

Arkema Plant Explosion

The 2017 Arkema Plant Explosion following Hurricane Harvey in Crosby, Texas

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Submitted to

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ChE333T

Fall 2018

Abstract

In August of 2017, Hurricane Harvey brought destruction to southeast Texas. With the hurricane came extremely high water levels that the Crosby plant was not prepared for. In addition to underestimating the floodwaters, Arkema had not anticipated a total power outage at the plant. The Crosby plant housed thousands of pounds of organic peroxides, a chemical that is highly reactive and instable at temperatures above freezing. As water surrounded the emergency refrigeration trailers where organic peroxides had been moved to, temperatures inside the trailers increased and the peroxides began to self-heat, decompose, and combust. The combustion of three trailers caused an explosion whose effects are still felt in the Crosby community. The purpose of this report is to examine the decisions made by Arkema Chemical, using the AIChE code of ethics. Their decisions in preparation for Hurricane Harvey, during the hurricane and explosion, and after the explosion will be analyzed. Arkema acted unethically by not having the right preparations for Hurricane Harvey and not dealing with any after-effects on the community. If Arkema had reexamined their safety protocols after receiving ten OSHA violations, the result may have been different. Although Arkema employees acted ethically during their emergency response to Hurricane Harvey, they neither prepared sufficiently for intense flooding nor responded adequately to the after-effects on the community. Today, the Crosby plant is still running, but the explosion has not only made Arkema review their plans for natural disasters and general safety, but has made the entire chemical industry more aware of the need to be prepared for disasters no matter how improbable they may seem.

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The 2017 Arkema Plant Explosion following Hurricane Harvey in Crosby, Texas

Introduction

On August 25th of 2017, Hurricane Harvey struck the coast of Texas causing flooding and destruction in Houston and much of the surrounding area. The Arkema chemical plant in Crosby, Texas, 20 miles outside of Houston, faced these same conditions. Unfortunately, the flooding of the plant caused a power outage in both the main and backup electric sources. Without power, the chemicals stored in the plant rose above stabilizing temperatures, resulting in combustion and an explosion on August 31st. Residents surrounding the plant were forced to evacuate their homes and 21 people sought medical attention after being exposed to the fumes and smoke (Bloomer & Koschnik, 2017).

Arkema is a specialty chemical company headquartered in France. The company began as a reorganization of the Total chemical company in 2004. By 2006, Arkema became its own recognized company and began trading publicly on the Paris stock exchange. The company employs 19,800 people in 55 countries and reported €8.3 billion in sales in 2017 (Arkema Group at a Glance, n.d.). The production plant in Crosby, Texas has 55 employees and is located 20 miles from downtown Houston. This location focuses on the production of organic peroxides, which are primarily used in the making of plastics (Crosby, Texas Production Plant, n.d.).

Prior to Hurricane Harvey, the Occupational Safety and Health Administration (OSHA) had reprimanded Arkema's Crosby plant for multiple safety violations. The fact that safety protocols were not being followed was made evident through the OSHA evaluations, yet the Crosby plant continued to operate under compromised conditions (Mannan, 2016). Arkema paid the OSHA fines

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for the violations, but no safety changes were implemented or enforced in the plants. The negligence Arkema showed finally culminated with the explosion following Hurricane Harvey.

This incident is significant because it exposed the reality that safety is not standardized efficiently across all parts of industry. Companies that operate in regions prone to natural disasters must adhere to safety protocols to provide the safest work environment for its employees during such extreme conditions. After receiving multiple OSHA violations in the previous year, Arkema did not act to correct their safety deficiencies. Although Arkema employees acted ethically during their emergency response to Hurricane Harvey, they neither prepared sufficiently for intense flooding nor responded adequately to the after-effects on the community.

In this report we will provide additional background into the factors leading up to the explosion on August 31, 2017, the aftermath following the incident, and an evaluation on Arkema's ethics.

Background

This section provides the essential background information needed to understand the factors of the Arkema plant explosion. Specifically, the Arkema company and the Crosby plant will be discussed along with the impact Hurricane Harvey had on the city of Houston and the surrounding areas.

Arkema Group

The Arkema group is a specialty chemical company headquartered in Paris, France. The company was created in October of 2004 as a result of Total, the fourth largest global oil and gas company, reorganizing their chemical branch (Total at a Glance, n.d.). Just two years after creation,

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in 2006, Arkema began public trading on the Paris Stock Exchange. Through various acquisitions, the company grew to be a large player in the specialty chemical field with a presence in 55 countries and a total of 19,800 employees worldwide. In 2017, the company reported an annual sale of 8.3 billion euros, or 9.6 billion dollars (Arkema Group at a Glance, n.d.).

