Incident

The Aqaba 2022 chlorine release — lessons in hazardous material lifting operations

Sami Amarneh, Chairman, JCPSES, Jordan; Amro Kasht, Vice Chairman, JCPSES, Jordan; Roger Stokes, BakerRisk, UK

Summary

On 27 June 2022, a catastrophic chlorine release occurred at the Aqaba Port in Jordan, resulting in 13 fatalities and over 250 injuries. The incident, triggered by a failed lifting sling during loading operations, exposed critical leadership, safety culture, and risk management deficiencies. This article outlines the details of the incident, its root causes, and recommendations to enhance safety systems and leadership accountability, together with wider lessons for the global industry.

Keywords: chlorine, release, lifting equipment

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Background

At approximately 16:15 on 27 June 2022, at the Aqaba Port terminal situated 18 km south of Aqaba City, a T50 ISO container containing 20 tons of liquid chlorine dropped while being loaded onto a cargo vessel. The container was punctured which caused a loss of containment resulting in 13 fatalities and over 250 injuries. The Aqaba Company for Ports Operations and Management (ACPOM) was managing the loading of 18 containers containing liquid chlorine manufactured by the Jordan National Chlorine Industries Company (NCI) for shipment to Djibouti in East Africa, as detailed in Figure 1.

Marine vessel

The vessel being loaded, the Forest 6, was a 134 m long x 22 m wide deck cargo ship sailing under the flag of Hong Kong, as shown in Figure 2.

Figure 1 – Aqaba City (circled) and Aqaba New Port[2]

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Figure 2 – Forest 6 Deck Cargo Ship[3]

Hazards of chlorine

Chlorine is a highly toxic gas at room temperature and has the following characteristics:

- Toxicity:
  - Threshold Limit Values (TLVs): 1 ppm Short-Term Exposure Limit (STEL) and 0.5 ppm Time-Weighted Average over an 8-hour shift (TWA).
  - National Institute for Occupational Safety and Health (NIOSH) Immediate Danger to Life or Health: 10 ppm.
- Physical properties:
  - Chlorine gas is 2.5 times denser than air, remaining close to the ground when released.
  - A strong oxidiser, chlorine can exacerbate fires in the presence of reactive metals and organic material.
- Health impacts:
  - Low concentrations cause coughing and wheezing.
  - High concentrations lead to pulmonary oedema (fluid in the lungs) and respiratory failure.

Transportation of chlorine

Chlorine is usually transported as a pressurised liquid as it can be held under ambient conditions at a pressure of about 6 barg. Transporters commonly use dedicated road tankers for bulk chlorine within the country, while exporters typically ship it in 20 ft long ISO containers. The T50 container is designed specifically for the intermodal transportation of liquefied gases like chlorine and LPG, with the following design specifications[4]:

- capacity: 24,600 litres
- maximum gross weight: 36 tons
- maximum payload: 28.9 tons
- maximum working pressure: 22 barg
- design temperature: 55 degC
- shell material: carbon steel
- shell thickness: 13.4 mm
- safety relief valve setting and rupture disc: 22 barg.

Incident description and timeline

- Morning shift (10:00) 27 June 2022:
  The ACPOM morning crew started offloading empty chlorine containers from the FOREST 6 using a mobile crane and wire rope slings.
- Shift change (15:00):
  Following a shift change, the afternoon crew began loading 18 full chlorine containers onto the vessel using the same lifting equipment. The crew loaded four full containers without incident.
- Critical failure (16:15):
  The wire rope sling failed while lifting the fifth container, which dropped about 4 m onto the ship's steel poles. The impact breached the container, releasing approximately 20 tons of liquid chlorine that rapidly vaporised.

Immediate consequences

The vaporised chlorine formed a dense, lethal cloud encompassing the ship and loading area. This resulted in 13 fatalities and 250 injuries.

Incident response

The site was immediately sealed off, and nearby areas were evacuated. Over 2,000 personnel, including emergency responders and specialists, were deployed. The interior minister initiated an investigation led by a team comprising forensic specialists to determine root causes and recommend corrective measures.

