International Journal of Advance and Applied Research (IJAAR)
Peer Reviewed **Bi-Monthly**
ISSN – 2347-7075
Vol. 1 No.2
Nov – Dec 2013

ASSESSMENT OF ACCIDENTAL RELEASES HEAVY GAS DISPERSION FROM CHEMICAL INDUSTRIES VARYING WIND PARAMETER

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ABSTRACT:

Accidental releases of heavy gases such as chlorine, natural gas, liquefied petroleum gas, etc do occur, though rarely, in many chemical industries. The impact of these heavy gases in the surrounding atmosphere is very harmful/ hazardous to the human health. In this paper, the study of an analytical model for heavy gas dispersion based on modifications in plume path theory. Study has been carried out to simulate the effect of the wind speed, density of the gas and venting speed on the dispersion of heavy gas.

Case study of industrial accidental release scenarios to identify the downwind concentration along with the horizontal distances is presented. Comparison of the predicted values of heavy gas concentrations obtained from the SLAB model for the heavy gas dispersion and integrated jet models is also presented.

Key words – Heavy gas dispersion, Wind velocity, Integral jet model, SLAB model.

INTRODUCTION:

A dense gas is defined as any gas whose density is greater than the density of ambient air through which is being dispersed. This result can be due to a gas with a molecular weight greater than the air, or a gas with a low temperature due to auto-refrigeration during release. The mechanisms of dense gas dispersion differ markedly from neutrally buoyant clouds. When dense gases are initially released, these gases slump towards the ground and move both upwind and downwind. e.g. Ammonia, Chlorine, Hydrogen sulphide, Liquefied petroleum gas, CF_4, C_2F_6, etc.

As a gas cloud disperses two events occur; the concentration of the gas cloud decreases and with this change the gas cloud density will approach that of air. Therefore, as a gas cloud disperses its behavior changes and finally becomes neutral with air. A diluted gas will never separate again from air to produce higher concentrations. [17]

Many gases used in industrial processes may have molecular weights larger than air and are denser than air even at ambient temperatures. In proximity to the ground, a dense cloud will tend to spread laterally, and the vertical diffusion will be suppressed. This can give rise to high ground-level concentrations, so the prediction of dense gas dispersion in the atmosphere is a topic of considerable interest for emergency response and site safety studies.

The dispersion of a dense gas cloud or plume proceeds through several phases, dependent on the dominant physical mechanism involved as shown in figure 1. [12]

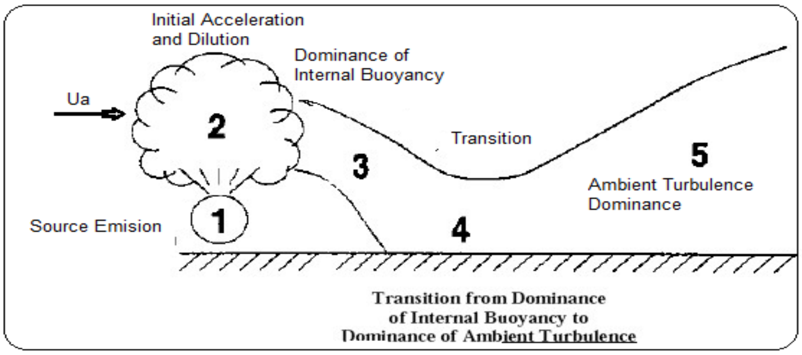

Figure 1: An illustration of different phases in the dispersion of heavy gas clouds.

METHODOLOGY:

Atmospheric dispersion of the release is calculated by solving the conservation equations of mass, momentum, energy and species. A continuous release (very long source duration) is treated as a steady state plume. In the case of a finite duration release, cloud dispersion is initially described using the steady state plume mode and remains in the plume mode as long as the source is active.

Integral jet Model:

Hoot, Meroney and Peterka (1973), Ooms (1974), Khan and Abassi (1999), Banerjee (1996), The integral jet models are used to describe continuous, elevated releases of the heavy gases. They are based on the integration of conservation equations of mass, species, downwind and crosswind momentum and energy averaged over a jet cross section. These equation directly pradict jet variables such as the concentration, jet velocity, radius, enthalpy. In steady state integral models the jet variables are evaluated as a function of the downwind distance.

In the HMP model(Hoot,1973) which is one of the very first models of this type it is assumed that the distribution of the variables within the jet of the circular shape are uniform at a given distance from the source. It is also assumed that the specific heats of the jet and air are equal. The model equatons are solved analytically for an upward-pointing jet leading to the analytical expressions. [11]

$$\frac{dh}{2R_0} = 1.32 \left[\frac{w_o}{u_a}\right]^{\frac{1}{3}} \left[\frac{\rho_{co}}{\rho_a}\right]^{\frac{1}{3}} \left[\frac{w_o^2 \rho_{co}}{2R_o g(\rho_{co} - \rho_a)}\right]^{\frac{1}{3}} \quad \text{---- (1)}$$

The ratios of the maximum concentration (C_m) to the initial mass concentration (C_o) at the downwind point where the maximum initial rise occur and at the point where the cetreline stricks the ground are as follows,

$$\frac{C_m}{C_o} = 1.688 \left[\frac{w_o}{u_a}\right] \left[\frac{dh}{2R_o}\right]^{-1.85} \quad \text{---- (2)}$$

-------maximum conc.at maximum initial rise

$$\frac{C_m}{C_o} = 2.43 \left[\frac{w_o}{u_a}\right] \left[\frac{h_s + dh}{2R_o}\right]^{-1.95} \quad \text{---- (3)}$$

--------maximum conc.at which centreline of plum strick the ground

Industrial Accidental Scenario:

Accidental release of ammonia from the storage tank vent and chlorine as vertical jet from stack are considered for computing ground level concentration using SLAB (a heavy gas dispersion model) and Integral jet model. The results obtained from these models are presented in this paper.

