Colonel Ram Athavale, PhD examines the styrene gas tragedy of May 2020

# Gas Everywhere!

It was 2:45 am on 7 May 2020 in the Indian city of Vishakhapatnam (Vizag for short). Amid the sleeping residential areas was a factory, largely shut due to the Covid-19 lockdown. The scaled down night shift staff were there for security and to monitor basic safety issues. No one dreamt that just a few minutes later all hell would break loose. "Gas, Gas!" shouted an alert night shift worker when he smelt and saw the fog drift from tank M6 at the LG Polymers factory. Within minutes the whole factory premises and the surrounding residential areas were engulfed in foul smelling vapours. The styrene gas leak accident at the factory resulted in 11 deaths and more than 1,000 sick after exposure to the gas.

## Background

LG Polymers operates a chemical plant located in R R Venkatapuram village, within the Gopalapatnam neighbourhood on the outskirts of Vizag. The city is on India's eastern coast in the state of Andhra Pradesh. LG Polymers India Private Limited (formerly Hindustan Polymers), is entirely owned by South Korean battery maker LG Chemical. It was established in 1961 to manufacture polystyrene and its co-polymers.

LG Chemical has a very strong presence in South Korea's styrenics business and has established an equally strong presence in the Indian market. LG Polymers is part of India's plastic resin and synthetic fibre manufacturing industry. It occupies an 86.2ha (213acre) site and at the time of the accident was engaged in manufacturing on a daily basis, approximately 313tonnes of polystyrene for use in general purpose polystyrene (GPPS) and high impact polystyrene, 102tonnes for expandable polystyrene and 36.67tonnes of engineering plastics. The storage status on 7 May 2020 was as follows:

- Styrene – Two tanks as below:
  - Tank M5 – Capacity 3,285 tonnes, holding 2,726 tonnes.
  - Tank M6 – Capacity 2,790 tonnes, holding 1,830 tonnes.
- Styrene Day Tanks – Three tanks of 300 tonnes capacity. Two tanks containing 242 tonnes each. The third was empty.
- Pentane – Four tanks of 80kl (17,600gal)
- HCL – One tank of 10kl (2,200gal)

Other required chemicals and fuels were present in smaller quantities.

## The chemical

Styrofoam and Thermocol are two very common packaging materials. Technically named polystyrene (PS), the material can be a solid plastic or foamed like Thermocol. PS is a synthetic aromatic hydrocarbon polymer made from the styrene monomer, a volatile flammable organic compound. GPPS is clear, hard and rather brittle. It is an inexpensive resin per unit weight and hence a very suitable low cost material for many applications such as polystyrene plastics, fibreglass, synthetic rubber, resins, insulation and latex. It occurs naturally in some fruits, vegetables, meats, nuts and beverages.

Styrene, a neurotoxin derivative of benzene, is a colourless oily liquid although aged samples can appear yellowish. It has a specific gravity of 0.91 and a flash point of 31°C (86°F) and is thus highly flammable. The compound evaporates easily and has a sweet smell, although high concentrations have a less pleasant odour. Styrene is therefore stored in stainless steel, zinc, and/or mild steel tanks at 20oC (68°F).

Polystyrene is an addition polymer that results when styrene monomers interconnect (polymerisation). Typically, a chain of polystyrene is comprised of a few thousand monomers. Styrene must be stored in gas tanks under 20°C to keep it stable. The temperature has to be continuously monitored, and any exposure to light or heat may result in polymerisation. If the temperature rises, inhibitors must be added to keep the styrene stable, so as a safety measure, styrene tanks are never filled to capacity.