Figure 3 – Chlorine cloud 2 and 3 seconds after impact

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Figure 4 – Damage to cell guides (circled) and railing

Figure 6 – Lifting wire failure

Investigation

Immediate causes

The T50 ISO container was breached at two locations upon impact with the ship's vertical steel poles on the hold cell guides. See Figure 4 and Figure 5.

An initial examination of the wire rope slings showed that these had snapped. See Figure 6.

The wire rope sling had a Maximum Rated Capacity (MRC) of 8.6 tons. This was just sufficient for the empty containers (approximately 7 tons), but without any significant safety margin, and grossly inadequate for full containers (approximately 29 tons). Remarkably, the slings were able to load the four previous containers without incident.

Contributory causes

The Aqaba 2022 chlorine incident investigation relied on a thorough collection of evidence, including physical site inspections, witness interviews, and a detailed review of relevant documentation. This evidence-driven approach highlighted critical deficiencies that contributed to the incident:

Inadequate equipment

- The sling lacked proper tagging to indicate its Safe Working Load (SWL), making rope mismatch errors easy.
- Other lifting equipment was out of service at the time, which may have influenced the decision to use the unfit lifting sling.
- No secondary checks of the lifting equipment were performed.

Relevant standards:

- *ISO 4309:2017 Cranes – Wire ropes – Care and maintenance, inspection and discard*[5]: Provides wire rope inspection and tagging guidelines to prevent mismatches.
- *OSHA 1910.184 Slings*[6]: Outline requirements for sling inspections, load limits, and secondary checks.
- *LEEA-059 1-5 Guide to Documentation and Marking*[7]: Guide to ensure that lifting equipment is supplied with the correct documentation and marking.

Training and competency deficiencies

- ACPOM staff lacked awareness of the cargo's hazardous nature and associated risks.
- Personnel were unqualified for critical roles, especially hazardous material lifting operations. For instance, the safety supervisor was not adequately trained and was absent on the day of the incident (during hazardous material lifting).

Relevant standards:

- *Port Skills and Safety (PSS) SIP018 – Guidance on Safety Induction and Training in Ports*[8]: Outlines training requirements for port operators, including hazard awareness and role-specific competencies.

Communication failures

- Critical information, such as container weight and content, was shared on informal communication channels such as WhatsApp.
- Shift handover processes were inconsistent, leading to gaps in key information delivery to the staff concerned.

Figure 5 – Puncture holes in ISO container

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Relevant standards:

- *ISO 45001:2018 Clause 7.4 – Communication*[9]: Guides formalised communication channels for critical safety information: Requires formal communication channels.
- *Managing Shift Work – Health and Safety Guidance*[10]: Provides key principles to ensure safe handover and structured information transfer.

Disregard for safety procedures

- Workers neglected to perform risk assessments, Job Safety Analyses (JSAs), or pre-task briefings.
- Hazardous material handling protocols and precautions were ignored.

  Relevant standards:
  - *OECD Management of Hazardous Substances in Port Areas*[11]: Provides a summary of chemical incidents in port areas and key risk management elements to prevent their recurrence.
  - *IOGP Report 376 Lifting and Hoisting Recommended Practice*[12]: Presents the essential principles of safe lifting and their application to lifting and hoisting operations.
  - *Port Skills and Safety (PSS) SIP003 – Guidance on Container Handling*[13]: Addresses the requirements for handling containers from and to vessels in ports.
  - H*SE UK L113 Safe use of lifting equipment – Lifting Operations and Lifting Equipment Regulations 1998*[14]: Provides detailed guidance about lifting operations and equipment.
  - *International Marine Contractors Association (IMCA) Guidelines for lifting operations*[15]: Comprehensive guide to lifting operations, including personnel, inspection, examination, marking, and record keeping.

Inadequate management oversight:

- Management failed to enforce safety standards and ensure compliance with regulations and standards.
- A top-down culture of negligence and inadequate accountability prevailed.

  Relevant standards:
  - *ISO 45001:2018 Clause 5.1 – Leadership and Worker Participation*[9]*:* Emphasises management's role in promoting a safety culture.
  - *ILO Code of Practice on Safety and Health in Ports*[16]: Highlights accountability frameworks for port operations.
  - *LEEA-072 Roles and responsibilities for ensuring the continued safety of lifting equipment*[17]: Outlines the roles and responsibilities of those involved in lifting equipment operation, inspection, and maintenance.

