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The safety assessment system based on virtual networked environment for evaluation on the hazards from human errors during decommissioning of nuclear facilities

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ABSTRACT

This paper is intended to suggest a system for evaluation on the hazards from human errors during decommissioning of nuclear facilities. The system was developed under virtual networked environment. The innovative features are real-time changing direction of workers in a scenario and real-time measuring personal exposure dose and collective exposure dose. The system will be expected to be utilized as a training tool for improving familiarization of a workplace and for preventing workers from accidents.

1. Introduction

Decommissioning of nuclear facilities has to be accomplished by assuring the safety of workers because the decommissioning activities of nuclear facilities are under high radioactivity and work difficulty.

Human error has been associated with significant losses in many industries [1]. Despite years of research, difficulties still exist in quantifying the contribution of human error to accidents that result in disaster and/or losses. Incorporating human errors into safety analyses is a rather difficult and complex exercise. Indeed, engineers still find it difficult both to incorporate human and organization sources and to realistically quantify them [2]. Maintenance-related human errors have imposed heavy costs on industry [3]. Research studies have reported on the significant role of maintenance-related human errors in aviation accidents [4–6], hazardous events in nuclear power plants [7], and software faults [8]. The impact of human errors in maintenance was found n the literature and come to the end with the finding that human error in maintenance is a pressing problem [9].

There are a lot of radiological and non-radiological hazards during decommissioning of nuclear facilities. Workers need to be protected by eliminating or reducing the radiological hazards and non-radiological hazards that may arise during routine decommissioning activities and as well as during accidents. The hazards associated with decommissioning of structures and buildings or with construction of temporary facilities are important because not only they may be a direct cause of harm to workers but also their occurrence may indirectly result in increased radiological hazard [10]. Therefore, workers always are situated on a workplace within the occupational radiation exposure during decommissioning of nuclear facilities.

An augmented reality has been used in decommissioning of nuclear facilities to support temporary placement and conveyance operation simulation system [11]. The limitations of the legacy system are unable to real-time change working direction and to measure the occupational dose in a workplace and evaluate the hazards from human erros during decommissioning of nuclear facilities.

This paper was intended to suggest an innovative safety assessment system for measurement and evaluation during decommissioning of nuclear facilities.

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Table 1
The human errors during decommissioning of nuclear facilities.

Categories of items	Detailed items
Psychological evaluation of worker	• Experience and training • Pressure of time • Damage of failure
Physical evaluation of worker	• Narrow space and high location • Excessive behavior and posture • Interference of protective equipment
Human-machine evaluation	• Difficult of handling equipment • Difficult of working information • Difficult of working modifications and stops
Environment evaluation	• Radiation exposure • Temperature and brightness • Dust and noise

2. Hazards during decommissioning of nuclear facilities

A number of industrial hazards are associated with the decommissioning of any radiological facility. Many of theses hazards are routine to the non-nuclear industry and their mitigation consists of standard industrial safety practices. According to the reports of a decommissioning for nuclear facilities [12], in addition to radiation exposure and contamination, industry safety occurs such as falls, heavy equipment hazards, structural hazards (sharp metal and debris). And a substantial increase in the numbers/amount of scaffold use, confined use, welding/grinding atmospheres, dusts/vapors nuisance atmospheres and heavy lifts (loading and rigging).

The principal hazards anticipated during a decommissioning include physical hazards and potential exposures to activated material during a dismantling, surveying, moving and packaging potentially activated components. Workers need to be protected by eliminating or reducing the radiological and non-radiological hazards that may arise during routine decommissioning activities and as well as during accidents.

Overall radiological risks can be lower during a decommissioning than during a regular operation [13]. However, the nature of decommissioning activities can mean that there is an enhanced risk of an exposure for some workers during a decommissioning. Remote handling and robotics technologies can greatly mitigate these risks, but when there are unavailable, a worker's exposure must be carefully managed. Similarly, the ingestion and inhalation of radionuclides from a surface contamination present a genuine risk that must be clearly addressed by standard worker protection measures. The potential for a criticality and breach of containment are usually of less concern, but in some scenarios-such as the case where fissile material remains in process equipment-the possibility must be recognized and field activities planned accordingly. Containment systems can be particularly problematic. Those used during operation may no longer be working, and even if they are, there is no assurance that they can match the increased and varying demands of decommissioning activities. Radiological protection against these hazards is provided by a number of technical and managerial measures, including an isolation and removal of radioactive material, a spill prevention and dust/aerosol suppression techniques, bulk shielding of workers, discrete individual shielding through personnel protective clothing etc., training, air filtering, wastewater treatment, and appropriate waste-disposal techniques. Nonradiological hazards include fire (the most common risk due to the presence of flames in cutting technologies coupled with the accumulation of potentially combustible wastes), explosions (originating in dusts produced), toxic material (particularly in aged facilities where material no longer allowable [e.g., asbestos] may be present) and electrical and physical hazards (e.g., noise, confined space risks, impact trauma from falling objects, etc).

Hazard identification should begin by identifying all the potential radiological/non-radiological hazards which harm could be realized. A radiological hazard is a worker's exposure. And non-radiological hazards include industrial safety practices such as fire, explosions, falling, collision, etc closer to construction safety than operational safety. Radioloigcal hazard is a worker radiation exposure and non-radiological hazards include a fall, upset/rollover, falling objects, collapse/destruction, crushing/winding, electric shock, fire/explosion and hazardous environments.

3. Evaluation on the hazard from human errors during decommissioning of nuclear facilities

3.1. Considerations of human erros during decommissioning of nuclear facilities

According to the reports and experts of decommissioning, items of the assessment model on human errors were categorized and classified as shown in Table 1 [14]. Items of the assessment model on human errors could be categorized as ‘psychological evaluation’, ‘physical evaluation’, ‘man-machine evaluation’, and ‘environmental evaluation’.

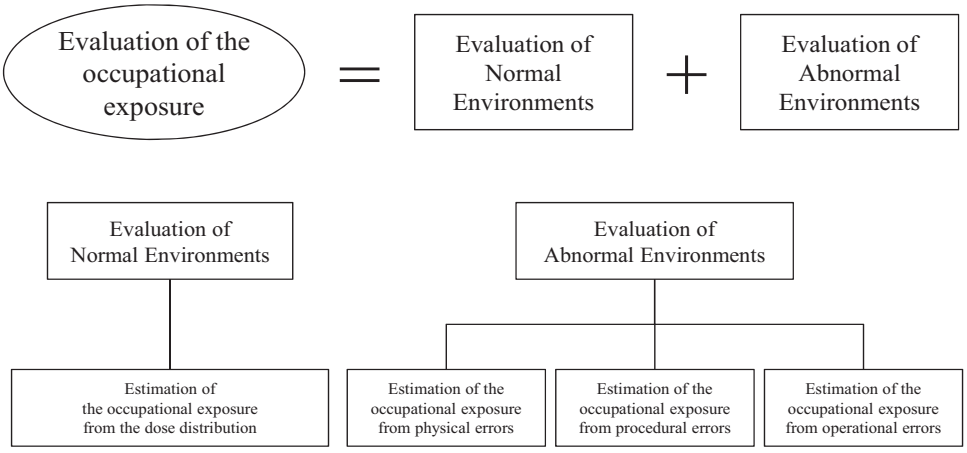

Fig. 1. An evaluation model of the occupational exposure from human errors.