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Review Article

An incident of massive styrene monomer gas poisoning

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ABSTRACT

Following a temporary and partial shutdown of the LG polymers factory for nearly 44 days due to the COVID-19 lockdown, routine maintenance of the plant was affected. At around 3 a.m. on 7 May 2020, a failure of the refrigeration system and the inhibitor tank attached to the styrene storage tank, resulted in an auto polymerization reaction that caused nearly half of the 1800 tonnes styrene gas stored to leak into the atmosphere. Since the volatile organic compound detection system was defunct, no alert or alarm was raised and, driven by north easterly winds, a cloud of toxic styrene gas spread over a radius of nearly 3 km, affecting five villages in the vicinity. The pungent smell was initially mistaken by the residents as emanating from a fire accident or a COVID-19 sanitization measure in the vicinity. Following initial triage, over 350 victims were hospitalized in various hospitals. 254 symptomatic adults and 64 children were shifted to the Government King George hospital. The main symptoms were burning sensation of eyes, skin and throat, nausea, vomiting, diplopia, muscle twitching, breathlessness and loss of consciousness. Nearly 10,000 residents from five villages were evacuated to relief camps set up in the perimeter and given first aid and food. There were 11 human and 22 animal fatalities in the immediate vicinity. This incident reports the world's first fatalities due to massive styrene poisoning

Keywords: Styrene monomer gas, Toxicity, Chemical disaster

INTRODUCTION

The Hindustan polymers factory was established in 1961 over 231 acres of land in RRV Puram, Gopalpatnam (15 km away from the Visakhapatnam city centre) to manufacture general purpose polystyrene. The unit was merged with McDowell & Co. of the UB group in 1978 and by LG chemicals South Korea in 1997 and renamed LG polymers. It was upgraded to manufacture high impact and expandable polysterene as well as engineering plastics. The site has refrigerated tanks capable of storing 2400 tonnes of styrene gas at temperatures below 17°C.

Following a temporary and partial shutdown for nearly 44 days due to the COVID-19 lockdown, routine maintenance of the plant was affected. Compounded by a failure of the refrigeration system, and failure of the inhibitor tank attached to the styrene storage tank, auto polymerization reaction set in and half the 1800 tonnes styrene gas leaked into the atmosphere at around 3 am on 7 May 2020 (Figure 1). Since the volatile organic compound detection system was defunct, no alert or alarm was raised and, driven by north easterly winds, a cloud of toxic styrene gas spread over a radius of nearly 3 km, affecting five villages in the vicinity (Figure 2).

Figure 1: Styrene gas leak from storage tank at LG polymers, Visakhapatnam.

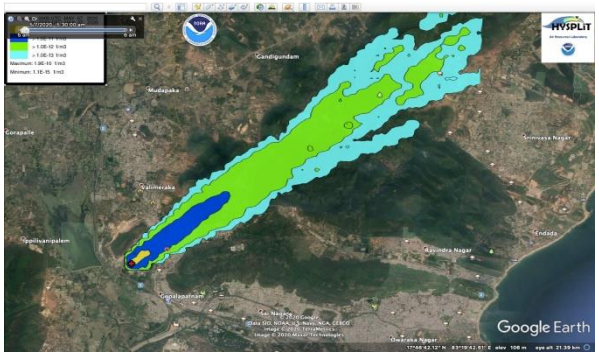

Figure 2: Spread of styrene monomer gas cloud after leak.

The immediate scenario

A cloud of styrene gas enveloped the villages of RR Venkatapuram I and II, SC/BC colony, Padmanabhapuram and Nandamurinagar. The pungent smell was initially mistaken by the residents as emanating from a fire accident or a COVID-19 sanitization measure in the vicinity. When many of the residents became symptomatic with nausea, dizziness, severe burning sensation in eyes and throat, suffocation and dizziness, panic ensued. Scared for their lives, the villagers grabbed their valuables and headed out on two wheelers while others ran into the streets and hailed whatever available transport to distance themselves. Many of them locked themselves in their houses to avoid ingress of the gas. Blinded by the vapour, a 19 years old medical student lost his bearings and fell to his death from the second floor of his apartment while two others fell into a well and drowned. A six years old girl and seven adults developed severe breathlessness and succumbed.

The Gopalpatnam police station received an alert at 3:45 a.m., and by 4 a.m. the first team reached the spot to assess the situation. They radioed for help and 30 ambulances, police jeeps and patrol vehicles, as well as state transport buses were mobilized to evacuate victims and residents after initial triage. Loud hailers advised residents within a radius of 5 km to cover their face with a wet cloth or mask abandon their residence and move to areas of safety. By 6 a.m., the state disaster relief teams supported by a naval team donning protective suits and equipped with 50 breathing sets and portable air compressors conducted house to house search and rescue operations in the affected zones and rescued residents trapped in their residences.

