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Hazard Identification and Risk Assessment (Hira) in the Fertilizer Industry: A Study of Process Safety and Occupational Hazards

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Abstract

The fertilizer industry is a high-hazard process industry involving toxic, flammable, corrosive and high-pressure substances. Manufacturing processes for ammonia, urea and NPK fertilizers involve significant risks arising from chemical handling, high-temperature and high-pressure operations, rotating machinery, electrical systems, confined spaces, maintenance activities and material handling. Hazard Identification and Risk Assessment (HIRA) is an important systematic approach for identifying hazards, evaluating their likelihood and consequences, and establishing appropriate control measures. HIRA asks three fundamental questions: what can go wrong, how severe could the consequences be, and how likely is the event to occur. CCPS

This paper examines the application of HIRA in fertilizer manufacturing, identifies major hazards associated with ammonia and urea production, and proposes control measures based on the hierarchy of controls. Particular attention is given to toxic ammonia releases, fire and explosion hazards, pressure-related incidents, chemical exposure, machinery hazards, electrical hazards, working at height and confined-space operations. The study demonstrates that systematic HIRA can support preventive safety management, prioritize high-risk activities and reduce the probability and consequences of industrial accidents.

Keywords: HIRA, Hazard Identification, Risk Assessment, Fertilizer Industry, Ammonia, Urea, Occupational Safety, Process Safety, Risk Management.

Introduction

The fertilizer industry plays an important role in agricultural productivity by manufacturing products such as urea, ammonia-based fertilizers and nitrogen-phosphorus-potassium (NPK) fertilizers. However, fertilizer manufacturing involves complex chemical processes and the handling of hazardous materials. A fertilizer plant may contain high-pressure vessels, pipelines, compressors, reactors, storage tanks, rotating equipment and chemical processing units.

Ammonia is particularly important from a safety perspective because an uncontrolled release can create serious toxic exposure. Fertilizer plants may also involve nitric acid, sulfuric acid, carbon dioxide, hydrogen and other hazardous substances depending on the process configuration. An Indian integrated-fertilizer risk assessment identifies material, process, mechanical and electrical hazards among the major hazard categories and uses HIRA to assess potential consequences and mitigation measures. Environment Clearance

HIRA provides a structured method for identifying hazards and evaluating risk. It can be conducted during plant design, construction, operation, maintenance, modification and decommissioning. Early identification is particularly valuable because hazards can often be eliminated or controlled more economically during design. CCPS

Objectives of the Study

The main objectives of this research are:

1. To identify major occupational and process hazards in fertilizer manufacturing.
2. To assess the risks associated with identified hazards using HIRA.
3. To classify hazards according to their likelihood and severity.
4. To identify existing and additional control measures.
5. To recommend measures for reducing high and unacceptable risks. inadequate control systems. Published research on a fertilizer facility producing ammonia, urea and NPK fertilizer demonstrates the usefulness of systematic risk ranking for identifying units requiring more detailed assessment.
6. To demonstrate the importance of HIRA as a preventive safety-management tool in fertilizer plants.

Overview of Hazards in Fertilizer Manufacturing

The principal hazard categories in a fertilizer plant include:

Chemical hazards

Chemical hazards arise from handling substances such as ammonia, nitric acid and other process chemicals. Accidental leakage can result in inhalation exposure, chemical burns, environmental contamination and, depending on the substance and conditions, fire or explosion.

Process hazards

Process hazards can result from loss of containment, excessive pressure or temperature, equipment failure, process deviations and inadequate control systems. Published research on a fertilizer facility producing ammonia, urea and NPK fertilizer demonstrates the usefulness of systematic risk ranking for identifying units requiring more detailed assessment. ScienceDirect

Mechanical hazards

Workers may be exposed to rotating machinery, pumps, compressors, conveyors, lifting equipment and moving components. Maintenance activities can introduce additional risks such as unexpected equipment movement, dropped objects and entanglement.

Electrical hazards

Typical electrical hazards include electric shock, short circuits, arc flash, faulty electrical equipment and inadequate isolation during maintenance.

Physical hazards

Noise, heat, vibration, inadequate lighting, slippery surfaces, working at height and falling objects are common occupational hazards.

HIRA Methodology

HIRA generally consists of two interconnected activities: **hazard identification** and **risk assessment**. Risk assessment considers the likelihood of an event and the severity of its consequences. PubMed Central (PMC)+1

A typical HIRA procedure is:

Hazard identification → Consequence identification → Likelihood assessment → Risk rating → Existing controls → Additional controls → Residual-risk assessment

A commonly used approach is:

Risk Score=Likelihood×SeverityRisk\ Score = Likelihood \times Severity

For example, a 5 × 5 risk matrix can be used.

