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Case Study of H2S Exposure & Fatality on External Floating Roof Tank Deck Hydrogen Sulphide Incident at MRPL Refinery

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Abstract: ***On 12 July 2025, two operators at the Oil Movement and Storage (OM&S) section of a large petroleum refinery in India were fatally overcome by hydrogen sulphide (H_2S) gas while conducting a routine inspection of a floating roof slop tank. This paper presents a systematic analysis of the incident, examining the sequence of events, the physicochemical conditions that led to lethal H_2S accumulation on the floating roof deck, and the compounding failures of procedural compliance, hazard communication, and safety management systems. Post-incident sampling confirmed H_2S concentrations of 890 ppm in the tank and 40 ppm at the top platform 48 hours after the event, concentrations far exceeding the Immediately Dangerous to Life or Health (IDLH) threshold of 100 ppm. The investigation identified multiple latent organisational failures including the absence of confined space entry permits, non-use of personal H_2S detection equipment, solo entry in violation of safe work protocols, and failure to act on documented warning signs of H_2S presence. The paper concludes with fourteen evidence-based recommendations covering engineering controls, procedural safeguards, training, and regulatory compliance, aimed at preventing recurrence in similar petroleum storage operations.***

Keywords: Hydrogen sulphide; H_2S fatality; floating roof tank; confined space entry; occupational safety; petroleum refinery; slop tank; toxic gas exposure; OISD standards; process safety management

1. Introduction

Hydrogen sulphide (H_2S) is one of the most acutely hazardous gases encountered in petroleum refining and storage operations. A colourless, heavier-than-air gas with a characteristic rotten egg odour at low concentrations, H_2S rapidly causes olfactory fatigue at moderate exposures (>100 ppm), rendering the human nose an unreliable detector precisely when concentrations become life-threatening [1]. At concentrations above 300 ppm, loss of consciousness can occur within seconds, and death can follow within minutes if the victim is not removed from the toxic atmosphere [2].

External Floating Roof (EFR) tanks are widely used in petroleum storage facilities for volatile hydrocarbon products. When the floating roof descends to more than 3 metres below the tank shell top, the space between the roof and the tank rim constitutes a confined space under Indian regulatory standards (OISD-STD-105, Clause 5.3) [3]. Slop tanks, which receive off-specification products, unstabilised intermediates, and sour process streams during unit startups, carry a heightened risk of dissolved H_2S in their contents. The combination of these factors: volatile, sour content in a confined-space-forming floating roof tank - creates a hazard scenario that demands stringent procedural and engineering controls.

Despite well-established safety standards and a long history of H_2S-related fatalities in the petroleum industry globally, recurring incidents continue to be reported. The present paper documents and analyses a fatal H_2S exposure event at a major Indian refinery, with the dual objective of learning from systemic failures in this incident and formulating actionable recommendations for the broader industry.

2. Incident Background

2.1 Site Description

The incident occurred in the Oil Movement and Storage (OM&S) section of a large petroleum refinery on the western coast of India. Tank is a single-deck External Floating Roof (EFR) tank used for slop storage - receiving off-specification hydrocarbons, unstabilised intermediate streams, and sour water from various process units. The tank was not originally designed for sour service or for products with a low flash point. Historical inspection records had previously documented wet H_2S corrosion failures in the tank; however, recommended metallurgical upgrades to HIC-resistant SA516 Gr.60 steel were deferred citing financial constraints and the COVID-19 pandemic.