Root cause

The root cause analysis of the Aqaba 2022 chlorine incident pinpointed the following root causes:

Leadership failures

- Senior and middle management demonstrated inadequate leadership, accountability, and safety oversight.
- Safety culture deficiencies were pervasive. Management failed to act as safety leaders and role models, undermining safety systems compliance.

  Relevant standards:
  - *OECD Corporate governance for process safety – Guidance for senior leaders in high-hazard industries*[18]: Sets the business case for process safety management and outlines the essential elements of corporate governance for process safety.
  - *ISO 45001:2018 Clause 5.1 – Leadership and Worker Participation*[9]: Emphasises management's role in promoting a safety culture.

Systemic gaps

- Safety Management Systems: Inadequate or non-existent management standards, procedures, and administrative controls (SPACs) for lifting of loads. Particularly, an inherently safer standard mandating solid connections (lifting spreaders) instead of lifting slings, was absent.

  Relevant standards:
  - I*SO 45001:2018 Occupational Health and Safety Management Systems*[9].
  - *CCPS Guidelines for Risk Based Process Safety*[19]: Provides frameworks for SPACs.
  - *LEEA Code of Practice for the Safe Use of Lifting Equipment*[20]*:* This practical guide covers manual and power-operated lifting machines and structures, as well as a wide range of below-hook equipment. It is useful in devising safe working practices for anyone using lifting equipment and provides all the information necessary for safety training in this critical area of activity at work.
  - BS 7121 - Code of practice for the safe use of cranes Part 1-14[21]: Provides recommendations for the safe use of cranes and is widely recognised as best practice in any industry.
- Risk management: A robust risk assessment framework for hazardous material lifting operations was absent.

  Relevant standards:
  - ISO 31000:2018 Risk Management – Guidelines[22].
  - ISO/IEC 31010:2019 Risk management – Risk assessment techniques[23].
- Communication deficiencies: Lack of standardised shift handover processes and inadequate communication hardware.

  Relevant standards:
  - *ISO 45001:2018 Clause 7.4 – Communication*[9]: Guides formalised communication channels for critical safety information.
  - *Managing Shift Work – Health and Safety Guidance*[10]: Provides key principles to ensure safe handover and structured information transfer.

Regulatory non-compliance

- Failure to adhere to relevant laws, regulations, and standards.

Recommendations from investigation

The investigation team proposed the following key recommendations to address the immediate and systemic issues identified:

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Organisational restructuring and leadership development

- **Restructure the port operating company:** Establish a senior leadership team with safety qualifications and accountability.
- **Leadership training:** Provide leadership development programs that foster a robust safety culture and ensure accountability.

Safety systems enhancement

- **Inherently safer systems**: Establish an inherently safer system where solid lifting connections, such as lifting spreaders, replace ropes. Additionally, personnel exclusion zones should be enforced around hazardous material lifting operations.

  Relevant standards:
  - CCPS Inherently Safer Chemical Processes: A Life Cycle Approach[24]: Methodology for replacing high-risk systems.
- **Develop SPACs:** Create detailed management systems, standards, and procedures for all lifting operations.

  Relevant standards:
  - ISO 45001:2018 Occupational Health and Safety Management Systems[9].
  - CCPS Guidelines for Risk Based Process Safety[19]: Provides frameworks for SPACs.
  - LEEA Code of Practice for the Safe Use of Lifting equipment[20]: A practical guide covering manual and power-operated lifting machines and structures together with a wide range of below-hook equipment useful in devising safe working practices for anyone using lifting equipment, as well as providing all the information necessary for safety training in this critical area of activity at work.
  - BS 7121 – Code of practice for the safe use of cranes[21]: Provides recommendations for the safe use of cranes and is widely recognised as best practice in any industry.
- **Permit systems:** Update and enhance work permits to include safety-critical steps for handling hazardous materials.