Releases of Chlorine Vapour:

This problem is a hypothetical release of chlorine vapor from a vertical jet. Since chlorine has a molecular weight greater than that of air, the resulting cloud is denser-than-air at all concentrations. The maximum ground level concentration is computed using Equations 1 to 3 are computed for different wind velocity ranging from 1 m/sec to 25 m/sec. These maximum ground level concentrations are computed its values obtained from SLAB model for the same release scenario. The input parameters used for this case of taking are using Table 1. The SLAB dispersion calculation begins with the plume rise calculation which extends over a downwind distance varying from x = 107.55 m to x =116.78 m, for wind velocity varying from u_a = 1 m/sec to u_a = 25 m/sec. Beyond the plume rise region, the SLAB dispersion calculation continues in the steady state plume mode until the release is terminated at t = 300 s. At this time, the dispersion calculation changes to the transient puff mode for the duration of the simulation. [4]

The sensitivity of the downwind concentration of vertical release of Chlorine gas with changes their wind velocities are determined for ranging 1 m/sec to 25 m/sec. The maximum ground level concentration obtained using Equation 1 to 3 for different wind velocities are compared with the result obtained from SLAB model for same wind velocities and the result as shown in Figure 2.

The Source and the meteorological parameters are given in Tables I and II respectively.

Table I: Source Parameters

Source Parameters	**Values**
Initial velocity (m / sec)	5.62
Initial density (Kg / m^3)	3.61
Initial radius (m)	0.02
Height of release (m)	10

Table II: Meteorological Parameters

Air density (Kg / m^3)	1.277
Wind velocity (m / sec)	From 1 to 25
Stability class	D (neutral)

RESULT & DISCUSSION:

It is observed that the maximum downwind concentration decreases with respect to the increasing the wind velocity. Figure 2 shows same behaviour for the maximum downwind concentration predicted using Equation 1 to 3 and SLAB model with respect to the increasing wind velocity. For the predicted equation the maximum downwind concentration at distance Xg = 107.55 m is 0.004963 (volume fraction) at the wind velocity u_a = 1 m/s. For SLAB model the maximum downwind concentration at Xg = 107.55 m is 0.0027 (volume fraction) at same wind velocity u_a = 1 m/s. Also, at u_a = 25 m/sec, the maximum downwind concentration predicted by equations 1 to 3 is 0.000496 (volume fraction) and for SLAB model is 0.000408 (volume fraction) at maximum horizontal distance of Xg = 116.7855 m.

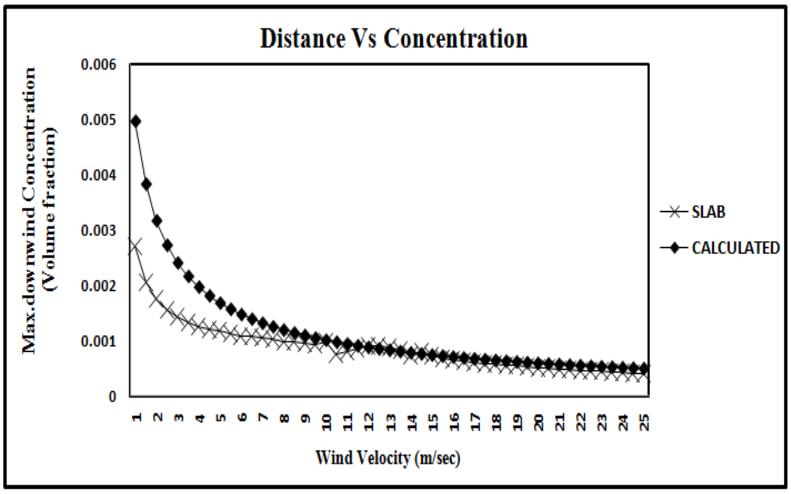

Figure 2: Variation of downwind concentration by using SLAB model and predicted equations with different wind velocities

CONCLUSION:

The present study covers the different steps required for the identification of the various hazardous distances and their concentration due accidental release of heavy gas through the vertical jet form. The study includes the different model equations to analyse the maximum horizontal safety distance at surrounding atmosphere release of heavy gas.

Accidental release of heavy gases from the chemical industrial processes or storage containers can typically be modelled by either dense-gas model i.e. SLAB or Integral jet model. While each model has its assumptions and limitations, the common limitations among these models discussed in this study include:

- A single set of meteorological conditions is used to represent the whole dispersion phenomenon.
- A flat terrain is assumed. In other words, the effects of complex terrain (e.g. hilly areas) or building downwash are not considered.
- A single release source is allowed in case study.
- No chemical reactions in the plume are considered.

As shown in the case studies, while more than one model can be applied to a specific release scenario, different models may give different results due to inherent assumptions and limitations associated with each model. Details of the release scenario should be reviewed carefully in order to reach a reasonable decision. More importantly, a model that gives best result may not be the most suitable model for the occasion.

As the pollutants being heavier than air it is recommended that use of heavy gas dispersion model such as SLAB, which are conservative values. Applications of SLAB model and other heavy gas models will be useful for computing safe distances and for providing risk based action plan for taking appropriate measures for reducing any material/human loss due to accidental releases.

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