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Radiation protection protocol for environmental defense using nano-scopic water spray in nuclear accident

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ABSTRACT

The environmental defense system in the nuclear power plants (NPPs) using water spray is investigated. A new kind of radiation protection system modeling is introduced in the case of NPPs accidents. The spray system is added to the conventional radiation protection barriers for the nuclear defense in depth concept where the water is considered as nano-scopic molecular substance. The effectiveness of aqueous solution is verified in a NPPs accident. The quantitative simulation for solubility of radioactive material is performed by the Monte-Carlo method, which is produced in the nuclear fuels. The safety concept is newly modified in the multiple barriers for the post accident. The cheap and simple system is suggested for the ecological safety in the NPPs accident as the political protocol.

1. Introduction

In a nuclear power plant (NPP) accident, it is important to protect against the radioactive material damage. The defense system is designed for the complete shielding against the hazard radiation. The system, however, had not worked effectively in the cases of Chernobyl and Fukushima nuclear accidents. The final barrier system could not protect the environment from the radioactive fallout. Therefore it is necessary to design a more reasonable method in the case of an immedicable nuclear disaster. The water spray is suggested to control of the radioactive material which is coming out to environment after breaking the shielding systems in an NPP. Under an accident situation, it is very difficult to manage the dispersed radioactive material in which the material is composed of nano-scopic molecular sized elements.

Table 1 shows the concept of the nuclear defense in depth where the strategies of the radioactive material control is described (IAEA, 1996), which is a general systematic philosophy of the nuclear accident situation. In addition, the 4 stages of the radiation protection barriers are shown in Table 2 (IAEA, 1996). This is based on the radiation shielding concept. The barrier structure can withstand radioactive materials. In this paper, water is used for defense of radiation, which could dissolve the huge amount of radioactive material. The spray can carry the water in the containment rupture accident. This is a new kind of concept that the shielding is substitute with the water resolving with the spray system or shower system.

It is defined that the solubility is the property of a solid, liquid, or gaseous chemical substance in which it is called as solute to dissolve in a solid, liquid, or gaseous solvent to form a homogeneous solution of the solute in the solvent (Hill and Petrucci, 1999). The solubility depends on how strong the substance of ion and molecule is attracted to each other and how they interact with water molecules which are related to solvent, temperature, and pressure, and the extent of the solubility (American Chemical Society, 2007). The dissolving is affected by the interaction among the molecules of the solvent and solute. (American Chemical Society, 2007). It is considered that the solubility product shows the degree of completeness of precipitation reactions (Rosenberg and Epstein, 1997). If some solid ion is contacted with the solution, some more ions could be dissolved (Rosenberg and Epstein, 1997).

In the past study, Krauskopf worked on the solubility of nuclear material in the nuclear waste where the method for disposing of high-level radioactive waste includes converting it to a stable solid form, enclosing it in metal canisters, placing the canisters in mined cavities several hundred meters below, the surface, and filling and sealing all entries to the cavities (Kruskopf, 1986). In addition, Akers studied that examinations have been performed to characterize the distribution of core materials and fission products at the damaged Three Mile Island Unit 2 (TMI-2) reactor (Akers et al., 1990). Furthermore, Tigeras studied that Iodine's environmental and biological risks have been extensively studied in case of a severe reactor accident (Tigeras et al., 2011). Nevertheless, little information is available about iodine behavior under normal

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Table 1
Nuclear defense in depth (INSAG-10, IAEA, 1996).

Level	Objective	Meaning
1	Prevention of abnormal operation and failures	Conservative design and high quality in construction and operation
2	Control of abnormal operation and detection of failures	Control, limiting and protection systems and other surveillance features
3	Control of accidents within the design basis	Engineered safety features and accident procedures
4	Control of severe plant conditions, including prevention of accident progression and mitigation of the consequences of severe accidents	Complementary measures and accident management
5	Mitigation of radiological consequences of significant releases of radioactive materials	Off-site emergency response

Pressurize Water Reactor (PWR) operating conditions. Recently, the fan based modeling was studied where the dispersion of radioactive material was investigated (Woo, 2012a).