Arkema's three business segments include: high performance materials, industrial solutions, and coating specialties. High performance materials make up the largest portion of sales by the company at 46%. High performance materials consist of adhesives and "advanced materials." Organic peroxides fall under the umbrella of advanced materials and will be the product of interest in our evaluation (Arkema Group at a Glance, n.d.).

Crosby plant. Arkema has 51 locations within the United States. These locations specialize in various processes and products. The Crosby plant, located 20 miles northeast of Houston, was built for chemical processing in the 1960s. This location produces about 367,000 pounds of liquid organic peroxides, used in the making of plastic products. Crosby's Arkema location also employs 55 people and claims a local economic impact of \$7.7 million (Crosby, Texas Production Plant, n.d.).

Hurricane Harvey

The Houston area has had a long record of costly and devastating tropical storms and hurricanes due to its proximity to the Gulf of Mexico. On August 25, 2017, Hurricane Harvey made landfall near Port Aransas, Texas as a category 4 hurricane, meaning that the sustained wind speed was between 130 and 156 mph and that catastrophic damage was imminent (Saffir-Simpson Hurricane Wind Scale, n.d.). As the system moved inland, the storm began to slowly move across southeast Texas. The slow movement of Hurricane Harvey resulted in unprecedented accumulated

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rainfall totals, which created a massive amount of flooding in the area. This amount of rainfall set records nationally with a total of 1 trillion gallons of water falling over Harris County during a four-day period. To put this amount of water into perspective, it is equivalent to the amount of water that would flow over Niagara Falls during a 15-day time period (Lindner & Fitzgerald, 2018, p. 1-32).

The city of Houston was also faced with a large economic impact after the storm. The flooding destroyed numerous homes, business, vehicles, and property. Hurricane Harvey was the second costliest hurricane to hit the United States at 125 billion dollars' worth of damage, only second to Hurricane Katrina in 2005 with an amount of 160 billion dollars' worth of damage. The effects of the storm were not only monetary. The storm caused 68 direct fatalities, mostly from fast moving water. This death toll is the largest for a landfalling hurricane in Texas since 1919, even with the more advanced prediction technology and evacuation plans of the modern era (Lindner & Fitzgerald, 2018, p. 1-32).

Organic Peroxides

An organic peroxide can be defined as a carbon-based compound containing two oxygen atoms bonded together and resembling the structure of R-O-O-R, where R is a group of carbons and hydrogens. This type of chemical is essential to polymerization, the process of forming a long chain by connecting small molecules. Polymerization is how plastic polymers are created (Organic Peroxide, n.d.). Since there are so many types of organic peroxides, there are a variety of plastics that can be made with different qualities. Organic peroxides can be “used as accelerators, activators, catalysts, cross-linking agents, curing agents, hardeners, initiators, and promoters” in the

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process of making plastics (Organic Peroxide, n.d.). The radicals produced upon peroxide decomposition are essential for polymerization (Organic Peroxide, n.d.). A radical is an ion, molecule, or atom with an unpaired valence electron. Because of the instability of having an unpaired electron, radicals are highly reactive. Industries involved in plastics, construction, pharmaceuticals, and even skin care use organic peroxides to manufacture their products.

There are many hazards associated with organic peroxides. If an organic peroxide is inhaled, ingested, or comes into contact with your eyes or skin, poison control or a physician must be called immediately (Victory, 2013). Based on the acute toxicity and corrosive nature of organic peroxides, there is severe danger associated with ingesting, inhaling, and coming into contact with the chemical. In addition to the threat organic peroxides pose to one's body, organic peroxides are also oxidizing agents. Oxidizing agents cause other substances to lose electrons; thus, they "increase the risk of fire and... aid combustion" (Victory, 2013). Organic peroxides have the potential to ignite or intensify fires, which may increase pressure enough to burst a container (Victory, 2013). Decomposition of organic peroxides also produces dangerous substances such as carbon dioxide and carbon monoxide (Victory, 2013). Although organic peroxides are necessary and useful across industries, they are highly hazardous and must be handled with extreme care.

