Journal of Hazardous Materials 308 (2016) 164–172

Contents lists available at ScienceDirect

Journal of Hazardous Materials

journal homepage: www.elsevier.com/locate/jhazmat

Case study and lessons learned from the ammonium nitrate explosion at the West Fertilizer facility

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HIGHLIGHTS

- In-depth technical analysis of the West, Texas ammonium nitrate incident.
- Regulatory analysis for compliance with federal, state and local regulations.
- Facility siting and land use planning implications.
- Need for local coordination of risk information and emergency planning.

ARTICLE INFO

Article history:
Received 8 September 2015
Received in revised form 13 January 2016
Accepted 14 January 2016
Available online 18 January 2016

Keywords:
Case study
Ammonium nitrate
Consequence analysis
Regulations

ABSTRACT

In West, Texas on April 17, 2013, a chemical storage and distribution facility caught fire followed by the explosion of around 30 tons of ammonium nitrate while the emergency responders were trying to extinguish the fire, leading to 15 fatalities and numerous buildings, businesses and homes destroyed or damaged. This incident resulted in devastating consequences for the community around the facility, and shed light on a need to improve the safety management of local small businesses similar to the West facility. As no official report on the findings of the incident has been released yet, this article first investigates the root causes of the incident, and presents a simplified consequence analysis. The article reviews the regulations applicable to this type of facility and recommended emergency response procedures to identify gaps between what happened in West and the current regulations, and discusses how the current regulations could be modified to prevent or minimize future losses. Finally, the federal response that followed the incident until the publication of this paper is summarized.

1. Introduction

On April 17, 2013, an ammonium nitrate (AN) explosion occurred in a chemical storage and distribution facility in West, Texas, leading to 15 fatalities, and more than 200 injuries. The facility was completely destroyed and buildings, businesses and homes were damaged up to 1 km from the plant [1]. AN has caused dozens of major incidents in the last 100 years all over the world, from the production, storage, and transportation of the material [2]. More incidents and lessons learned can be found in literature [2].

This article presents an analysis of the West Fertilizer incident and lessons learned from it. This paper is a preliminary study since an official report summarizing findings from the incident has not been released yet. In addition to the preliminary investigation of the causes and consequences of the incident, the paper will present a detailed analysis of AN storage regulations in the US—both the existing regulations that have not been followed, and the gaps that exist in the current regulations. Finally, the paper will discuss the government response that followed the incident, up to the publication of this paper.

2. Incident description and analysis

2.1. West Fertilizer facility

West Fertilizer Company is a chemical storage and distribution facility [3], located approximately 75 miles south of Dallas, in the City of West, Texas. The facility was owned by Donald Adair from

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http://dx.doi.org/10.1016/j.jhazmat.2016.01.039
0304-3894/