2.2 Operational Context

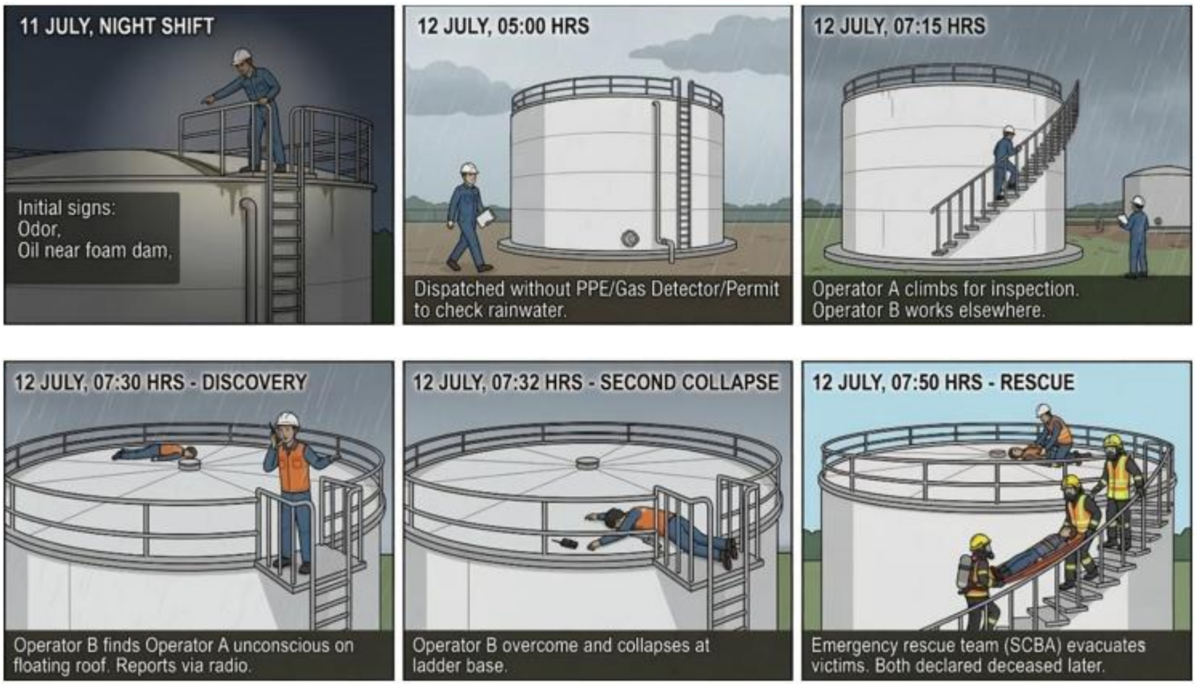
Several process units at the refinery, including hydrocracking units, had been restarted following a scheduled Maintenance and Inspection (M&I) turnaround in the days preceding the incident. During startup and stabilisation, unstripped or partially stripped Naphtha and Diesel range streams from hydrotreating and hydrocracking units, carrying dissolved H_2S, are commonly routed to slop tanks. A modification to route settled water from the slop tanks to the Sour Water Stripper (SWS) via an oil separator had been implemented at the facility without formal Management of Change (MOC) documentation. The OM&S operating manual itself noted that high H_2S concentrations were observed during water draining to the oily water sewer — explicit prior evidence of H_2S presence in the slop tank contents.

2.3 Meteorological Conditions

Heavy monsoon rainfall was occurring during both the night preceding the incident and the morning of the event. The concurrent level rise in Tank, attributed by operations personnel to rainwater accumulation on the floating roof was a primary motivator for the inspection visits that led to the fatalities. Rainfall is known to suppress gas dispersion above open surfaces, creating a more concentrated and persistent gas layer near the roof level [4].

3. Sequence of Events

The following chronology of events was reconstructed from operational logbooks, walkie-talkie communications, shift handover records, and post-incident investigation findings.