Organic peroxides are thermally unstable, meaning they must be kept at cold temperatures. To categorize organic peroxides, self-accelerating decomposition temperatures (SADTs) are used (Organic Peroxides Chemical Hazards & Risk Minimization, n.d.). A self-accelerating decomposition temperature "is the lowest temperature at which a material will undergo self-accelerating decomposition, which could result in an intense fire or detonation" (Organic Peroxides

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Chemical Hazards & Risk Minimization, n.d.). As seen by Figure 1, an organic peroxide above its SADT becomes dangerous and quickly reaches a point of violent decomposition, where combustion will occur. Self-accelerating decomposition temperatures are dependent on the formula, or actual composition, of the organic peroxide as well as the size and shape of the packaging it's in (Organic Peroxides Chemical Hazards & Risk Minimization, n.d.). In general, all organic peroxides should be stored 10-20 degrees below their relative SADTs. For plants producing and using organic peroxides, there are strict safe handling procedures that have to be followed (Organic Peroxide, n.d.). Storing materials at low temperatures in well-ventilated areas and away from heat and fire sources is essential for such procedures (Organic Peroxide, n.d.). Though there are many precautions taken in safely storing organic peroxides, it is important to follow handling procedures as hazards significantly increase if a fire starts.

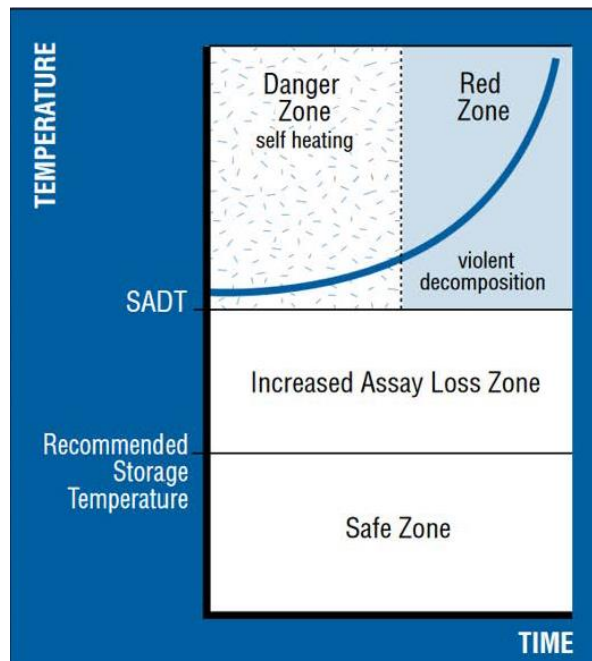


Figure 1: This illustrates organic peroxide's self-accelerating decomposition temperature (SADT), above which the organic peroxides decompose and combust (CSB, 2018, p.20).

When an organic peroxide surpasses its SADT and starts decomposing, combustion is very likely to occur. These fires created from combustion are not only harder to extinguish, but they also have the potential to be more dangerous and explosive compared to typical fires. Organic peroxides “provide the necessary oxygen to support combustion” (Organic Peroxides Chemical Hazards & Risk Minimization, n.d.). In addition, water will not completely put out an organic peroxide fire. According to the article “Organic Peroxide” by Chemical Safety Facts, water is recommended to control and contain peroxide fires as it provides cooling. Cooling the area will decrease the amount of energy fed to the fire by reducing the rate of decomposition. By cooling and containing the fire, it can burn out with the little energy it has. Another difficulty with organic peroxides is that they are lighter than water, meaning they can burn on top of the liquid. This fact combined with the increased pressure caused by a fire can cause an organic peroxide fire to be “explosive and intense” (Organic Peroxide, n.d.). As the organic peroxide burns, it decomposes into hydrocarbons and alcohols, which will burn off the fire; however, some hydrocarbons and alcohols will be contained in the smoke plumes from the fire and dissipate into the air (Organic Peroxide, n.d.). Organic peroxide’s characteristics make them extremely hazardous in terms of their thermal instability, difficulty to extinguish, explosive capabilities, and poisonous qualities. These hazards are why such strict handling and storing procedures of organic peroxides are a necessary component of maintaining a safe environment.

History

This section will provide a description of the previous OSHA violations that the Crosby Arkema plant was liable for before Hurricane Harvey. Also, the original hurricane and flood safety

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procedures preceding Hurricane Harvey at the Crosby plant will be reviewed. Finally, we will explain general safety failures by Arkema that played into the plant explosion.

Previous OSHA Violations

In February of 2017, just six months before Hurricane Harvey, the Occupational Safety and Health Administration charged the Crosby plant with 10 violations. These violations had descriptions for “general requirements,” “hazardous (classified) locations,” and 8 referring to “process safety management of highly hazardous chemicals” (U.S. Department of Labor: Occupational Safety and Hazard Administration (OSHA), 2017). In response to these violations, Arkema paid an informal settlement totaling over \$100,000. All 10 of the violations were rated as “serious,” which means the conditions were “extremely hazardous and potentially fatal” (OSHA, 2017). There has been no evidence as to whether or not these violations led directly to the events that occurred during Hurricane Harvey, however they do provide evidence of a weak safety culture within the Crosby plant.

