Prediction of Dispersion Model for Chlorine Release Using Open Source Software

Sameer Kumar Dohare[1], Ronak Patel [2*]

[1] Environment Engineer, Ramans Enviro Services Pvt. Ltd., Ahmedabad, 380015
[2]Assistant Professor, Chemical Engineering Department Institute of Technology, Nirma University, Ahmedabad, 382481
E-mail addresses: ronakrpatel@nirmauni.ac.in

Abstract: Understanding the behavior of toxic gas release due to chemical accidents is important for health and safety of personnel as well as its effect on environment. India is on its mission to be a developed country by year 2020, environmental issues are the one of the constraints headed towards it. Increase in per capita water consumption requires more water treatment plants to fulfill the demand. Chlorine is being used as a disinfectant in water treatment plants. Chlorine can be added to drinking water in the form of chlorine gas, chloramine, chlorine dioxide, etc. It may have adverse effects on personnel and environment, as it causes severe respiratory tract, eye, and skin burns. There is also chance of fire hazard, as it causes fire when it comes in contact with combustible materials. The proper safety measures were always taken into consideration while handling of chlorine gas. But there is always a chance of accidental release of chlorine gas. By proactive approach for the accidents, we can minimize the effects of toxic gas release by taking appropriate measures. Air dispersion model is used for prediction of chlorine gas cloud. It helps to identify the possible affected zone and to predict consequence on personnel and environment. Therefore determination of air dispersion of chlorine by computational tool is strongly desired. "ALOHA" can be considered for the prediction of air dispersion model. This software helps user to identify toxic threat zone created by sudden release of chlorine gas, which can be taken into consideration for health and safety plans. Proper antidotes as well as communication system can reduce its effect on personnel. By the same methodology we can predict the gas cloud of any other toxic gas and take the pre-accidental measures to reduce its effect.

Key Words: Toxic gas release, Chlorine, Water treatment, Health and safety, Disaster management plan, Air dispersion model, "ALOHA".

1. Introduction:

One of the greatest hazards associated with the use of chlorine is that, in becoming a familiar part of a process, it is often forgotten that it is potentially dangerous. Chlorine gas is primarily a respiratory irritant. The characteristic penetrating odor of chlorine gas usually gives warning of its presence. At higher concentration it is visible as greenish yellow gas. Effect of liquid chlorine by absorption through skin, lungs, or intestinal canal is unknown, but when exposed to normal atmospheric pressure and temperature it vaporizes to gas, which will produce the same physiological effects of chlorine gas[1].

The dense gas cloud behavior of a chlorine gas makes it extremely dangerous for human health and environment, as it tends to fall to the ground due to its negative buoyancy and to remain there at usually high levels of concentration for comparatively long periods[2].

ALOHA (Areal Locations of Hazardous

Atmospheres) is designed to model chemical releases to produce reasonable results quickly enough to be of use to emergency responders and planners during a real emergency. Using ALOHA, we can calculate how quickly chemical is escaping from chlorine storage cylinders and also predict how that release rate changes over time. ALOHA is open source program developed jointly by the National Oceanic and Atmospheric Administration (NOAA), United States, and the United States Environmental Protection Agency (EPA) as a part of CAMEO (Computer Aided Management of Emergency Operations) software suite[3].

2. Methodology:

2.1 Heavy Gas Model:

ALOHA uses DEGADIS model[4] for the calculations of heavy gas dispersion. The numerical methods used in ALOHA i.e. ALOHA-DEGADIS have been simplified compared to DEGADIS. The ALOHA uses ambient air pressure as independent of position and time. ALOHA assumes that pollutant and air behave as non-interacting ideal gases. Therefore, ALOHA is designed to model time dependent releases[3].