1) On 11 July 2025, level fluctuation was observed in slop Tank. The OM&S shift in-charge contacted the Refinery Shift Manager (RSM), who confirmed that no deliberate slop routing was in progress from any process unit.
2) In the night shift prior to the incident, the night-shift operator sent to check the tank roof noted a foul smell near the dip-hatch area and observed oil near the foam dam on the floating roof deck. A dead peacock was found on the south side of the top platform. These observations were recorded in the logbook but did not trigger a hazard review or escalation.
3) At approximately 05:00 hrs on 12 July 2025, the morning shift in-charge dispatched a lone operator to inspect Tank for rainwater accumulation during heavy rainfall. No PPE, gas detector, or confined space entry permit was obtained.
4) At approximately 07:00 hrs, two operators (Operator A and Operator B) were dispatched to the off- site area. Operator A was assigned to Tank; Operator B was assigned to a different tank.
5) After completing his own inspection, Operator B waited for Operator A to descend. When Operator A had not returned after 15–20 minutes, Operator B climbed Tank to check.
6) At approximately 07:30 hrs, Operator B found Operator A lying unconscious on the floating roof deck, approximately 10 metres from the roof ladder. Operator B communicated this via walkie- talkie before he too was overcome by H_2S and collapsed at the foot of the ladder.
7) A third operator, responding to the distress call, ascended to the tank top and detected H_2S with his

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personal monitor reading out-of-range (>100 ppm). He retreated without entering and alerted the control room and the Fire & Safety (F&S) department.

8) The emergency rescue team, equipped with Self-Contained Breathing Apparatus (SCBA) sets, evacuated both victims. Operator A was declared dead on arrival at the Occupational Health Centre (OHC). Operator B succumbed to injuries during subsequent medical treatment.

Post-incident measurements recorded H_2S concentrations of 40 ppm at the top platform 48 hours after the event. A tank sample collected 11 days post-incident reported 890 ppm H_2S in the top sample, with an Initial Boiling Point (IBP) of 37°C and Final Boiling Point (FBP) of 355°C, confirming the presence of Naphtha and Diesel range intermediates capable of releasing significant dissolved gas.

4. Health Effects of H_2S: A Toxicological Reference

Table 1 summarises the physiological effects of H_2S at various concentrations, as defined by ACGIH, OSHA, and NIOSH standards [1, 2, 5]. Concentrations encountered in this incident were almost certainly in the 300–700+ ppm range on the floating roof deck, based on the out-of-range readings (>100 ppm IDLH) of personal monitors carried by the rescue team.

Table 1: Health effects of H_2S exposure at varying concentrations

H_2S Concentration	Health Effect	Classification
0.01 – 0.3 ppm	Odor threshold (rotten egg smell)	Detectable, not hazardous
1 ppm (TWA)	No immediate symptoms; chronic risk	ACGIH time-weighted average
5 ppm (STEL)	Eye & throat irritation, nausea	15-min exposure limit
10 – 15 ppm	Coughing, burning eyes, fatigue	Recommended alarm threshold
50 ppm	Serious eye/respiratory irritation within minutes	OSHA peak permissible level
100 ppm (IDLH)	Olfactory paralysis, dizziness, rapid incapacitation	Immediate evacuation required
300 – 500 ppm	Respiratory failure, unconsciousness in < 5 min	Life-threatening
> 700 ppm	Collapse within seconds; death within minutes	Fatal exposure

Sources: ACGIH TLV Booklet; NIOSH Pocket Guide to Chemical Hazards; OSHA 29 CFR 1910.1000.

A critical physiological mechanism that contributes to H_2S fatalities is olfactory paralysis, which occurs at concentrations at or above 100 ppm. At this level, the sense of smell is rapidly and completely suppressed, removing the only warning signal available to an unequipped worker. Operators entering the floating roof area of Tank without gas detection equipment had no means of perceiving the lethal atmospheric hazard before succumbing to it.

5. Investigation Findings

5.1 Sources of H_2S Accumulation

The OISD investigation identified multiple concurrent pathways through which H_2S accumulated in the slop tank and on its floating roof deck:

- **Post-Startup Process Streams:** Unstripped or partially stripped Naphtha and Diesel from post- turnaround hydrocracking and hydrotreating units, carrying dissolved H_2S, were routed to the slop tank during startup stabilisation.
- **Sour Water Co-ingress:** Sour water generated during plant startup may have co-entered the slop tank with product streams.
- **Meteorological Suppression:** The heavy monsoon rainfall suppressed atmospheric gas dispersion, trapping H_2S in a concentrated layer at roof level.
- **ETP Transfer:** Material transfer from the Effluent Treatment Plant (ETP) constituted an additional H_2S entry pathway.
- **Tank Design Limitations:** The tank was not designed for sour service; deferred metallurgical upgrades had left it vulnerable to wet H_2S corrosion.