Original Hurricane Plan

After the incident following Hurricane Harvey, the Chemical Safety Board (CSB) reviewed the safety plans that were in place at the Crosby plant. Before the storm, the Crosby plant paused production of materials and took precautionary steps to prepare for the storm: securing loose materials, such as tanks and dumpsters, that could cause damage with hurricane force winds or floating in floodwater; elevating equipment to keep it above flood waters; acquiring a boat and forklift that could operate in floodwater; providing waders for personnel; staging sandbags; and checking reserve fuel levels (U.S. Chemical Safety and Hazard Investigation Board (CSB), 2018, p. 9, 10, 83). The CSB recognized that the Crosby plant had enough safeguards in place to be

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prepared for a loss of refrigeration in their peroxide containment warehouses for a 100-year flood; however, their Emergency Response Plan focused on low levels of water and did not address the possibility of loss of electricity due to flooding (CSB, 2018, p. 14, 83, 84).

Flaws in Safety Plans

There were several key findings by the CSB that showed flaws in Arkema's procedures and thought processes going into Hurricane Harvey.

Peroxide safety measures. At the Crosby plant, there were several systems to ensure that the organic peroxides did not reach their SADTs: backup refrigeration in the storage warehouses, emergency generators, liquid nitrogen for additional cooling, and refrigerated trailers for temporary storage. All of these protection levels failed during Hurricane Harvey because of the intense flooding. The systems meant to keep organic peroxides below their SADTs could not handle the high waters, leaving the Crosby plant without any backup measures during the storm. The safeguards against the loss of electricity did not meet industry or company standards for independent levels of protection at Harvey-level flooding, meaning that each safeguard on its own would not be able to withstand extreme flooding (CSB, 2018, p.14).

Federal Emergency Management Agency (FEMA) flood map. When the Crosby plant was built before any there was any flood map information in the region, and the first map showed minimal flood risk for the plant. However, in 2007 FEMA revised the flood map, placing the Arkema facility within a floodplain, where parts are in a 100-year and the remainder in a 500-year flood plain. Although Arkema had been told of the flood risk designations by their insurer, employees, other than a former manager, seemed unaware of this information (CSB, 2018, p.14).

Industry guidance. In terms of industry standards, there was little or no information on how to handle flooding protocol with organic peroxides. What little information did exist, was too generic or did not include sufficient measures to have helped Arkema in this situation (CSB, 2018, p.14).

Sequence of Events

On August 25th of 2017, Hurricane Harvey hit land. Meteorologists predicted that the storm would primarily impact the middle and upper coast of Texas by producing 12-20 inches of rain across Texas and upwards of 30 inches in specific areas (CSB, 2018, p. 9). The Crosby plant was not predicted to be in the direct path of the storm, but workers decided to take precautionary measures in advance of the hurricane. The day before Hurricane Harvey hit, Arkema decided to put their hurricane preparedness plan into action. Due to the possibility of roads flooding from the heavy rainfall, a ride-out crew was to stay at the plant incase other workers would have difficulty driving to and from the facility (CSB, 2018, p. 9).

The immediate effects of Hurricane Harvey were worse than predicted, with a significant amount more rainfall occurring. Houston itself recorded approximately 60 inches of rain, a number more than double the worst-case prediction (Kennedy, 2018). No one was expecting the amount of flooding or could have anticipated the immense damage Houston received. Like the unanticipated high water levels, no one at the plant had imagined a total power outage that would compromise the safety systems (CSB, 2018, p. 9). As Hurricane Harvey made landfall, all production ceased, and the original hurricane plan was followed to keep equipment, chemicals, and employees safe from flooding (CSB, 2018, p. 10).

Recognizing that organic peroxides must be kept at low-temperatures or they have the possibility to decompose and combust, the Crosby plant had to ensure the organic peroxides were kept below their self-accelerating decomposition temperatures for the duration of the hurricane. Some organic peroxides at the plant “required continuous refrigeration to prevent decomposition” (CSB, 2018, p. 10). Those materials needing constant refrigeration, being kept at -20 °F, had to be moved to a different refrigerated area in case power was lost in the original cold storage unit (CSB, 2018, p. 10). As water levels continued to rise, it was the responsibility of the ride-out crew to “de-energize electrical equipment to prevent short-circuiting” (CSB, 2018, p. 10). Problems began to arise as the ride-out crew continued to underestimate the hurricane, thinking “the event would be manageable...[and] water levels would stop rising” (CSB, 2018, p. 10). Hazardous material and equipment became threatened with the extreme flooding, leading to the decision to cut off the plant’s power to several low-temperature warehouses containing organic peroxides on Sunday (CSB, 2018, p. 10).