2.2 Study Area:

The selected study area for the ALOHA simulation is Ahmedabad, Gujarat. As Ahmedabad is the fifth largest city of India having population of nearly 63 million [5] and seventh largest metropolitan area of about 464 km^2 with population density of about 12 thousand people per kilometer square [6]. Ahmedabad is located at 23.03° North latitude and 72.58° East longitude in western India at an average elevation of 53 meters from sea level on the banks of the Sabarmati River, in north central Gujarat.

2.3 Release Location:

The arbitrary potable water treatment plant in Chandlodia, Ahmedabad, Gujarat is considered for the study. The selected plant site is located at 23° 5.13’ North latitude and 72° 32.5’ East longitude at an elevation of about 53 meters from sea level.

2.4 Release Time:

The considered release time of chlorine gas for the study is 1st January 2014 at 2:40 Hours.

2.5 Site Terrain:

The single story building with sheltered surroundings, i.e. trees or buildings, is considered for the release of liquefied chlorine gas.

2.6 Data Collection:

The latitude and longitude of selected site was collected by Google Earth. The meteorological data i.e. wind speed of 2.1 m/sec from NNE direction, ambient temperature of 13 ^{o}C, humidity of 75%, etc. for the chlorine gas release time was collated from WunderSearch through Averaged Metar Reports (AMR) [7].

2.7 Chlorine Storage:

The single liquefied chlorine gas cylinder of standard size having capacity of 70 kg is considered.

2.8 Release Scenario:

The following four types of chlorine gas release scenarios were studied in ALOHA.

Scenario 1: Direct continuous release of chlorine gas with the release rate of 70 kg/hr for the duration of 60 minutes.

Scenario 2: Direct instantaneous release of 70 kg of chlorine gas in a minute.

Scenario 3: Liquid chlorine of 70 kg mass release from cylinder to form evaporating puddle of 1 meter diameter on concrete floor.

Scenario 4: Chlorine gas leakage from the damaged vertical cylinder of capacity 70 kg.

3. Results and Discussion:

The chlorine toxic threat zone is an area where a toxicity of chlorine has exceeded a user-specified Level of Concern (LOC) [3]. The considered LOCs for modeling of liquefied chlorine gas release is 60-min AEGLs (Acute Exposure Guideline Levels)" of chlorine gas.

The toxic treat zone results of the ALOHA will be presented in the form of contour plots and can be displayed on Google Earth Images with scale.

Figures 1, 2, 3 and 4 shows toxic treat zone generated by ALOHA for the considered release scenario 1, scenario 2, scenario 3 and scenario 4 respectively. As can be seen after an hour of release, chlorine cloud of 0.5 ppm, 2.0 ppm and 20.0 ppm concentration has already spread out to cover the urban area.

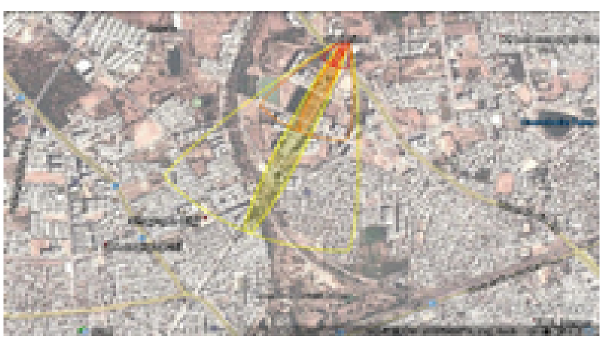

Figure 1: Toxic threat zones of considered release scenario 1.

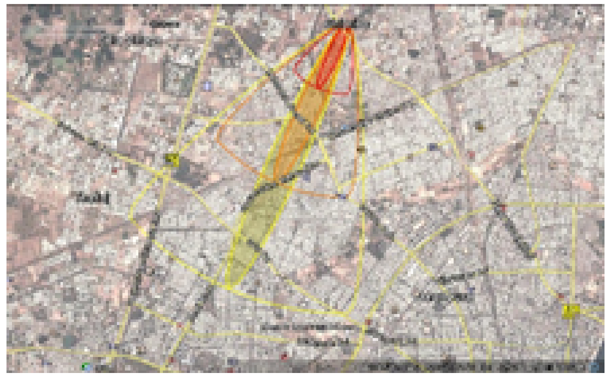

Figure 2: Toxic threat zones of considered release scenario 2.

