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Characteristics of Hazards of Coke-Oven Gas and Blast Furnace Gas - A Case Study

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ABSTRACT

Industrial disaster can strike at any time, but the Bhopal gas tragedy remains a catastrophe with no parallel. It is, till date, the worst industrial disaster in the history of mankind. Fire hazards of coke-oven gas and blast furnace gas lead to fatal consequences. This paper highlights some salient features of the fire hazards scenarios from a coke-oven storage tank and blast furnace storage tank, which ultimately lead to jet-fire/flare with enormous heat wave all around and their consequence analysis with affected areas. Damage distances have been calculated by using Complex Hazardous Air Release Model (CHARM) software and it has been observed from the study that there may be 100% fatality within a radius of 350 m for the coke-oven storage tank, and 283 m from blast furnace storage tank.

INTRODUCTION

The rapid increase in the manufacturing, storage and handling of a wide variety of hazardous chemicals have brought about a situation in India where the safety of workers employed in the factory and the general public living in the vicinity of the factory could be endangered at any point of time because an accident involving these chemicals may cause injury or loss of life or damage property including adverse effect on environment or disruption in and around the factory. Bhopal and other similar catastrophes gave rise to a new classification of industries having potential for major accidents such as major emission, fire or explosion with off-site consequences on human life and environment. The Bhopal incident triggered interest from industry, academia and legislators and is widely acknowledged as one of the defining events in the history of process-safety. In spite of the improved design procedures being followed by the industry to set up the plants, there are accidents of various degrees of severity taking place in chemical industry. Most of them are minor in nature and get analysed by the concerned industry itself. But, some of them turn out to be of very serious nature and result in death and damage not only inside the factory premises but also outside.

As per the Factories Act, carbon-monoxide poisoning is one of the noticeable diseases throughout the world. Coke-oven and blast furnace gas consist of carbon-monoxide gas and hence it is also very important from the medico-legal aspect.

Under the Manufacture, Storage and Import of Hazardous Chemicals Rules, 1989, amended in 2000, issued by the Govt. of India, threshold quantities of hazardous substances presenting major accidents are mentioned. The rules defined hazardous chemicals based on their inherent characteristics of toxicity, flammability and explosivity.

In India a total of 586 Maximum Accident Hazardous (MAH) units and 75 hazardous chemicals are distributed throughout the country. The distribution of MAH units and hazardous chemicals across the various States of India (Raghvan & Swaminathan 1996) is given in Table 1.

In Durgapur, one of the scenario identified is jet fire/flare of coke-oven gas from coal gas plant and blast furnace gas from steel plant. Hazards of jet fire/flare are illustrated as an emergency scenario.

The study area and hazards of coke-oven and blast furnace gas: Taking situation of Durgapur area in Burdwan district located at 23.48° N and 87.32° E at 160 km from Kolkata, there are 11 MAH installations as per "The Manufacture Storage and Import of Hazardous Chemicals Rules (MSI)". The MSI Rules enacted in 1989 under the Environment Protection Act, 1986, subsequently amended in 1994 by Govt. of India represent a comprehensive attempt to regulate major accident hazard installations, comprising factories, isolated storage and cross-country pipelines. All these industries have their own on-site emergency plan. In this context, the sub-division is also having off-site emergency plan for which District Collector of Burdwan acts as Emergency Authority. Coke-oven gas is categorized as a hazardous/toxic chemical, containing mainly hydrogen and methane. On the other hand blast furnace gas is also categorized as a hazardous/toxic chemical, containing mainly carbon monoxide.

Coke oven gas, a hazardous gas, also called coal gas, is the gas obtained when coal is heated in an air tight place in pyrolysis process. It consists mainly hydrogen and methane. Coke oven gas is burned to produce heat in industrial plants and in homes. The coke-oven gas contains hydrogen-55%, methane-24%, ammonia-3.5%, carbon monoxide-9%, carbon dioxide-3%, nitrogen-3%, oxygen-0.5%, and hydrocarbons and others (ethane, ethylene, benzene, cyclopentadiene, toluene, naphthalene, hydrogen sulfide, water vapour, hydrogen cyanide, cyanogen, nitric oxide)-2% . Coke-oven gas is yellowish in colour with pungent odour and lighter than air (0.45 times lighter).