Likelihood	Description
1	Rare
2	Unlikely
3	Possible
4	Likely
5	Almost certain

Severity	Description
1	Insignificant
2	Minor
3	Moderate
4	Major
5	Catastrophic

The resulting risk score can then be categorized as low, medium, high or extreme according to the organization's risk matrix.

HIRA for Major Fertilizer-Plant Activities

Activity/Area	Hazard	Possible Consequence	Typical Risk	Key Controls
Ammonia handling	Ammonia leakage	Toxic exposure, environmental impact	High	Gas detectors, ventilation, emergency shutdown, PPE
Ammonia storage	Loss of containment	Toxic cloud/release	High	Inspection, pressure protection, isolation systems
Urea synthesis	High pressure/temperature	Equipment failure, serious injury	High	Process controls, alarms, interlocks, inspection

Activity/Area	Hazard	Possible Consequence	Typical Risk	Key Controls
Compressor operation	Rotating equipment	Entanglement, mechanical injury	High	Guards, isolation, preventive maintenance
Chemical transfer	Hose/pipe failure	Chemical exposure/spillage	High	Inspection, proper connections, emergency isolation
Electrical maintenance	Electrical contact	Shock, burns, fatality	High	LOTO, earthing, authorized personnel
Working at height	Fall from elevation	Serious injury/fatality	High	Guardrails, full-body harness, work-at-height procedure
Confined-space entry	Toxic/oxygen-deficient atmosphere	Asphyxiation/fatality	Extreme	Permit, gas testing, ventilation, standby person
Material handling	Falling loads	Injury/equipment damage	Medium–High	Certified lifting equipment, competent operators
Maintenance/welding	Fire/ignition	Fire/explosion	High	Hot-work permit, gas testing, fire watch

Risk-Control Measures

The hierarchy of controls should be applied rather than relying solely on personal protective equipment.

Elimination and substitution

Where technically feasible, hazardous materials or hazardous operations should be eliminated or substituted with safer alternatives.

Engineering controls

Examples include:

- Automatic shutdown systems.
- Pressure relief devices.
- Gas detection systems.
- Fixed fire-protection systems.
- Machine guarding.
- Ventilation systems.
- Interlocks and alarms.
- Remote operation and isolation.

Administrative controls

Administrative measures include:

- Standard operating procedures.
- Permit-to-work systems.
- Lockout/tagout.
- Preventive-maintenance programs.
- Emergency-response procedures.
- Safety training.
- Toolbox meetings.
- Periodic HIRA review.

Personal protective equipment

PPE should be selected according to the specific hazard and exposure potential. Depending on the task, this may include helmets, chemical-resistant gloves, eye/face protection, protective clothing, safety footwear and appropriate respiratory protection.

Discussion

Research on fertilizer facilities demonstrates that systematic hazard ranking can help prioritize process units for more detailed risk assessment. In one fertilizer-industry study, HIRA was used as an initial screening/ranking method before applying a more detailed computerized risk-assessment technique to selected units. ScienceDirect

A more recent study of a fertilizer company's production department identified respiratory, hearing and fall hazards and used HIRA to prioritize risks and recommend improvements to the working environment and safety practices. Paperity

HIRA should therefore not be treated as a one-time document. It should be reviewed following incidents, process modifications, introduction of new chemicals or equipment, changes in operating conditions and significant maintenance activities.

Conclusion

The fertilizer industry contains significant chemical, mechanical, electrical, thermal and process-safety hazards. HIRA provides a systematic framework for identifying these hazards, assessing their likelihood and consequences, prioritizing risks and implementing appropriate controls.

The most critical areas in ammonia and urea fertilizer plants generally require particular attention to **loss of containment, toxic ammonia exposure, high-pressure equipment, chemical handling, fire and explosion potential, rotating machinery, electrical work, confined spaces and working at height**. Effective engineering controls, operating procedures, maintenance, emergency preparedness and worker training are essential for reducing residual risk.

HIRA is most effective when integrated with other process-safety techniques such as HAZOP, FMEA, LOPA, quantitative risk assessment and incident/near-miss analysis. AIChE's process-safety guidance similarly describes HIRA as a family of techniques whose depth should match the decision and lifecycle stage being assessed. CCPS

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