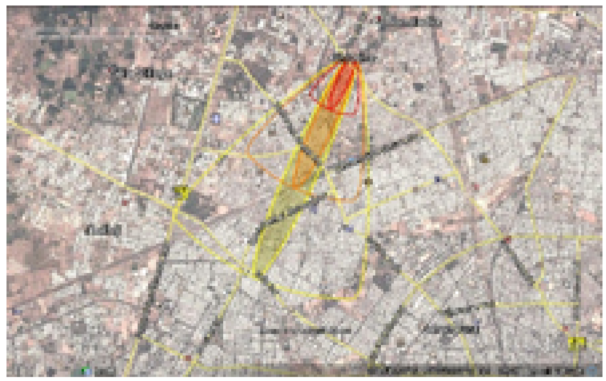

Figure 3: Toxic threat zones of considered release scenario 3.

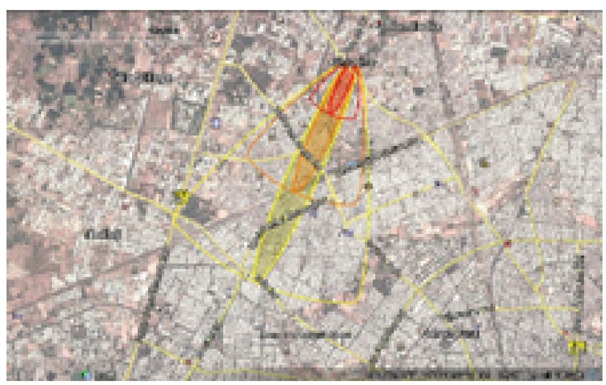

Figure 4: Toxic threat zones of considered release scenario 4.

Figure 5, 6 and 7 compare concentrations of 0.5 ppm, 2 ppm, and 20 ppm, respectively, after the chlorine gas release for all release scenarios. Observation of the contour plots of chlorine release shows that the highest toxic treat zone area is obtained in release scenario 2, characterized by instantaneous chlorine gas release of about release rate of 1.17 kg/second i.e. 70 kg/minute.

By considering scenario 2 i.e. Prediction of maximum toxic threat zone area, we can make better Disaster Management Plan, Environmental Management Plan, Health & Safety Plan, etc. of the potable water treatment plant.

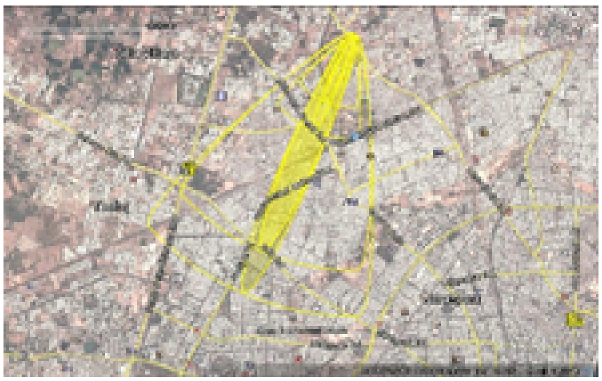

Figure 5: Toxic threat zone for AEGL concentration of 0.5 ppm for all the considered releases of liquefied chlorine gas.