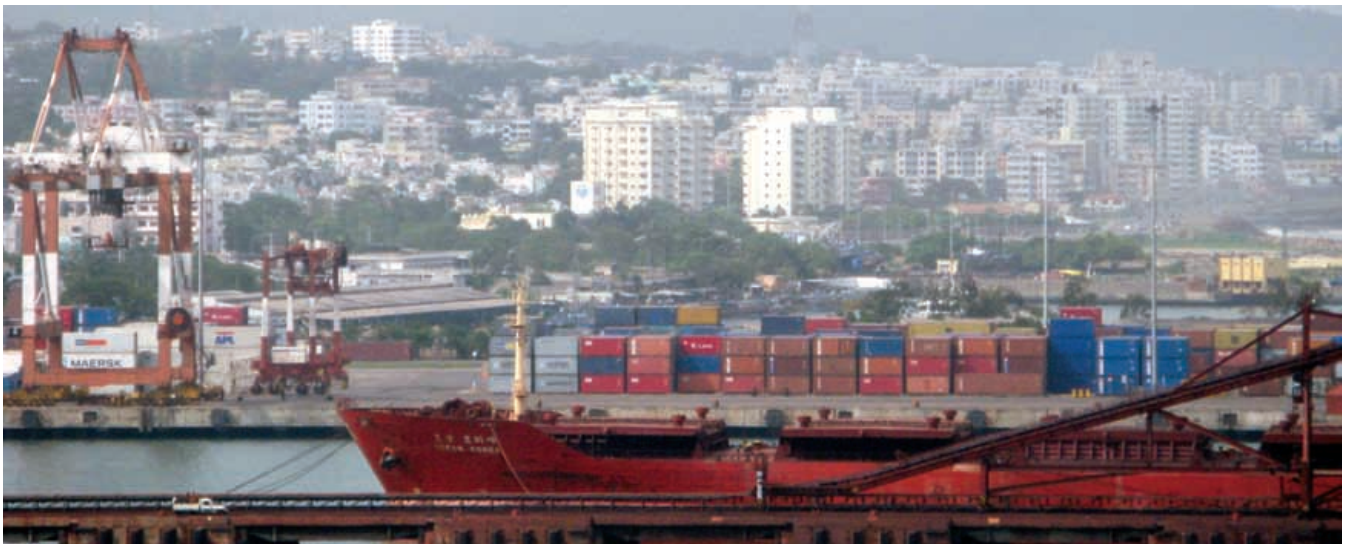
Exposure to styrene, can affect the central nervous system (CNS), causing headache, fatigue, weakness, breathlessness, respiratory problems, irritation in eyes, indigestion, nausea, transient loss of consciousness, unsteady gait, giddiness and depression. Extreme exposures can result in death.

## The accident/response timeline

On 7 May 2020 the M6 tank containing 1,830 tonnes of styrene developed a leak, with vapour coming from the top of the tank. The night shift workers heard the gas detector alarm at 2.54am and the volatile organic compounds alarm five minutes later. The workers noted a foul smelling gas release from the M6 storage tank, which soon spread westwards beyond the factory boundary due to the wind direction. The gas plume moved westwards at a height of up to 6metres (20ft) due to its properties and the prevailing meteorological conditions. Within minutes, the gas had affected the residents of five nearby areas namely Venkatapuram, Venkatadri Nagar, Nandamuri Nagar, Pydimamba colony and the BC and SC colony.

By 3.02am, the control room staff alerted the night duty officer and the management team comprising plant safety head, director operations, medical officer and others. In the meantime, the temperature of the tank began rising. The night duty officer alerted the on-site team and tried to activate the sprinklers to cool the tank, but due to strong vapours he could not access them. The team assembled by 3.05am after donning hazmat suits and self contained breathing apparatus (SCBA) sets.

The security officer called in backup from the fire brigade and nearby hospital. Around 3.10am, the on-site technician in charge identified the



*The syrene release at Vizag was entirely preventable and lives could have been saved ©Creative Commons*

cause. The director operations and safety head arrived on site by 3.45am. The styrene had auto polymerised due to a prolonged stagnant period. Around 4.30am the hazmat response team managed to reach the hydrant facility and started sprinklers for the two large styrene tanks (M5 and M6) and the pentane tanks, too. It was, however, impossible to stop the leakage.