At the time of Hurricane Harvey, approximately 367,000 pounds of organic peroxides were held at the plant, all in warehouses, in 1 to 5 pound plastic containers (CSB, 2018, p. 20-25). To prepare for floodwaters, Arkema decided to shut off half of the low-temperature warehouses and only move the organic peroxides that were in those warehouses. Although there was a large volume of organic peroxides, they were easily maneuverable by person or machine. However, the water levels continued to rise and further threaten the remaining warehouses that were left operating. The ride-out crew, with directions from Arkema, were not working on a plan, instead working on crisis management. Once a low-temperature warehouse was shut off, the organic peroxides housed in that warehouse were moved to refrigerated trailers. The trailers were then lifted to an elevated surface onsite, a place where the chemicals could hopefully stay out of the floodwaters (CSB, 2018, p. 10).

At 2:00 am on August 28th, the water levels reached past the generators, shutting off all power at the plant, including the one remaining low-temperature warehouse (CSB, 2018, p. 11). This meant that the ride-out crew had to physically move the remaining 4,000 containers of organic peroxides into 3 refrigerated trailers. By this time, the water was over 4 feet high and had flooded the forklift used to elevate the trailers (CSB, 2018, p.11). Consequently, the trailers could not be moved to higher elevation. Water from the hurricane started to overflow the trailers' fuels tanks, which could result in loss of refrigeration (CSB, 2018, p. 11).

Arkema quickly realized that if the organic peroxides lost refrigeration, the chemicals could quickly reach their self-accelerating decomposition temperatures and combustion could occur (CSB, 2018, p. 11). Local emergency responders were informed of the situation and Unified Command was given the organic peroxides' SADTs, general data, and estimated temperatures as refrigeration was threatened. Unified Command is a group within the Incident Command System that "enables effective and efficient domestic incident management" (U.S. Department of Homeland Security, 2018). On August 29, an emergency response team evacuated the ride-out crew and implemented a 1.5-mile evacuation zone around the plant, assuming the trailers would combust (CSB, 2018, p. 11).

It was obvious that a dangerous reaction was imminent for the Crosby plant. However, the emergency responders were not only dealing with this eventuality, but also with the current onslaught of hazards in the local community caused by Hurricane Harvey. The highway cutting through the evacuation zone, the primary road used "for transporting hurricane relief and rescue resources," became flooded (CSB, 2018, p.12). The need for access to this road took precedence, and the evacuation zone was condensed, with emergency personnel ready to block the road in the case of combustion (CSB, 2018, p.12).

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On August 30, white smoke could be seen coming from the Arkema facility. Subsequently, the highway was blocked off (CSB, 2018, p. 12). Two members of the Crosby Fire Department were sent to investigate but said they did not see any signs of organic peroxide decomposition (CSB, 2018, p. 12). Unified Command then reported that the temperature readings within some of the trailers exceeded their self-accelerating decomposition temperatures. The problem was that one third of the trailers were not providing temperature readings and the reading itself was on the inside of the trailer, not of the actual organic peroxides (CSB, 2018, p. 12). This meant that although the inside of the trailer was above SADT, the organic peroxide might not be and therefore, would not be decomposing or combusting. Since the Crosby Fire Department reported nothing out of place, the highway was reopened.

The police officers who reported the white smoke stated that their dashboard camera was indicating a chemical release occurring at the facility (CSB, 2018, p. 12). To further analyze the situation, additional police officers were dispatched. Their cameras confirmed the evidence of white smoke and the chemicals being released (CSB, 2018, p. 12). The police officers realized they had exposed themselves to dangerous chemicals and shortly afterwards, began to experience the symptoms of such exposure, resulting in the need to immediately seek medical attention. The highway was closed once again in the area while inadvertently that night, organic peroxides began to decompose and combust in one of the nine trailers (CSB, 2018, p. 13). The next day, two more trailers caught fire. The three trailers that combusted were identified as the three trailers not moved to higher ground; the remaining, elevated six had yet to catch fire (CSB, 2018, p. 13). Unified Command was unable to check on or remove the contents of the remaining trailers so each of the remaining six trailers still posed the threat of combustion (CSB, 2018, p. 13).