5.2 Safety Management Lapses

The investigation documented the following critical safety lapses, each of which, individually, should have prevented the incident:

- **Absence of PPE and Gas Detection:** Operators dispatched to inspect and access Tank carried no personal H_2S responders, no Breathing Apparatus (BA) sets, and no portable gas detectors. Despite documented evidence of H_2S presence during draining operations, the operating procedures did not mandate gas monitoring for routine tank inspection activities.
- **Confined Space Entry Without Permit:** At the time of the incident, the floating roof of Tank was approximately 5 metres below the tank shell top. Under OISD-STD-105 Clause 5.3, this constitutes a confined space. No confined space entry permit was obtained for any of the visits on the night of 11 July or the morning of 12 July 2025.
- **Unsupervised Solo Entry:** The initial inspection was conducted by a single operator, in heavy rain, without a standby person or communication plan. This directly violated the buddy system requirement applicable to hazardous area inspections.
- **Failure to Act on Warning Signs:** The night-shift operator had documented a foul smell near the dip-hatch area and oil on the floating roof deck. A dead bird was observed on the tank platform. These were credible indicators of a toxic atmosphere; however, no hazard escalation or shift-to- shift risk communication occurred.
- **Absence of Job Safety Analysis:** No Job Safety Analysis (JSA) was conducted prior to dispatching operators onto the tank. The task of checking for rainwater accumulation was treated as a routine activity without formal hazard assessment.
- **Management System Deficiencies:** The modification to route sour water to the SWS was implemented without

MOC documentation. Slop tanks were not included in the Leak Detection and Repair (LDAR) programme despite routinely receiving volatile streams.

6. Root Cause Analysis

Applying the framework of a multi-barrier failure model, the incident can be understood as a simultaneous failure of multiple independent safeguards, each of which, had it been operative, would have been sufficient to prevent the fatalities [6].

The immediate cause was acute inhalation of H_2S at concentrations exceeding the IDLH threshold in a confined space formed by the floating roof being more than 3 metres below the tank rim. The underlying root causes, however, were systemic:

1) **Normalisation of Deviance**: Prior indications of H_2S presence in the slop tank , from inspection records, wet H_2S corrosion findings, sour water routing modifications, and the night-shift operator's logbook entries were not collectively recognised as constituting a toxic hazard requiring elevated precautions.
2) **Procedural Inadequacy**: The operating procedures for the slop tanks did not mandate personal H_2S monitoring for routine activities such as gauging, sampling, water draining, or roof inspection, despite documented knowledge of H_2S presence.
3) **Permit System Non-Compliance**: The work permit system for confined space entry was not enforced, permitting entry into a defined confined space without the required safety precautions under OISD-STD-108 Clause 9.2.
4) **Management System Failure**: The process modification to route settled water to SWS, implemented without MOC, and the exclusion of slop tanks from LDAR, represent failures of the management of change and risk identification processes.
5) **Latent Hardware Deficiencies**: Deferred metallurgical recommendations, the retention of emergency roof drains in the single-deck EFR tank, and the tank's continued use for sour service products beyond its design intent represent latent hardware deficiencies that contributed to the conditions enabling H_2S accumulation.

7. Recommendations

On the basis of the investigation findings, the following recommendations are made for petroleum storage and refining facilities operating floating roof tanks and handling H_2S-bearing streams. These align with the OISD investigation recommendations and are supplemented with broader process safety considerations.