Medical management

Following initial triage, over 350 victims were hospitalized in various hospitals. 254 symptomatic adults and 64 children were shifted to the Government King George hospital. 165 others were admitted to 10 private and corporate hospitals. 25 victims were severely breathless and in a critical condition and 20 of them with pulmonary edema required endotracheal intubation and ventilatory support in the ICU. The main symptoms were burning sensation of eyes, skin and throat, nausea, vomiting, diplopia, muscle twitching, breathlessness and loss of consciousness. A pungent odor was appreciated in the breath and sweat for several days following admission. Those requiring ventilation exhibited elevated serum lactate and respiratory acidosis in the blood gas. Serum electrolytes and other blood parameters were normal and all of them could be weaned off supports within 48 hours. Lungs were clear in the rest of those admitted and chest X-rays normal. Urine was normal in color. Urine mandelic acid assay could not be done for any of the victims due to non availability of kit or reagents.

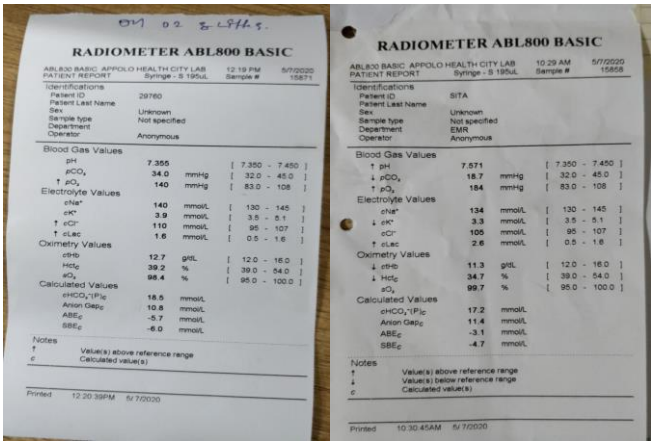

Figure 3: Blood gas analysis of a victim of styrene gas poisoning before and after ventilation.

Treatment protocols observed were body wash with water, high flow oxygen inhalation and intravenous fluids. Those with obtunded levels of consciousness were kept nil oral while those with severe agitation were administered low dose midazolam or haloperidol. No specific antidote was advised or exhibited.

Nearly 10,000 residents from five villages were evacuated to relief camps set up in the perimeter and given first aid and food. While 24 children were

discharged on day 3, 38 others with persistent symptoms were under observation for delayed effects of styrene monomer poisoning.

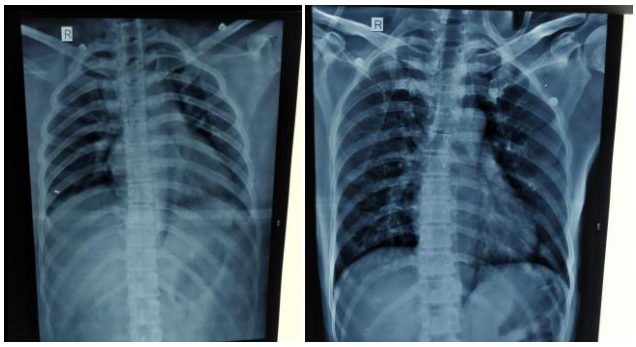

Figure 4: Chest X-ray views of two styrene gas poisoning victims.

The aftermath

The SDRF and NDRF teams undertook water mist spraying to drive atmospheric styrene into the ground while the styrene storage tanks were cooled with water jet sprays. Despite these measures, the styrene gas continued to leak from the tanks when 500 kg para tertiary butyl catechol (PTBC) was airlifted from Vapi, Daman, at 10.30 p.m. on 7 May Thursday to solidify the styrene gas remaining in the leaking tanks and prevent its escape. Other storage tanks in the plant containing 13,000 tonnes of styrene monomer gas were loaded into two vessels in two consignments of 8000 and 5000 tonnes to the parent company in South Korea by 15 May 2020.

About 22 domestic animals including cows and buffaloes and their calves were killed in the incident within a 1.5 km radius of the factory. Additionally, six stray dogs and one cat also perished due to gas inhalation.