The nearby community that had been evacuated from the earlier installment of the 1.5-mile evacuation zone quickly became worried about their home and belongings. People were forced to

wait for the combustion of the other trailers to occur before they could return home (CSB, 2018, p. 13). Two days following the combustion of the three trailers, emergency responders made the decision to burn the remaining trailers themselves (CSB, 2018, p. 13). A controlled burn allowed for the combustion to be contained by the emergency responders. This process allowed the evacuation zone to be eliminated, the residents to return to their homes, and for the highway to be reopened more expeditiously.

Aftermath

This section provides information on the immediate effects that the plant explosion had on the surrounding community, the current state of the Crosby plant, and how Arkema should continue operations in the future.

Immediate

Following the explosion at the Crosby plant, the nearby community faced the repercussions of the toxicity released by Arkema. The residents of Crosby were told little about the events leading up to and during the explosion at Arkema. Arkema's reluctance to share information continued after the plant explosion as well. Arkema's inadequate information disclosure resulted in a lack of understanding the impact the air quality and the water content had on residential health. Tests confirmed peroxide content in the air and levels of acetone, a chemical heavily present within the Crosby plant, in tested wells. Relative to the number of wells located in the community; few were tested for water quality.

Despite test results showing peroxide content in air and acetone readings in private wells, the residents were assured that the environment was safe to live in. Arkema's assurance to Crosby

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was later undermined by the fact that animals in the surrounding area were found dead and twenty-one members of the community had to seek medical attention as a result of the chemical exposure. To this day, people in the affected area are still unaware of the chemical contamination in their wells, which are still used for everyday purposes (Stuckey, 2018).

Current State

In the wake of the explosion, there is a lack of evidence showing significant changes in safety protocol or operation. The Crosby plant is currently tied up by lawsuits from community members who were negatively affected by the explosion. These plaintiffs are taking legal action in response to the negligence and hazardous behavior exhibited by Arkema (Platoff, 2018).

Future Action

After considering the events at the Crosby plant, the CSB calls for a revision of the risk management to amend the coverage of reactive chemicals. This is specific to the work done at the Crosby plant by emphasizing a need for technical reform, specifically on self-reacting chemicals, such as organic peroxides. Regarding the weather protocols in place at the Crosby plant, the CSB advises a reduction of risk with floods by confirming that the technical side of Arkema's flood protection meet future necessary requirements. In conjunction with this approach to weather safety and handling of organic peroxides, Arkema is recommended to perform routine analysis of facilities to confirm their ability to handle extreme weather (CSB, 2018, p. 126).

Ethical Evaluation

Arkema's behavior surrounding the explosion at the Crosby plant was determined to be unethical. The American Institute of Chemical Engineers (AIChE) has designed a code of ethics

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that establishes the ethical responsibility a chemical engineer must hold themselves to. Analysis of the actions and behavior at the Crosby plant explosion under the AIChE code shows a breach in fundamental, ethical rules.

Arkema did not “hold paramount the safety, health and welfare of the public,” nor did the company “protect the environment in performance of their professional duties” (Grubbe, 2015, p. 26). In 2007, a revision of the FEMA flood insurance map showed Arkema’s Crosby plant within the scope of flood danger. This map showed that this plant had areas in the 100-year floodplain, but also the 500-year floodplain. FM Global, Arkema’s insurer, outlined these flood revisions in 2016; however, employees of Arkema were seemingly unaware of the danger their own plant faced (CSB, 2018, p. 14). Given this information, the unethical behavior stems from a lack of preparation in accordance with the risk of flood waters. The Arkema group was not equipped to handle the floodwaters of Hurricane Harvey, a 500-year flood. Harvey resulted in flood levels within a scope of danger that Arkema had been warned about, yet the company did not have a strong enough safety plan in place to manage this level of disaster. The reality of the Crosby plant explosion proves that Arkema did not have the proper safety precautions in place. Had the Crosby plant followed safety guidelines and flooding preparations correctly, the health and welfare of the community would have been properly considered, but this was not the case. Arkema was unaware of information that was critical to the safety at the Crosby plant. This lack of knowledge, coupled with weak safety precautions, demonstrated an unethical approach to their business in chemical engineering (Grubbe, 2015, p. 26).

On the day of the Crosby incident, the explosion at the plant was unavoidable given the company’s previous decision making. As the weather became more severe and the systems began

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to fail, there was no decision Arkema could make to lessen the effect. The Crosby plant officials behaved ethically by choosing to activate a controlled fire within the remaining trailers. The safety of the Crosby residents was taken into account by eliminating any question of danger and choosing to ignite all unstable organic peroxides (Grubbe, 2015, p. 26).

