Bhopal, India: A Disaster Magnified by Atmospheric Conditions

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The gas leak incident in Bhopal, India has been considered one of the worst, if not the worst, industrial catastrophes ever. On the evening of December 2nd, 1984, large amounts of water entered a tank at a Union Carbide pesticide plant and reacted with around 40 tons of methyl isocyanate (MIC) (Boybeyi et al, 1995). The ensuing release of toxic gas, which followed the reaction, killed around 4,000 people within a few hours and the lingering effects of the inhalation killed somewhere between 15,000 and 20,000 people in total (Encyclopedia, 2008). The energetics and chemical characteristics of the reaction and gas release, combined with the atmospheric conditions of the event, played a large role in the magnitude of disaster. This paper will analyze the hazardous airborne constituents that were released into the air as well examine the atmospheric conditions that affected the transport and dispersion of the released material.

The energetics and chemical characteristics of the release initially determined how the constituents would be released into the atmosphere. MIC, an intermediate in producing the pesticide carbaryl, reacted exothermically with water in a tank containing the gas, releasing energy in the form of heat (Encyclopedia, 2002). This led to temperatures increasing to around 400 degrees Fahrenheit and large pressure increases in the system as well. These increases led to a relatively fast release of enormous amounts of a toxic gas, made up MIC, phosgene, monomethylamine, and hydrogen cyanide among others (Bhopal, 2011). The gas collected inside the tank and became large enough to open the safety valves. Additional safety measures that either needed to be repaired or were simply out of use to save money, allowed the release of toxic materials in plumes.

Once these plumes of gas began to enter into the atmosphere, they formed a poisonous white cloud that swept through the city, waking up residents with burning sensations in their eyes and throats (Bhopal, 2011). The release of the plumes of gas from the tank was believed to be about 88 meters per second (Boybeyi et al., 1995). MIC, which was believed to be the largest component of the gas, is denser than air and thus, less buoyant (Boybeyi et al, 1995). Exposure to MIC, which attacks the eyes and respiratory system of people, created panic, anxiety, and disorientation (Bhopal, 2011). This caused people to run out of their homes and into the gas

cloud, which resulted in many people being exposed to increased doses or higher concentrations of the highly toxic gas (Encyclopedia, 2002).

The atmospheric conditions during the release of the toxic gas determined how profound the impacts of the gas would be on humans. Conditions such as inversion and a low wind speed prevented dispersion of the gas (Dhara et al, 2002). Eyewitnesses reported that a cloud of gas enveloped the area and moved slowly through the residential neighborhood (Dhara et al., 2002) Although there was no meteorological record on the early morning of the release, available records and local residents indicate that the atmosphere was quite stable (Boybeyi et al, 1995). The atmosphere was suppressed of turbulence because of the night time nature of the incident. The winds were near calm, but there were northwesterly and subsequently northerly winds and the mixed layer was estimated to be at around 200 meters in altitude (Boybeyi et al, 1995).

Although dispersion of the gas was initially quite slow, mesoscale and Monte Carlo dispersion models have shown three-dimensional wind and turbulence estimates of the early morning. Upper Lake, which is located southwest of the Union Carbide plant, was shown to have its own land breeze mesoscale circulation which affected the Bhopal urban area circulations and, thus, dispersion of the gas (Boybeyi et al., 1995). The land breeze mesoscale circulation was caused by the Upper Lake area because, during sunset, the land surface and air in contact with it cools faster than the lake surface (Boybeyi et al., 1995). The magnitude of these interactions combined with minimal dispersion leaves much uncertainty, however.

The gas leak disaster of Bhopal was greatly magnified by the chemical characteristics of the gas and atmospheric conditions during the gas release. The atmosphere was very stable and lacking turbulence during the toxic gas leak, in part because of the event occurring before sunrise. This meant that it was not easy for the toxins to easily move above the lower troposphere via mixing or transport and that the gas cloud persisted over the city and its residents. Slow wind speed and wind direction towards the majority of the population also made conditions worse. The great amounts of MIC released, as well as its high relative density, worsened conditions even further. This horrible disaster would have taken place regardless of the atmospheric conditions, but these specific conditions that Bhopal faced on that morning, certainly increased the impact of the disaster.

References

[1] The Bhopal Medical Appeal, cited 2011: What Happened? [Available online at http://www.bhopal.org/what-happened/.]

[2] Boybeyi, Z., S. Raman, and P Zannetti, 1995: Numerical Investigation of Possible Role of Local Meteorology in Bhopal Gas Accident. *Atmos. Environ.*, **29**, 479-496.

[3] Dhara V.R., R Dhara., S.D. Acquilla, and P. Cullinan, 2002: Personal exposure and long-term health effects in survivors of the union carbide disaster at Bhopal. *Environ Health Perspect*, **110**, 487-500.

[4] The Encyclopedia of the Earth, cited 2008: Bhopal, India. [Available online at http://www.eoearth.org/article/Bhopal,_India.]