  Relevant standards:
  - ISO 45001:2018 Clause 8.1.2 Hazard Identification and Risk Assessment[9]: Guides integration of PTW into broader safety management systems.
  - UK HSE HSG250 Guidance on Permit-to-Work Systems[25]: Define roles and responsibilities, isolation procedures, and shift handover requirements. Includes checklists for hazardous material handling.
  - IChemE Safety Centre Guidance – Lead Process Safety Metrics – Supplementary Guide – Permit to Work[26]: Details formal processes to control potentially hazardous work. This resource is particularly useful for understanding the integration of PTW systems within broader safety management frameworks.
- **Structured shift handover:** Implement a formalised shift handover process to seamlessly transfer critical safety information.

  Relevant standards:
  - ISO 45001:2018 Clause 7.4 – Communication[9]: Guides formalised communication channels for critical safety information.
  - Managing Shift Work – Health and Safety Guidance[10]: Provides key principles to ensure safe handover and structured information transfer.
- **Hazard Identification and Risk Analysis (HIRA):**
  - Conduct hazard identification and risk assessments for all hazardous material lifting operations.
  - Use the findings to develop detailed procedures and safety controls.
  - Conduct studies to designate hazardous material handling zones safely and efficiently.
  - Use consequence modelling to plan for worst-case scenarios.

  Relevant standards:
  - ISO 31000:2018 Risk Management – Guidelines[22].
  - ISO/IEC 31010:2019 Risk management – Risk assessment techniques[23].
  - G. S. Job Hazard Analysis – A Guide to Identifying Risks in the Workplace[27].

Training and competency

- **Personnel training:**
  - Train workers on updated SPACs.
  - Schedule refresher training to maintain competency.

  Relevant standards:
  - Port Skills and Safety (PSS) SIP018 – Guidance on Safety Induction and Training in Ports[8]: This document provides a comprehensive overview of training and competency requirements specifically for port operators.
- **Emergency response training:** Train emergency responders to handle hazardous chemical releases.

  Relevant standards:
  - OSHA 1910.120 Hazardous Waste Operations and Emergency Response (HAZWOPER)[28].
  - Port Skills and Safety (PSS) SIP016 – Guidance on Emergency Planning in Ports[29].
- **Competency assessment:** Evaluate personnel competency through performance-based assessments and certifications.

  Relevant standards:
  - CCPS Guidelines for Defining Process Safety Competency Requirements[30].

Maintenance and inspections

- Schedule routine inspections and testing of lifting equipment by qualified personnel.
- Ensure all equipment has proper tags and markings indicating load capacity.

  Relevant standards:
  - ISO 4309:2017 Cranes — Wire ropes — Care and maintenance, inspection and discard[5]: Provides wire

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rope inspection and tagging guidelines to prevent mismatches.

- OSHA 1910.184 Slings[6]: Outline requirements for sling inspections, load limits, and secondary checks.
- LEEA-059 1-5 Guide to Documentation and Marking[7]: Guide to ensure that lifting equipment is supplied with the correct documentation and marking.

Emergency management system

- Review and update the emergency management plan based on HIRA studies.

  Relevant standards:

  - OSHA 1910.120 Hazardous Waste Operations and Emergency Response (HAZWOPER)[28].
  - Port Skills and Safety (PSS) SIP016 – Guidance on Emergency Planning in Ports[29].

Continuous improvement – audit program

- Develop a structured audit program for hazardous materials operations.
- Ensure findings are reported to senior management with clear Key Performance Indicators (KPIs).

  Relevant standards:

  - ISO 19011:2018 Guidelines for Auditing Management Systems[31]: Defines audit principles, planning, and reporting and aligns audits with organisational objectives.
  - ISO 45001:2018 Clause 9.2 (Internal Audit)[9]: Requires audits to assess compliance and identify improvement opportunities.
  - API RP 754 Process Safety Performance Indicators Tier 3 (Leading Indicators)[32]: Metrics like "percentage of audit actions closed on time" to measure program effectiveness.

Convictions

On Sunday 16 July 2023, a Jordanian court imposed a three-year prison sentence on five individuals concerning the incident[33].

> *"The convicted individuals, four executives, and one worker are all associated with the Aqaba Company for Ports Operation and Management. The Aqaba Court of First Instance also found the company guilty and mandated it to pay a fine of 3,000 Jordanian dinars ($4,234)."*

Lessons for the process industry

The Aqaba chlorine incident is a stark reminder that safety management and hazardous material handling risks extend beyond individual lifting operations and must be considered across the entire supply chain. While many organisations may believe their existing safety systems and lifting procedures are robust and sufficient, this incident highlights how leadership, communication, and equipment management gaps can lead to catastrophic failures, even when systems appear to be in place. The root causes of this incident—leadership failures, inadequate training, and poor risk management—are not unique to Aqaba and can occur in any organisation handling hazardous materials at any link in the supply chain.