The events in the aftermath of the Crosby plant explosion were also handled with a lack of responsibility. The lack of information provided to the community within the affected radius resulted in uncertainty, unease, and a need for medical attention in some cases (Stuckey, 2018). Arkema did not hold true to the fundamental AIChE principle of caring for the environment and those who it serves by choosing to omit information, as well as allowing a false sense of security about the safety of location. Arkema ignored the impact they had on the community and their responsibility to serve these residents, a choice that is unethical in nature for the company due to the negative impact on the local environment and people of Crosby (Grubbe, 2015, p. 26).

Arkema has also shown a history of unethical behavior within their system of operations and dealings with safety protocols in the past. After receiving 10 OSHA violations, all 10 of which were deemed to be serious in nature, the Crosby plant was able to settle for a fine and continue operation (OSHA, 2017). While there is no direct tie of these violations to the explosion, the way that this was resolved shows a disregard of safety. Under AIChE's code of ethics it is declared that chemical engineers must "accept responsibility for their actions," after they "seek critical review" (Grubbe, 2015, p. 26). Legally, Arkema met OSHA's requirements by paying a fee, but this interaction sets a precedence of unethical behavior. The fact that Arkema chose to ignore the OSHA violations, without regard for how their employees or the surrounding community could be affected, demonstrates that the general workplace safety culture can be ignored if an appropriate

amount of money is paid. This behavior shows a lack of responsibility for mistakes and inhibits the ability to move forward for the betterment of the greater good (Grubbe, 2015, p. 26).

Conclusion

Arkema's Crosby plant did not act ethically prior to and following Hurricane Harvey. They did not fully research and prepare for the extent of dangers that the plant susceptible to, leaving the employees and Crosby residents at risk. After the hurricane and chemical release, the Arkema group was not clear with how information was communicated to the surrounding community, letting unclean air and water be used by Crosby residents. Here, Arkema neither "held paramount the safety, health and welfare of the public," nor did the company "protect the environment in performance of their professional duties" thus violating AIChE's first code of ethics (Grubbe, 2015, p. 26). During the hurricane however, Arkema employees made the best decisions they could within the given circumstances. Hurricane Harvey and the extent of flooding was an uncontrollable factor and those workers on-site worked to keep danger to a minimum, even igniting the six trailers of viable organic peroxides to ensure that there were no further risks to the community.

In the wake of the disaster there is still a question of whether Arkema's Crosby plant has strengthened their safety culture, and how they have emphasized this when restarting operations. In terms of the chemical industry, there is no government regulation regarding flood plans. This begs the question of when there will be governmental action to require these procedures. With the changes in climate, flooding will likely occur more often, leaving other companies at risk of an event like what happened at Arkema in the future.

Word Count: 5,111

Annotated References

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This is the Arkema corporate website. They would have a conflict of interest if information on the Crosby explosion was being cited. However, it was used purely to gain background knowledge on the company and the employment and production of the Crosby plant itself and Arkema as a whole.
- Bloomer, L., & Konschnik, K. (2017). Arkema chemical plant & the 2017 risk management program amendments. *Harvard Law School: Environmental & Energy Law Program*. Retrieved from http://environment.law.harvard.edu/wp-content/uploads/2018/03/HARVARD-Arkema_RMP_WriteUp_FINAL_logo.pdf
This source says how the Arkema plant explosion happened and what the repercussions were on the company and environment. Also given was background information about Arkema's previous safety transgressions along with the new rules and regulations by the Risk Management Program for facilities who have a more serious accidents compared to others. We will use this to explain what happened at the plant, prior negligence by Arkema, and the government's involvement to help correct such behavior.
- Crosby, Texas production plant. (n.d.). Retrieved from https://www.arkema-america.com/en/arkema-america/united-states/crosby-tx/index.html?_ga=2.52764968.1240392210.1541471821-412867348.1537910520
This is the Arkema official website for the Crosby plant. This reference was used to gather key facts about the location, such as number of employees.
- Grubbe, D. L. (2015). Ethics - examining your engineering responsibility. *American Institute of Chemical Engineers*. Retrieved from <https://www.aiche.org/sites/default/files/cep/20150221.pdf>
This article holds the AIChE code of ethics that all professional engineers should abide by. It also defines ethics and gives good examples on violations of the code as well as how best to uphold the code. We will use this as a comparison for the Arkema plant explosion as in what pieces of the code of ethics were violated.
- Kennedy, M. (2018). Harvey the 'most significant tropical cyclone rainfall event in U.S. history'. *National Public Radio, Inc*. Retrieved from <https://www.npr.org/sections/thetwo-way/2018/01/25/580689546/harvey-the-most-significant-tropical-cyclone-rainfall-event-in-u-s-history>
This source explains the actual effect Hurricane Harvey had on the Texas, we will use the information about the amount of rainfall that actually occurred compared to what was predicted.
- Lindner, J., & Fitzgerald, S. (2018). Hurricane Harvey - storm and flood information. In *Harris County flood control district*. Retrieved from <https://www.hcfc.org/media/2678/immediate-flood-report-final-hurricane-harvey-2017.pdf>
This memo was used as a reference for the magnitude of Hurricane Harvey in the Houston area. Due to the casual nature of a memo it may not be as clearly unbiased as other sources, but the authors were reliable in their knowledge on the subject.