The Vizag police control room also received a call from a resident about a foul pungent smell spreading over the area, suffocating people. By 3.45am a team of police, along with a fire tender and an ambulance rushed to Venkatapuram. Due to heavy foul odours the police team was unable to proceed to the factory and called for backup around 4am. Soon, people woke up in horror, breathless and with a burning sensation in their eyes as the emission spread to the nearby villages.

Around 5.30am the technical team began pumping chemical inhibitors (n-Dodecly Mercaptan and Eunox-76) into tank M6. Styrene was simultaneously pumped out to temporary feed preparation tanks. Continuous water sprinkling and cooling of the tank brought temperature down from 154°C to 100°C in the next 24 hours.

By 4.30am, residents were starting to leave their homes and rush towards safer places. Some of those fleeing collapsed on the roads due to breathing problems. The police and fire brigade team had to enter the factory premises from the rear due to foul gas clouds at the front. The team carried people who were unconscious and lying on the roads to the periphery and rushed them to nearby hospitals. Nearly 300 people were evacuated.

The National Disaster Response Force's (NDRF) CBRN first responder team reached the site by 5.15am. Fully equipped and in hazmat suits, the team was deployed to do house searches and take any stragglers or affected people to safety. In the meantime, the LG Polymers technicians had managed to arrest the leak.

By 6am police teams on site had set up a control room and called in additional ambulances to evacuate the area. An evacuation perimeter was established with a radius of 5km (3.11 miles). Local hospitals and clinics were alerted regarding the cases. By daylight, police vehicles were blaring warnings sirens and asking people to evacuate to safer places. All available vehicles were pressed into service to evacuate the residents. Many local volunteers were helping in the evacuation.

The district collector and senior officials of the Greater Visakhapatnam Municipal Corporation set up the incident command centre around 6am for better coordination and management of the situation. State authorities and the chief minister were briefed on the developing situation. The police cordon was expanded and a continuous flow of ambulances continued to evacuate people to hospitals or safer places till 8.30am.

A special technical team was flown into Vizag on the evening of 7 May, to investigate the accident and provide expert assistance. The team, comprising senior NDRF officers, experts from the National Environmental Engineering Research Institute and the Indian Institute of Petroleum, carried out a site assessment and investigation.

## What went wrong

Styrene production is a critical procedure and many mishaps have occurred in such units elsewhere. In the LG Polymers unit at Vizag, too, there were some glaring lapses that led to the disaster on 7 May 2020. The issues given below have been highlighted in the report of the joint monitoring committee of the National Green Tribunal (NGT), Government of India, New Delhi and the high-power committee (HPC) constituted by the Andhra Pradesh state government.

**Stagnancy**. India declared a complete lockdown on 24 Mar 2020 due to rising Covid-19 cases. Accordingly, all factories and industries except essential services were shut down, including the LG Polymers unit. As at the day of lockdown, the raw material, styrene was present in four storage

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tanks at the factory with the inventory of 1,830tonnes, 2,725.9tonnes, 242.6tonnes, 242.5tonnes. The unit was permitted daily maintenance activities during the lockdown period with 15 persons per shift so a total of 45 personnel worked there every day. They were responsible for monitoring key storage parameters and ensuring plant safety.

The government allowed partial opening of industries at the end of April 2020. LG Polymers started preparations for its proposed resumption of operations on May 7, 2020. The month and a half long shut down had allowed the styrene to settle. Circulation of the liquid had also halted, with refrigeration only provided to the lower part of the tanks.

