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Review

# Establishment of the hazard reduction methodology to be taken into account for safety assessment during decommissioning of nuclear facilities

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ABSTRACT

This paper is to establish the hazard reduction methodology for decommissioning of nuclear facilities. There are radiological and non-radiological hazards during decommissioning of nuclear facilities. Based on a review of industrial methods and requirements of decommissioning safety, a method of hazard reduction has been designed and a mathematical method of cost estimation has been developed using a parametric method.



**Contents**



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## 1. Introduction

Decommissioning is an invasive process that presents industrial and chemical hazards as well as radiological ones, and indeed the non-radiological hazards generally represent greater overall risk to workers (IAEA, 2013; Jeong and Lim, 2009).

This paper is to establish the hazard reduction methodology for decommissioning of nuclear facilities. Based on a literature review of hazard evaluation and process safety, characteristics of hazard reduction methods had been evaluated. Through reviewing the safety, requirements of hazard reduction during decommissioning of nuclear facilities were drawn up. In the end, a procedure and mathematical model of hazard reduction and mathematical model were developed to reduce hazards during decommissioning of nuclear facilities using radioactive materials.

## 2. Literature review of the hazard reduction methodology

### 2.1. Overview of hazard evaluation

A hazard is a physical or chemical condition that has the potential for causing harm to people, property, or the environment. A hazard evaluation is an organized effort to identify and analyze the significance of hazardous situations associated with a process or an activity (CCPS, 2008).

Hazard evaluations usually focus on the potential causes and consequences of episodic events, such as fires, explosions, and unplanned releases of hazardous material, instead of the potential effects of conditions that may routinely exist such as a pollutant emitted from a registered emission point. Also, hazard evaluations usually do not consider situations involving occupational health and safety issues, although any new issues identified during the course of a hazard evaluation are not ignored and are generally forwarded to the appropriate responsible person. Historically, these issues have been handled by good engineering design and operating practices. In contrast, hazard evaluations also focus on ways that equipment failures, software problems, human errors, and external factors can lead to fires, explosions, and releases of toxic material or energy (CCPS, 2008).

### 2.2. Overview of process safety

One definition of process safety is the sustained absence of process incidents at a facility. To prevent these process incidents, one must understand how they can occur. Using hazard evaluation methods can help the organization to better understand the risks associated with a process and how to reduce the frequency and severity of potential incidents.

A process hazard represents a threat to people, property and the environment. Examples of process hazards are given in Table 1. Process hazards are always present whenever hazardous materials and hazardous process conditions are present. Under normal conditions, these hazards are all contained and controlled.

An incident in defined as an unplanned event or sequence of events that either resulted in or had the potential to result in adverse impacts. Thus, an incident sequence is a series of events that can transform the threat posed by a process hazard into an actual occurrence. The first event in an incident sequence is called the initiating cause, also termed the initiating event or, in the context of most hazard evaluation procedures, just the cause. The types of events that can initiate incident sequences are generally equipment or software failures, human errors, and external events.

### 2.3. Typical objectives of hazard evaluation at different phases

The appropriate objective for a hazard evaluation depends upon several factors, including the life cycle phase the project is in when the hazard evaluation is performed. Obviously, as a project evolves, the types of hazardous situations investigated change from general questions about basic process chemistry to more detailed questions about equipment and procedures. Table 2 lists some typical hazard evaluation objectives at different stages of a process lifetime (CCPS, 2008).

**Table 1**
Elements of process incidents.

| Process hazards | Initiating causes | Incident outcomes |
|---|---|---|
| Significant inventories of:<br>Flammable materials<br>Combustible materials<br>Unstable materials<br>Corrosive materials<br>Asphyxiants<br>Shock-sensitive materials<br>Highly reactive materials<br>Toxic materials<br>Inert gases<br>Combustible dusts<br>Pyrophoric materials<br><br>Physical conditions<br>High temperatures<br>Cryogenic temperatures<br>High pressures<br>Vacuum<br>Pressure cycling<br>Temperature cycling<br>Vibration/liquid hammering<br>Ionizing radiation<br>High voltage/current<br>Mass storage<br>Material movement<br>Liquefied gases | Containment failures<br>Pipes, ducts, tanks, vessels, containers flexible hoses, sight glasses, gaskets/seals<br><br>Equipment malfunctions<br>Pumps, compressors, agitators, valves, instruments, sensors, control failures<br>Spurious trips, vents, reliefs<br><br>Loss of utilities<br>Electricity, nitrogen, water, refrigeration, air, heat, transfer fluids, steam, ventilation<br><br>Human errors<br>Operations<br>Maintenance<br><br>External events<br>Vehicle impact<br>Extreme weather conditions<br>Earthquake<br>Nearby incident impacts<br>Vandalism/sabotage | Loss events<br>Discharge or releases<br>Fires<br>Pool fires<br>Jet fires<br>Flash fires<br>Fireballs<br><br>Explosions<br>Confined explosions<br>Unconfined vapor cloud explosions<br>Vessel rupture explosions<br>BLEVEs<br>Dust explosions<br>Detonations<br>Condensed-phase detonations<br><br>Impacts<br>Toxic, corrosive, thermal, overpressure, missile, and other effects on:<br>Community<br>Workforce<br>Environment<br>Company assets<br>Production |