7.1 Engineering Controls

- **Fixed Gas Detection:** Fixed H_2S detectors with audio-visual alarms shall be installed in hazardous areas around slop tanks. These shall be supplemented by portable gas detectors for field personnel.
- **Confined Space Marking:** A marking or painted band at the 3-metre level on the interior shell of all EFR tanks shall be provided to alert personnel entering or ascending the tank about the confined space threshold.
- **Emergency Roof Drain Removal:** Emergency roof drains of all single-deck EFR tanks shall be blinded and removed at the next available M&I opportunity, as per OISD-STD-108 Clause 4.9.3, to prevent oil and water accumulation on the floating roof.
- **Slop Line Instrumentation:** Flow transmitters and temperature transmitters shall be installed on slop lines from all process units to enable real-time tracking of slop transfer quantity and quality.
- **Tank Integrity Review:** A comprehensive review of all storage tanks shall be conducted to verify compliance of stored products with design metallurgy and service intent, and to implement overdue integrity recommendations.

7.2 Administrative and Procedural Controls

- **Permit System Enforcement:** Confined space entry permits shall be strictly enforced for all entries onto floating roof tanks when the roof is below the 3-metre threshold, in full compliance with OISD-STD-105 and OISD-STD-108 Clause 9.2.
- **Mandatory Pre-Entry Gas Testing:** Pre-entry gas testing for H_2S, LEL, and oxygen levels shall
- be mandatory before any access to floating roof tanks, regardless of the purpose of entry.
- **Mandatory PPE:** Personal H_2S responders, BA sets, and portable gas detectors shall be compulsory for all operations on or around slop tanks, including routine activities such as gauging, sampling, and inspection.
- **Buddy System Enforcement:** No individual shall be permitted to enter or inspect a hazardous area alone. A standby person with communication equipment and appropriate PPE must be present for all such tasks.
- **Job Safety Analysis:** A formal Job Safety Analysis (JSA) shall be conducted for all non-routine activities, particularly those involving confined spaces or H_2S-bearing streams.
- **Slop Transfer SOP:** A Standard Operating Procedure shall be established for monitoring and recording of slop transfer activities, including mandatory prior intimation from upstream units to OM&S of the quantity and quality of material being sloped.
- **Management of Change:** Management of Change (MOC) procedures as per OISD-STD-178 shall be strictly followed for all process, equipment, or service changes. Retroactive MOC reviews shall be conducted for undocumented historical modifications.
- **LDAR Programme Coverage:** Slop tanks receiving volatile products shall be included in the Leak Detection and Repair (LDAR) programme as per G.S.R. 186(E) and OISD-STD-224.

7.3 Training, Awareness, and Drills

- **H_2S Hazard Training:** Regular and refresher training on H_2S hazards, properties, health effects, and emergency response shall be conducted for all operations and maintenance personnel.
- **Emergency Drills:** Periodic drills for H_2S exposure scenarios shall be conducted to ensure personnel

familiarity with correct emergency response actions, including the use of SCBA and rescue procedures.
- **Hazard Signage and HIRA:** Warning signage regarding H_2S presence potential shall be displayed around all relevant areas. HIRA shall be conducted for such areas and mandatory PPE requirements shall be formally incorporated into the facility PPE policy.

8. Discussion

The MRPL Tank incident is not an isolated occurrence. H_2S fatalities at petroleum facilities share a consistent pattern across geographies: a toxic atmosphere develops in a confined or semi-confined space; workers enter without adequate detection equipment or breathing protection; the incapacitating properties of the gas prevent self-rescue; and subsequent responders, lacking situational awareness, become secondary victims [7]. What distinguishes this incident is the convergence of multiple documented warning signs, historical inspection findings, a modified sour water routing system, logbook entries recording foul odours and oil on the roof, and a dead bird on the tank platform- none of which were collectively interpreted as a toxic hazard.

This reflects a well-documented phenomenon in process safety: the normalisation of deviance [8]. When workers repeatedly observe signals that fall outside normal parameters- foul smells, oil on the roof, unusual level rises — without adverse consequences, these signals gradually come to be perceived as normal. The cognitive re-framing of the level rise as merely rainwater accumulation, in a facility that had prior experience of EFR roof tilting during monsoon, illustrates how plausible alternative explanations can suppress appropriate risk responses.