Blast furnace gas is a by-product of blast furnaces, also a hazardous gas that is generated when the iron ore is reduced with coke to metallic iron. It has a very low heating value, about 93 BTU/cubic foot, because it consists of about 56% nitrogen,16.5% carbon dioxide, which are not flammable. Hydrogen 2% and methane 0.5 % are also present in this gas. The rest 25% is carbon monoxide, which has a fairly low heating value. It is commonly used as a fuel within the steel works, but it can be used in boilers and power plants equipped to burn it. It may be combined with natural gas or coke oven gas before combustion or a flame support with richer gas or oil is provided to sustain combustion. Blast furnace gas is sometimes flared without generating heat or electricity.

Blast furnace gas is generated at higher pressure and at about 100-150°C in a modern blast furnace. Auto-ignition point of blast furnace gas is approx. 630-650°C and it has LEL (Lower Explosive Limit) of 27% and UEL (Upper Explosive Limit) of 75% in an air-gas mixture at normal temperature and pressure. Blast furnace gas is almost colourless (mild whitish), odourless and heavier than air. Higher concentration of carbon-monoxide makes the gas hazardous.

A jet fire/flare is a pressurized stream of combustible gas or atomized liquid that is burning. If such a release is ignited soon after (i.e, within 2-3 minutes), the result is an intense jet fire/flare. This jet fire stabilizes to a point, which is close to the source of release, until the release is stopped.

The consequences arising out of the release of flammable chemicals and toxins are dependent on the prevailing meteorological conditions. The meteorological data of Durgapur with respect to wind speed and wind direction are given in Table 2. The average values show that there are predominantly two directions from which wind blows in this area, viz., south and north.

MATERIALS AND METHODS

Consequences of hazards of coke-oven gas and blast furnace gas: Prediction and consequence assessment of eventual accidents are not easy to accomplish due to the uncertainty of the kind and the amount of hazardous materials present at a certain time and place (ILO 1990). Nevertheless, typical scenarios of possible accidents can be developed considering the maximum quantities of typical dangerous substances often arriving at the port. Quantification of risk and consequences assessment associated with accidents involving hazardous materials have been carried out by several authors (Ruj et al. 2006, Ruj et al. 2009, Spadoni & Uguccioni 2003, Tixier et al. 2002, Ditali et al. 2000, Khan & Abbasi 1999, Ruj 2005, Ruj & Chatterjee 2007).

Considering all the possible identifications with regards to hazards of coke-oven and blast furnace gas, the following hazardous scenarios at Durgapur on the basis of engineering judgement and expertise in the field of risk analysis were studied.

Release of toxic/flammable gases from storage tanks storing coke-oven gas and blast furnace gas: The maximum credible loss scenarios have been assessed for possible inadvertent accidents by applying Complex Hazardous Air Release Model (CHARM) software package. CHARM is a modelling program that calculates and predicts the dispersion and concentration of airborne plumes from released chemicals. CHARM also predicts the footprints of thermal radiation and overpressure.

In this work, accidental scenario based on real data is presented. The results show that an eventual accident will extensively damage the surroundings, even causing significant fatalities in the affected population.

RESULTS AND DISCUSSION

Jet fire/flare from major leakage of coke-oven gas in coal gas storage tank: About 56,000 cu. m coke-oven gas is stored in one gas holder at an approximate pressure of 350 mm water gauge. The assumptions of this scenario are heavy leakage of gas due to rupture of outgoing/incoming pipe due to sabotage, riot, corrosion, etc., and getting ignited from an external source.

The thermal consequence models provided a set of radiant heat fluxes expressed in kW/m^2 at a set of distances at which the following heat flux thresholds occurred: 4.7 kW/m^2, a pain threshold, 12.5 kW/m^2, first-degree burn threshold and 37.5 kW/m^2, mortality threshold (AICE 1989).

It has been estimated by applying CHARM software that damage distance for heat flux of 37.5 kW/m^2 will have approximately 350 m radius and for heat flux of 4 kW/m^2, it will be about approximately 1 km. The total time duration would be about 1.2 hours. Hence, serious damage will occur to process equipments within 350 m radius zone. This will also have disastrous effect on the work force in that area.

Table 1: State-wise distribution of major hazardous units (MAH) and hazardous chemicals.