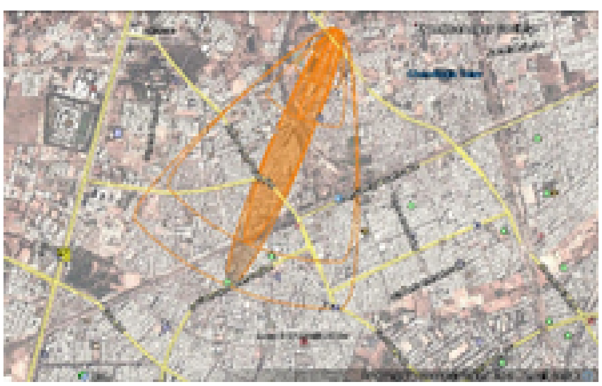

Figure 6: Toxic threat zone for AEGL concentration of 2.0 ppm for all the considered releases of liquefied chlorine gas.

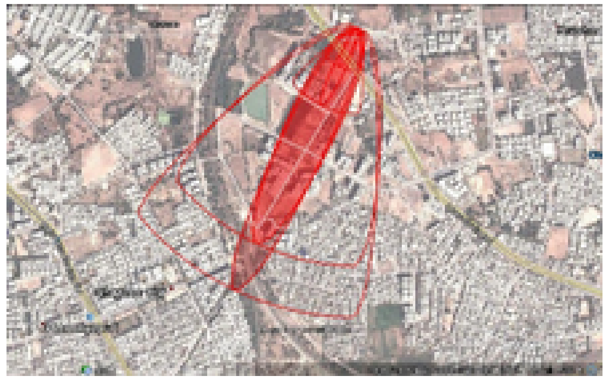

Figure 7: Toxic threat zone for AEGL concentration of 20.0 ppm for all the considered releases of liquefied chlorine gas.

The Table 1 shows the ALOHA generated results of considered release scenarios. It can be seen that for the same quantity of chlorine storage i.e. 70 kg, we get different release rate for different catastrophic scenarios. Hence, get different toxic threat zones. Therefore, always proper preventive measures should be taken while handling chlorine gas to restrict these type of catastrophic scenarios.

Table 1: ALOHA Results for Release Scenarios.

Release Scenario	**Red Zone (20ppm)**	**Orange Zone (2ppm)**	**Yellow Zone (0.5ppm)**	**Release Rate**
Direct continuous	128 m	445 m	928 m	1.17 kg/ min
Direct instantaneous	862 m	2.1 km	3.5 km	70 .0 kg/ min
Evaporating puddle	254 m	739 m	1.3 km	4.51 kg/ min
Vertical cylinder leakage	709 m	1.8 km	3.0 km	68.6 kg/ min

4. Conclusion:

The study shows that by using open source software like ALOHA, we can predict the toxic threat zone created by the release of hazardous chemicals. The ALOHA results show that, under the scenario hypothesized here, it is not feasible to actuate an evacuation program once the heavy gas cloud is released from the selected site of the potable water treatment plant, as the time elapsing before the gas cloud reaches the urban area is far too short. In this respect, mitigation measures such as installing loudspeakers to warn the population to stay indoors and take action to seal windows and doors are possibly the most useful to undertake.

5. References:

1. Bureau of Indian Standard, Code of Safety for Chlorine, IS: 4379-1967 (1995, Reaffirmed).
2. F. Scargiali, E. Di Rienzo, M.Ciofalo, F. Grisafi,A. Brucato, Heavy gas dispersion modelling over a topographically complex mesoscale: a CFD based approach, Trans. IchemE, Process Safety and Environmental Protection, Volume 83 (B5), pp.1-16, 2005.
3. ALOHA, U.S. Department of Commerce, National Oceanic and Atmospheric Administration, November, 2013.
4. J.A. Havens, T.O. Spicer, Development of an Atmospheric Dispersion Model for Heavier Than Air Gas Mixtures, Defense Technical Information Center, Volume 1, 1985.
5. Provisional Population Totals, Census of India, 2011.
6. India: Major Agglomerations, Thomas Brinkhoff, 25th January, 2014 (Retrieved).
7. Weather History for Ahmedabad, India, WunderSearch,10:00 AM (IST), 18th February, 2014. http:// www.wunderground.com