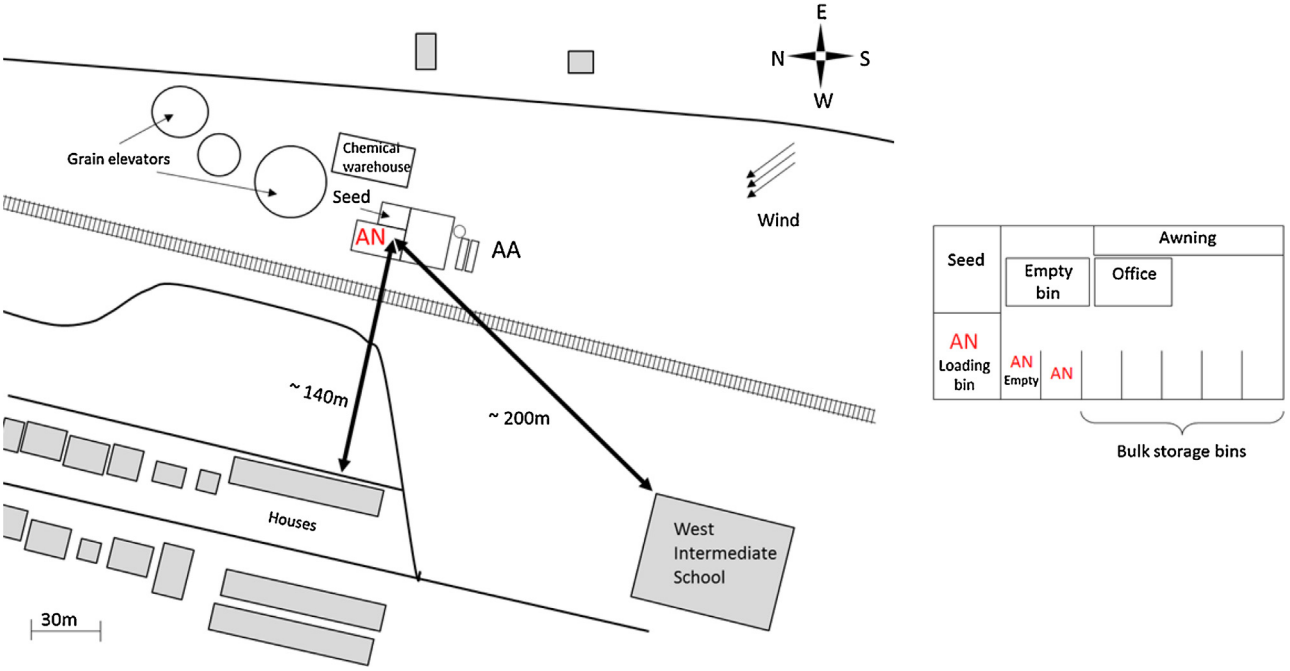

Fig. 1. Left: West Fertilizer facility and its surroundings, Right: Warehouse.

Adair Grain Inc., [4] and employed less than 10 people [5]. In 2012, the company reported annual sales of $4 million [6]. The facility layout, shown in Fig. 1, included grain elevators located at the North of the site. South of the grain elevators, a chemical warehouse contained different fertilizers and herbicides. The main building was 12,000 square feet [7]. and contained seed bags packed in pallets, and AN with 34% nitrogen (pure AN), stored in bulk granular form, in a 24 ft high vertical wooden bin. AN was also stored in smaller bins with 10 ft high wood panels as separation [7], together with other substances like potash, ammonium sulfate, or K-MAG—a fertilizer containing potassium, magnesium, and sulfur. Finally, south of the office building, tanks of anhydrous ammonia (AA) [8] were stored. Investigation later showed that 100 tons of AN was also stored in a railcar on the facility [1].

In their 2012 Tier II report, West fertilizer claimed to store 540,000 pounds of AN, 110,000 pounds of anhydrous ammonia, 540 pounds of Grazonnext (herbicide) [9,10], 60 pounds of Reclaim (herbicide), 192 pounds of Remedy Ultra (herbicide), 29.75 pounds of Surmount (herbicide), and 400 pounds of Yuma (insecticide) [11].

2.2. Incident timeline

At 5 pm on April 17, 2013, the West Fertilizer plant closed for the day. According to the facility owner's son, no machinery was left on [4]. At 7:30 pm, the local firefighters responded to a fire call at the plant. At 7:51 pm, the AN stored in the plant exploded. More information about the firefighter response is given in Section 3.2. From 8 pm, the emergency responders from North and Central Texas converged on West. Injured survivors were transported to hospitals in Waco, Temple, Fort Worth and Dallas, and the non-injured survivors were evacuated, including more than 100 residents from the nearby nursing home. At 11 pm, the fire at the fertilizer plant was under control but still smoldering. A storm the day after helped contain the smoke.

The explosion destroyed a middle school, nursing home, numerous residences, and businesses. In total, 50 structures were damaged significantly, 100 structures were slightly damaged, and an apartment complex was destroyed [12]. Debris were found up to 2.5 miles from the plant [7]. Fifteen people died and 228 people were sent to the hospital, among which 46 were admitted [12]. Of the fifteen people killed, ten were firefighters, two were civilians that responded to the fire, and three were civilians who lived in a close-by residential area [7].

2.3. Ammonium nitrate hazards

According to the National Fire Protection Association [13] standards NFPA 490 and 704, AN is not considered flammable or combustible. The EPA considers it a stable, generally difficult to detonate compound [14]. However, factors like strong shock, high temperatures under confinement or contamination can lead AN to detonate [15].

The melting point of AN is around 170 °C [14]. AN decomposes by different ways, which are described by different equations, producing various oxynitrides, and the most widely accepted decomposition pathways are introduced here. At relatively low temperatures (*i.e.*, around 170 °C), an endothermic reversible reaction occurs as the melted AN vaporizes and forms ammonia and nitric acid [10,16]:

$$NH_4NO_3(l) \rightleftarrows HNO_3(g) + NH_3(g),\ \Delta H = 176\ kJ\ mol^{-1}$$

At higher temperatures (*i.e.*, 170–280 °C), an exothermic irreversible reaction occurs and AN decomposes into water and nitrous oxide.

$$NH_4NO_3(l) \rightarrow N_2O(g) + 2H_2O(g),\ \Delta H = -59\ kJ\ mol^{-1}$$

If AN is suddenly heated up to a relatively high temperature, explosive decomposition will occur, producing nitrogen, oxygen, and water [10,16].

$$2NH_4NO_3 \rightarrow 2N_2\uparrow + O_2\uparrow + 4H_2O,\ \Delta H = -1057\ kJ\ mol^{-1}$$

The risk of explosion is increased if AN is contaminated by either organic or inorganic materials like chlorides or powdered metals [17]. Buczkozski and Zygmunt [18] showed that the addition of aluminum dust to pure AN dramatically increases the heat of reaction from 1592 to 6712 kJ kg^{-1}.