedi, Chirag. 2002, December 5. *The Great Smog of London*. Accessed January 12, 2011. [http://news.bbc.co.uk/2/hi/uk\\_news/england/2545759.stm](http://news.bbc.co.uk/2/hi/uk_news/england/2545759.stm).