There was an experience of water spaying protection against radiation which was produced from the nuclear accident. The Fukushima Daiichi nuclear accident had showed several kinds of methods in order to pour the water into the nuclear reactor core. Japanese authorities are continuing to spray water on unit 3 of the Fukushima Daiichi nuclear power station as the immediate concern remains for spent fuel storage conditions (Nuclear Engineering International, 2011). In addition, Japanese military helicopters dropped seawater over unit 3 and four drops of seawater took place in the morning (Nuclear Engineering International, 2011). Also, the riot police pumps water into reactor 3 from the ground and water spraying operations had taken by the police where the Japan Self-Defense Forces sprayed 30 tons of water into unit 3 from the ground using five special military fire trucks (Nuclear Engineering International, 2011). However, water cannons were unable to get close enough to the unit due to high radiation levels. Authorities had been dropping water from helicopters and using water cannons on the ground in an attempt to cool reactors damaged by earthquake, but despite these efforts, radiation was streaming into the atmosphere from exposed uranium rods at reactor number four, after a 45 ft deep pool designed to keep them stable boiled dry in a fire (The Telegraph, 2011).

As it is seen in the Fukushima case, the water pouring is very important to stabilize the situations of nuclear accident in NPP. Since the nuclear energy is produced mostly by the kinetic energy of neutrons, it is very important to stop or slow down the neutron movements where the collisions of neutrons by the hydrogen can slow down or stop the neutrons. So, the personnel in Fukushima site would like to pour the seawater into the containment, which acts as the moderator in the reactor. The water pouring could be done by the safety systems in the NPP which are made by several kinds of piping for water injections. However, if this system is failed, the alternative system like the spraying is extremely necessary. So, it is very reasonable to make the radiation protection protocol using radiation shielding and water spray. The Section 2 explains the method of the study. The Section 3 describes results of the study. There are some conclusions in Section 4.

2. Method

In the modeling, the water is spread by the sprayer. It is considered that there are 2 kinds of types for the spraying system. That is to say, the 1st type is the sprayers are equipped over the plant. The other type is using the sprayer car which is similar to the fire truck where the sprayer is equipped. In this case, many cars are ready for the operation. So, the operation costs are necessary. In addition, the car is easy to be moved following the necessity of accident situation.

Table 2
The barriers confining the fission products (INSAG-10, IAEA, 1996).

Stage	Meaning
1	Fuel matrix
2	Fuel cladding
3	Boundary of the reactor coolant system
4	Containment system

The 1st type is in Fig. 1, which shows the configuration of water spray system where the spray reacts to the radioactive fallout in the accident situation. The spray covers all areas of the containment building. Hence, the water is pumped by the spray line. If the system is out of order due to the some pipe breaks, the water quantity is significantly decreased. Therefore the compensating method is to use the spray car which is in the Fig. 2. The car showers water by the water spray as it is seen in the figure. So, these two methods are supplementary. The lower parts are designed to collect the drained water. This water could be disposed after accident is stabilized. The ecological contamination could be avoidable due to this technology modeling.

A water spray system is usually a domestic external fire sprinkler system designed to protect human and home from bushfires and wildfires. Otherwise, spray systems have long been used in fire protection for buildings and facilities, which refers to domestic bushfire and wildfire systems. So, it is necessary the system depends on type of risk and time of effectiveness. The feature is that copper piping is used to withstand high temperatures that may be experienced during a fire front or for higher reliability for in ceiling installations. In addition, the piping is made to protect the exposure to high radiant heat.

The solubility equation is used for the modeling of the water spray method for the radiation protections. The solubility of radioactive material in water is calculated with the general equation in

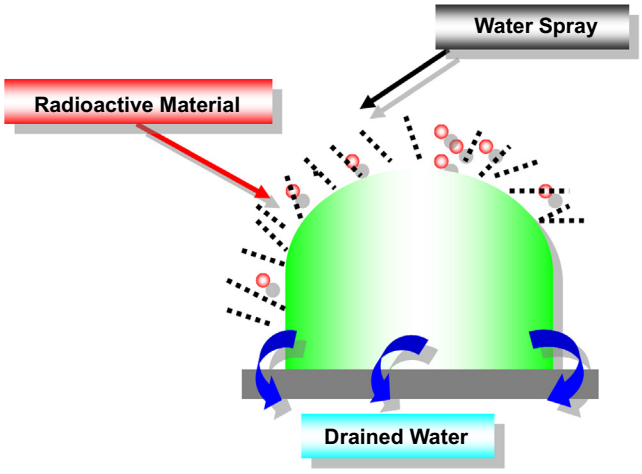

Fig. 1. Configuration of radiation dispersion by water spray (Type 1). This shows the configuration of water spray system in which the spray reacts to the radioactive fallout in the accident situation. The spray spreads out all areas of the containment building.