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- Mannan, M. S. (2016). Ranking of chemical facilities based on the potential to cause harm to the public. *Mary Kay O'Connor Process Safety Center*. Retrieved from <https://assets.documentcloud.org/documents/2822336/PCHP-Report-Updated-Edited-on-050216.pdf>
This particular report gives a general rating for hazardous systems based on the type of chemicals held, quantity, accident history, and population density. Although the paper was written prior to the explosion, it identifies the Arkema Crosby plant as possessing a high possibility of causing harm to the public. We will use this report to investigate the reasoning behind the explosion and what safety features Arkema ignored.
- Organic peroxide. (n.d.). *Chemical Safety Facts*. Retrieved from <https://www.chemicalsafetyfacts.org/organic-peroxide/>
The composition, uses, and safety associated with organic peroxides is all stated in this article.
- Organic peroxides chemical hazards and risk minimization. (n.d.). In *UNL environmental health and safety* (pp. 1-3). Retrieved from https://ehs.unl.edu/sop/s-organic_peroxides_chem_haz_risk_min.pdf
This safety sheet goes into detail about the danger associated with the use of organic peroxides. Specifically, self-accelerating decomposition temperatures and their thermal instability are explained.
- Platoff, E. (2018, March 30). As lawsuits over Texas chemical disaster add up, advocates blame Arkema and rules regulating it. *The Texas Tribune*. Retrieved from <https://www.texastribune.org/2018/03/30/arkema-disaster-harvey-regulations-texas-crosby/>
This source discusses Arkema's current state and will be used in reference to the aftermath of the Crosby explosion.
- Saffir-Simpson hurricane wind scale. (n.d.). Retrieved from <https://www.nhc.noaa.gov/aboutsshws.php>
This website was used as a reference for the National hurricane scale to categorize Hurricane Harvey and its expected effects on the Houston area.
- Stuckey, A. (2018, March 18). Silent spills. *Houston Chronicle*. Retrieved from <https://www.houstonchronicle.com/news/houston-texas/houston/article/For-Crosby-residents-a-bitter-taste-about-12771298.php>
This source discusses the immediate aftermath of the explosion at the Crosby plant and will be used in the discussion of the impact on the residents nearby and the surrounding environment. This source shows bias in that it interviewed residents of Crosby and has their personal narrative.
- Total at a glance. (n.d.). Retrieved from <https://www.total.com/en/our-group/total-a-major-energy-operator>
This reference was used to gather basic information on Total to explain its role in the origins of Arkema.
- U.S. Chemical Safety and Hazard Investigation Board (CSB). (2018, May). *Organic peroxide decomposition, release, and fire at Arkema Crosby following Hurricane Harvey flooding* (Report No. 2017-08-I-TX). Retrieved from <https://www.csb.gov/arkema-inc-chemical-plant-fire-/>

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The source gives detailed information on the entire Arkema plant explosion. This is including notes on every unit, Hurricane Harvey rainfall and repercussions, how to plan for flooding and how Arkema did so, and costs. We will use this source when needed specific descriptions or details about the plant explosion, how to properly plan for natural disasters, and how Arkema differentiated from such plans.

U.S. Department of Homeland Security. (2018, June). *Incident command system resources*.

Retrieved from <https://www.fema.gov/incident-command-system-resources>

This source defines the Incident Command System, a department we had no previous knowledge of.

U.S. Department of Labor: Occupational Safety and Health Administration (OSHA). (2017, May).

Inspection: 1170128.015 - Arkema, Inc. (Issue Brief No. 1170128.015). Retrieved from https://www.osha.gov/pls/imis/establishment.inspection_detail?id=1170128.015

This is the list of violations filed against the Crosby plant by OSHA in 2017. There should be little to no bias as it is just a list of their findings and results.

Victory. (2013). In *Safety data sheet* (pp. 1-8). Retrieved from <https://birite.com/wp-content/uploads/msds/2014/850063.pdf>

This is the MSDS for a common organic peroxide produced by EcoLab. This report explains the effects of ingesting, inhaling, and touching organic peroxides.