The gas leak disrupted the movement of 45 trains, nine shramik specials and the rest goods carriers, as rail workers suffering from irritation in their eyes and breathlessness halted work. Train services came to a halt at the Simhachalam north railway station (SCMN) in Visakhapatnam, near the chemical factory, between 8:35 hours and 12:00 hours, leading to several trains being stranded and prompting authorities to divert some others via Kondapalli and Ballarshah routes.

By 12 May, villagers began to return to their dwellings but complained of a pungent odour persisting in the water and foodstuff. The Government has established medical camps in the affected areas for long term health monitoring of the affected population.

Styrene ($C_6H_5CH=CH_2$) is a high production chemical and a derivative of benzene (C6H6). Styrene, also known as vinylbenzene, ethylbenzene, cinnamene, or phenylethylene is a synthetic colourless, volatile, inflammable liquid with a sweet odour at very low concentrations, but sharp and disagreeable at higher concentrations. The boiling point of styrene monomer is 145.2°C, flash point 31°C and autoignition temperature is 490°C and saturated vapor concentration is 6600 ppm at 20°C. It is insoluble in water. Styrene is stored in factories at temperatures under 20°C.

Acute styrene poisoning occurs as a result of inhalation or absorption from the skin surface. Styrene sickness in industry describes a clinical picture after heavy exposure to styrene and other solvents and manifests as headache, nausea, vomiting, weakness, dizziness, fatigue and ataxia.[1] The inhaled level defined as immediately dangerous to life or health is 5000 ppm.[2] The lowest lethal concentration=10000 ppm/30 minutes and lowest toxic concentration=600 ppm.[3] Increasing concentrations >800 ppm results in CNS depression associated with abnormal EEG patterns, asphyxia, muscular weakness, coma and death from respiratory paralysis.[4] Levels of significant exposure (LSE) is 376 ppm and minimal risk levels (MRLs) is 60 ppb (1000 ppb=1 ppm). Smell threshold is 320 ppb.

There have been no reports of deaths in humans directly associated with exposure to styrene in the workplace.[5,6]

STYRENE METABOLISM

The biological half-life of styrene, as measured by the appearance of metabolites like phenylglyoxylic acid and mandelic acid in urine is estimated between eight and nine hours in humans.[7] The styrene concentration in blood is found to decay in a biexponential fashion typical of a two-compartment kinetics model. Blood is proposed as the first component and tissues including adipose tissue as the second slow compartment. The half-life for styrene in blood in the initial phase is 0.58 hours and in the terminal phase 13 hours.[8-11] The half-life of concentration in adipose tissue is two to four days. [12]

About 1 to 2% of the dose is exhaled unchanged. The majority of the absorbed material (about 90%) is metabolised in the liver by oxidation of the vinyl side group to styrene oxide. Styrene oxide is the active metabolite.[13] The resulting major metabolites which are excreted are mandelic acid (60-80%) and phenylglyoxylic acid (about 30%). Only very small quantities of hippuric acid and 4-vinylphenol are produced and excreted in the urine.[14] Urine samples of mandelic acid should not exceed 800 mg/gram of creatinine and phenylglyoxylic acid 240 mg/gram of creatinine. Accepted level of styrene in venous blood is 0.55 mg/L.[15]

MANAGEMENT OF STYRENE TOXICITY

Rapid, effective decontamination by staff wearing PPE is essential in the management of styrene exposure. Victims must be shifted to a safe, sheltered facility and a careful clinical evaluation done. All contaminated clothing and

shoes are removed and eyes are irrigated with isotonic saline and skin surface washed thoroughly with water and non-abrasive soap for at least 15 minutes.

Evaluation of vital signs and life-supporting measures are the main principles in poisoning management. Maintenance of a clear airway, administration of high flow oxygen 10-12 L/min by face mask, treatment of respiratory failure with intubation and IPPV, intravenous fluids to ensure good urine output >2 ml/kg/h and vasoactive drugs if required.

Do not give any food containing fats and oils and gastric lavage may be considered in massive recent ingestion. Do not induce vomiting of consciousness is obtunded. There are no specific antidotes available. Routine investigations like CBC, ABG, LFT, creatinine and urine for styrene metabolites.[16]

CONCLUSION

This mishap resulted in extremely high levels of styrene monomer exposure to those residing in the close vicinity and constitutes the first fatalities reported worldwide from its inhalation. The lack of facilities to monitor atmospheric, blood and urine levels of styrene and its metabolites has precluded a better assessment of its toxic effects. The rapid evacuation of residents within a 5 km radius was responsible for a lower mortality rate. Morbidity was; however, high and long-term effects of the exposure remains to be seen in follow up monitoring.

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