Historically, manufacturers have assumed that their responsibility for hazardous materials ends once the shipment leaves their factory gates. However, Environmental, Social, and Governance (ESG) principles now demand a more comprehensive approach with shared responsibility, holding all stakeholders—from manufacturers to hauliers or shippers and the consumers—accountable for safety throughout the supply chain. A single failure, even in logistics or outsourced operations, can lead to severe human, environmental, and reputational consequences. Think of it like a chain: a weak link anywhere compromises the whole.

Key takeaways

- **End-to-end supply chain risk management:**
  - Companies must go beyond factory-based risk assessments and evaluate safety practices across the entire supply chain, mapping the entire journey of hazardous materials, i.e., during transportation, handling, and offloading.
  - Conduct supply chain risk assessments to identify "pinch points" where risks are highest, such as during loading and unloading operations.
  - Implement controls to mitigate supply chain risks from origin to final delivery. For example, ensuring that lifting equipment is rated for the actual load and that personnel are trained to recognise and address potential hazards.
  - Establish clear safety requirements for logistics partners and regularly audit their compliance.
- **Collaborative safety management:**
  - No organisation operates in isolation. A robust safety culture requires coordination between manufacturers, logistics providers, port operators, and end-users. This includes sharing information about hazards, coordinating emergency response plans, and conducting joint training exercises.
  - Implement joint safety programs where best practices, training, and lessons learned are shared across all entities involved in hazardous material transportation.
  - Contractual safety obligations should be integrated into procurement and logistics agreements to ensure compliance with recognised safety standards. Imagine a scenario where a manufacturer has detailed lifting procedures, but the transport company uses different equipment or has a less stringent training program. This disconnect creates a significant risk.
- **Leadership and accountability beyond direct operations:**
  - Leadership failures were a significant root cause of the Aqaba incident. Leaders at all levels must prioritise safety, enforce compliance with safety standards, and foster a culture where safety is non-negotiable. This includes regular audits, transparent communication, and holding individuals accountable for safety lapses.
  - Even if a failure occurs outside an organisation's direct control, the reputational damage, legal consequences, and financial impact can be widespread.

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- Companies must protect their brand, reputation, and ethical obligations by holding supply chain partners to high safety standards.
- Consider implementing safety performance monitoring for contractors, like internal safety Key Performance Indicators (KPIs).

Conclusion

The Aqaba chlorine incident was a preventable tragedy rooted in systemic failures across leadership, culture, and safety management. These failures are not isolated to Aqaba; they are warning signs for any organisation involved in the handling, transporting, or storing of hazardous materials. While individual companies may have robust safety systems for lifting operations, incidents like this highlight that safety must be embedded across the entire supply chain, from manufacturing to end use. This incident underscores a crucial point: even if your organisation has exemplary lifting procedures, you are still vulnerable if other supply chain stakeholders unsafely handle hazardous materials.

The critical lesson is that no organisation can assume it is immune just because it has internal procedures in place. Risk does not disappear when hazardous materials leave a facility. Companies must ensure continuous safety oversight across the entire supply chain, integrating risk assessments, proper equipment selection, training, and shared accountability among all stakeholders.

Organisations must move beyond compliance to prevent similar incidents and adopt a holistic approach to safety that spans the entire supply chain. This includes:

- Implementing robust safety management systems that address leadership, communication, and equipment management.
- Conducting regular risk assessments to identify and mitigate potential hazards.
- Promote a safety culture in which every employee, from the shop floor to the boardroom, understands their role in maintaining safety.
- Collaborating with all stakeholders to ensure that hazardous materials are handled safely at every stage of the supply chain.

The lessons from Aqaba are clear: safety is not just the responsibility of one organisation but a collective effort that requires commitment, collaboration, and continuous improvement. By applying these lessons, companies can safeguard lives, protect the environment, and uphold their reputations in an increasingly complex and interconnected world.

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