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Risk assessment on abnormal accidents from human errors during decommissioning of nuclear facilities

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ABSTRACT

This paper is intended to suggest an approach to the methodology of evaluation on abnormal accidents from human errors during decommissioning of nuclear facilities. A structure of model was established and a mathematical method was also designed to evaluate both normal and abnormal environments. The proposed methodology was verified by applying a practical test case of decommissioning scenarios using the assessment system in virtual decommissioning environment.

1. Introduction

Human error has been associated with significant losses in many industries (Candice and Sanskaran, 2015). 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 (Colombo and Demichela, 2008). Maintenance-related human errors have imposed heavy costs on industry (Asadzadeh and Azadeh, 2014). Research studies have reported on the significant role of maintenance-related human errors in aviation accidents (Wells, 2001; Hackworth et al., 2007), hazardous events in nuclear power plants (Heo and Park, 2010), and software faults (Hollnagel, 1998). 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 (Dhillon and Liu, 2006).

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 (IAEA, 2013). Therefore, workers always are situated on a work place within the occupational radiation exposure in the middle of decommissioning of nuclear facilities.

This paper was intended to suggest an approach to the methodology of radiological assessment on abnormal accidents from human errors during decommissioning of nuclear facilities.

2. Hazards during decommissioning of nuclear facilities

There are radiological hazards and non-radiological hazards throughout decommissioning of nuclear facilities. Radiological hazards, in general, fall into four categories: external exposure, ingestion and inhalation of radionuclides, criticality, and breach of containment. Overall radiological risks can be lower during decommissioning of nuclear facilities than during that. However, the nature of decommissioning activities can mean that there is an enhanced risk of exposure for some workers during decommissioning. 'External exposure' is the most potential hazard to workers during decommissioning of nuclear facilities than other hazards. In other words, 'external exposure' is an occupational exposure to workers during decommissioning of nuclear facilities (IAEA, 2013).

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3. Method

3.1. Concept of the safety assessment during decommissioning of nuclear facilities

During decommissioning activities of nuclear facilities, the procedure of radiological safety assessment consists of mainly four steps. The steps as presented in Fig. 1 are 'development of a decommissioning scenario', 'evaluation of the occupational radiation exposure, 'assessment of its acceptability', and 'taking actions of countermeasures to reduce the occupational radiation exposure'.

3.2. Considerations of the occupational exposure

During decommissioning activities of nuclear facilities, there are a lot of worker's intrusion into working in places. Decommissioning activities consist of decontamination and dismantling by hand-on equipments and remote equipments.

According to experiences of decommissioning activities in Korea, the occupational radiation exposure to workers belongs to the exposure of normal environments and the exposure of abnormal environments from human errors. The exposure of normal environments is the working condition that a worker is exposed to the dose distribution of radiation according to a scenario under radiological environments. The exposure of abnormal environments from human errors is composed of physical errors, procedural errors, and operational errors of equipments under radiological environments. The physical error means that a worker makes errors such as falling from elevation, turnover during decommissioning activities. The procedural error means that a worker commits out of order in the middle of according to precedence. The operational error means that a worker makes control error during in-tact and remote operations of equipments.

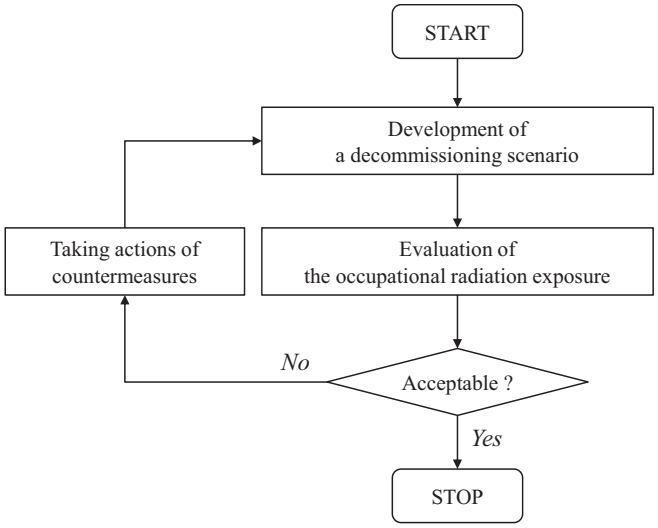

Fig. 1. Concept of the safety assessment for decommissioning of nuclear facilities.

3.3. Evaluation model of the occupational exposure

The structure of model to evaluate the occupational radiation exposure is shown in Fig. 2. As shown in Fig. 2, the structure of evaluation model consists of two categories. One is to evaluate the exposure under normal environments. Another is to evaluate the exposure under abnormal environments. Evaluation of normal environments is to estimate the exposure from the dose distribution in a work place. Evaluation of abnormal environments is to estimate the exposure from physical errors, procedural errors, and operational errors.

3.4. Mathematical model for evaluation of the occupational exposure

Evaluation of the occupational radiation exposure during decommissioning of nuclear facilities can be defined as the combination of the evaluation of normal environments and the evaluation of abnormal environments in a decommissioning scenario.

In the context of evaluation of the exposure, a simplified definition of evaluation of the exposure is as follows in Eq. (1)

$$R_i = N_i + A_i \tag{1}$$

where R_i is the evaluation of the exposure to workers in the *ith* decommissioning scenario, N_i is the evaluation of the exposure to workers under normal environments in the *ith* decommissioning scenario, and A_i is the evaluation of the exposure to workers under abnormal environments in the *ith* decommissioning scenario.

According to the simplified definition of evaluation of the exposure, N_i can be expressed as shown in Eq. (2)

$$N_i = D_i \times t_i \times n_i \tag{2}$$

where N_i is the evaluation of the exposure to workers under normal environments in the *ith* decommissioning scenario, D_i is the dose distribution rate of the exposure to a worker per time under normal environments in the *ith* decommissioning scenario, and t_i is the

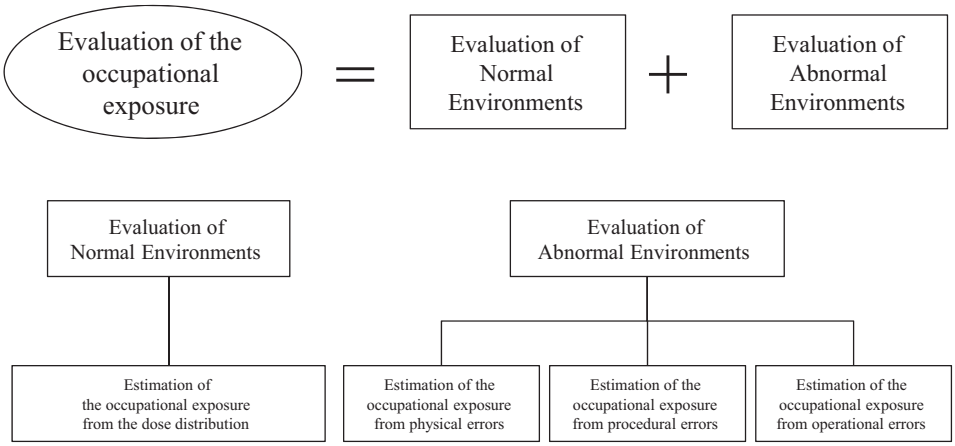

Fig. 2. The evaluation model of the exposure to workers.