**Refrigeration**. Insulation and refrigeration of storage tanks is essential in climates where temperatures exceed 24°C for prolonged periods. The average annual temperature of Vizag is 27.8°C, but it soars up to 37°C or more in May, which is the hottest month. The flash point of styrene monomer is 31°C, so there is a high chance of creating a flammable mixture in this warm climate. The tank which developed the leak was old and did not have temperature sensors at the middle and top surface. There was only a provision to measure the temperature at the bottom of the tank where refrigeration was provided. Mitigation of the impact could have been more effective had the chillers servicing tank M6 been running. The refrigeration had been switched off at 5pm on previous evening, which was routine site practice as ambient night temperatures required little or no chilling. Further, due to circulation stoppage as part of the Covid-19 lockdown, only the lower half of the tank remained cooled.

Styrene needs to be circulated constantly, but the temperature gradient allowed the upper levels to vaporise and auto polymerise. Styrene polymerises slowly at low ambient temperatures but very rapidly at elevated temperatures. The pressure in the storage tank progressively increased due to the runaway reaction and the safety valve released the styrene vapour to atmosphere. There was also no automation and the water sprinklers had to be activated manually, as this had never been anticipated.

**Inhibitor inadequacies**. Another reason for the accident was that tertiary butyl catechol (TBC), the inhibitor for the polymerisation reaction was not effective after the liquid styrene temperature in the storage tank rose above 52°C. Under these conditions, a short-stopper chemical should be added, however, LG Polymers did not consider this possibility. Also, the TBC had not been topped up in the affected tank, M6, since 1 April as there was no stock at site, and the TBC level in the contents was tested and appeared to be in range. Recommended practice is to maintain the inhibitor level at 10-15ppm of the styrene in the storage tank to prevent polymer formation. At low TBC levels, oxygen depletion is rapid, the inhibition system quickly becomes ineffective and polymerisation begins.

**Monitoring failures**. The increase in temperature and pressure was not observed by the company's employees. The leaked tank did not have any provision for measuring the vapour space temperature and so the the temperature build-up at the top of the tank went unnoticed. Had the safety valve failed, the whole tank would have exploded resulting in an even worse catastrophe.

**Other Lapses**. The following were cited: Safe distancing from residential areas, signposting of hazards outside the factory, lack of standard operating procedures (SOPs) for downtime activities such as refrigeration, circulation and mock drills, and a gross lack of diligence in monitoring and maintaining the plant.

At both municipal and district levels preparations for rapidly mobilising transport and ambulances for evacuating the casualties were inadequate. This fuelled panic and people ran in search of any available transport. Medical facilities were scarce in the suburb, and casualties had to be transported to hospitals at some distance in whatever vehicles could be found.

The root cause, as brought out in the report by the NGT's joint monitoring committee which investigated the accident, appears to have been the lack of experience at LG Polymers India and its Korean principal, LG Chemicals, in monitoring and maintaining full tanks of styrene that were idle for several weeks. Further, the report noted that tank M6 was old in design terms and this possibly contributed to the problem. Citing multiple inadequacies on the part of LG Polymers, the Andhra Pradesh state government's HPC faulted 'slackness of management' for poor safety protocols, poor safety awareness and an inadequate risk assessment response that aggravated the situation.

LG Chemicals had another accident in its Korean plant later in May 2020. It was felt that the company's record was taking a beating with regards to safety protocols and process safety management. LG Chemicals announced that its safety experts will inspect 40 plants - 17 in South Korea and 23 in foreign countries - by the end of June.

## Conclusion

The Vizag accident saw a reasonably fast response but lacked expertise and skilled first responders. It is imperative that SOPs and regulations be followed in letter and spirit. No negligence or carelessness can be tolerated. Chemical industry accidents have been occurring with growing frequency. In most cases the root cause analysis reflects inadequate safety protocols, poor monitoring, poor maintenance and inadequate awareness among staff and managers. As stated by Markets and Markets' research, the global chemical industry, estimated at $2.4tn, is one of the fastest growing sectors of manufacturing industry. It is imperative that the industry's management at every level exercises due diligence and ensures a no-accident operating protocol.

**Colonel Athavale is a veteran Indian Army officer with extensive experience in varied command and general staff assignments, who holds a PhD in CBRN security and incident management.**