The failure to enforce the confined space entry permit system, the non-use of personal gas detection, and the dispatch of a lone operator at 05:00 hrs in heavy rain each represent independent failures that individually should have prevented the tragedy. The Swiss Cheese Model of accident causation [9]- in which an accident occurs when the holes in multiple independent defensive layers align simultaneously- provides an apt framework: in this incident, every defensive barrier failed.

From an industry perspective, the regulatory framework was adequate: OISD-STD-105, -108, -178, and -224 collectively address confined space entry, tank integrity, MOC, and LDAR. The failure was not in the standards but in their implementation. This underscores the distinction between documented safety systems and a functioning safety culture, a distinction that is ultimately measured in human lives.

9. Conclusion

This paper has presented a comprehensive analysis of a fatal H_2S exposure incident at an Indian petroleum refinery, in which two operators died after entering the floating roof deck of a slop tank containing sour hydrocarbons without appropriate hazard awareness, gas detection equipment, or confined space entry controls. Post-incident measurements confirmed H_2S concentrations far exceeding the IDLH threshold, and multiple pre-incident warning signs had gone unrecognised.

The investigation reveals a failure mode that transcends individual error: a system in which latent hardware deficiencies, procedural gaps, undocumented process changes, and the absence of a culture of risk escalation collectively created conditions in which a fatal outcome was, in hindsight, foreseeable. The key lesson is that H_2S risk in slop tanks must be treated as a default assumption, not a condition requiring confirmation, particularly during or following post-turnaround unit startups.

The seventeen recommendations presented in this paper address engineering controls, administrative procedures, permit system enforcement, and training. Their implementation, consistently and without exception, represents the minimum necessary to prevent recurrence. Both fatalities in this incident were preventable ,a fact that must inform every future decision made about how personnel interact with H_2S-bearing storage infrastructure.

References

[1] ACGIH. Threshold Limit Values (TLVs) and Biological Exposure Indices (BEIs). American Conference of Governmental Industrial Hygienists, Cincinnati, OH, 2023.
[2] NIOSH. Hydrogen Sulfide. NIOSH Pocket Guide to Chemical Hazards. National Institute for Occupational Safety and Health, CDC, Atlanta, GA, 2019.
[3] OISD. OISD-STD-105: Recommendations on Safety Requirements for Storage of Flammable Liquids. Oil Industry Safety Directorate, Ministry of Petroleum & Natural Gas, Government of India, New Delhi.
[4] Hanna, S.R., Drivas, P.J., Chang, J.C. Hazardous Gas Model Evaluations. Air & Waste Management Association, 1996.
[5] OSHA. Occupational Safety and Health Standards: Air Contaminants. 29 CFR 1910.1000. U.S. Occupational Safety and Health Administration, Washington, DC.
[6] Reason, J. Human Error. Cambridge University Press, Cambridge, UK, 1990.
[7] API. API RP 2003: Protection Against Ignitions Arising Out of Static, Lightning, and Stray Currents. American Petroleum Institute, Washington, DC, 2015.
[8] Vaughan, D. The Challenger Launch Decision: Risky Technology, Culture, and Deviance at NASA. University of Chicago Press, Chicago, IL, 1996.
[9] Reason, J. Managing the Risks of Organizational Accidents. Ashgate Publishing, Aldershot, UK, 1997.
[10] OISD. Case Study No. OISD/CS/2025-26/P&E/10: H_2S Exposure and Fatality on External Floating Roof Tank Deck. Oil Industry Safety Directorate, Ministry of Petroleum & Natural Gas, Government of India, 15 September 2025.
[11] OISD. OISD-STD-108: Design and Safety Requirements for Liquid and Gas Storage Facilities. Oil Industry Safety Directorate, New Delhi.
[12] OISD. OISD-STD-178: Management of Change. Oil Industry Safety Directorate, New Delhi.
[13] OISD. OISD-STD-224: Leak Detection and Repair (LDAR) Programme. Oil Industry Safety Directorate, New Delhi.