State	MAH units	Hazardous chemicals
Andhra Pradesh	35	24
Assam	7	10
Bihar	12	11
Delhi	19	8
Goa	8	9
Gujarat	112	32
Haryana	7	4
Jammu & Kashmir	7	4
Karnataka	26	14
Kerala	19	19
Maharastra	97	24
Madhya Pradesh	33	10
Nagaland	1	1
Orissa	13	10
Pondicherry	3	3
Punjab	12	6
Rajashthan	54	17
Tamilnadu	41	31
Uttar Pradesh	40	14
West Bengal	40	23

It is observed from this analysis that there may be 100% fatality within a radius of 350 m from this coke-oven storage tank. In the remaining band damage due to fire burn injuries of varying degrees may result from thermal radiation.

A jet fire is usually a localized, but very destructive to anything close to it. This is partly because of producing thermal radiation; the jet fire causes considerable convective heating in the region beyond the tip of the flame. The high velocity of the escaping gas entrains air into the gas 'jet' causing more efficient combustion to occur than pool fires.

Although damage distances are calculated, based on thermal radiation level, the degree of injury also depends upon the duration of exposure. But, it is worth mentioning in this context that human beings are also vulnerable to prolonged exposure to low-level heat flux or thermal radiation.

The jet fire/flare may have serious domino and cascading effects on the storage/process areas of flammable chemicals, triggering off fire and explosion, the effect of which may travel off-site.

Jet fire/flare from major leakage of blast furnace gas in blast furnace storage tank: About 1,00,000 cu.m blast furnace gas is stored in one gas holder at an approximate pressure of 350 mm water gauge.

The assumptions of this scenario are heavy leakage of gas due to rupture of out-going/ incoming pipe due to sabotage, riot, corrosion, etc., and getting ignited from an external source.

It has been estimated by applying CHARM software that damage distance for heat flux of 37.5 kW/m^2 will have about 283 m radius and for heat flux of 4 kW/m^2, it will be about 832 m. The total time duration would be about 1 hour. Hence, serious damage will occur to process equipments within 283m radius zone. This will also have a disastrous effect on the work-force in that area.

Table 2: Meteorological data.

Month	Wind speed (m/s), Avg.	Wind direction (deg.)	
		Min.	Max.
May	0.79	182.11	2.59
June	0.84	1.54	269.96
July	1.12	3.55	0
Aug	1.20	0	51.04
Sept	5.92	0	310.66
Oct	8.61	0	45.81
Nov	6.33	238.0	44.43
Dec	1.58	282.04	31.45
Jan	1.21	217.40	337.34
Feb	3.71	250.76	4.53
March	2.81	266.60	335.78
April	1.86	48.94	357.97

It is observed from this analysis that there may be 100% fatality within a radius of 283 m from blast furnace storage tank. In the remaining band, damage due to fire burn injuries of varying degrees may result from thermal radiation.

The jet fire/flare may have serious domino and cascading effects on the storage/process areas of flammable chemicals, triggering off fire and explosion, the effect of which may travel off-site. Thus, preparedness is required to effectively handle the off-site emergency for adequate fire-fighting, rescue, evacuation and medical treatment for burn injuries.

CONCLUSIONS

It has been observed from this study that there may be 100% fatality within a radius of 350 m for the coke-oven storage tank, and 283 m for blast furnace storage tank. In the remaining band for both the coke-oven and blast furnace storage tank, damage due to fire burn injuries of varying degrees may result from thermal radiation. Followed by emergency plan preparations, regular mock-drills may provide enough preparedness required to avert a major crisis. Compliance to regular safety audits is necessary in addition to other mandatory requirements. Maintenance of proper working condition is necessary. Consequence analysis could help manufacture plants, local governments and communities to address needs for improving their mitigation facilities and warning systems for disaster prevention and protection programs. Moreover, government should regulate and mandate coke-oven gas storage tanks and blast furnace storage tank to execute their consequence analysis in order to identify problems in advance and to lessen possible impacts on public safety. A good communication system, regular interaction between various departments, education and safety training of the employees, review of past accidents/reports/published safety reviews, daily site inspection and ready availability of emergency equipment are the key areas of effective off-site emergency preparedness. Since, the disaster may result in burn injuries, upgradation of medical facilities and the associated infrastructure may be necessary to mitigate the effect of the crisis, particularly for the area under study.

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