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Öko-Institut e.V.
Institut für angewandte Ökologie
Institute for Applied Ecology

# Evaluation of the Radioactivity Release Event in December 2003 at Yonggwang Nuclear Power Plant Unit

Commissioned by: Korea Hydro and Nuclear Power Co., Ltd. (KHNP), Seoul, Korea

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Stephan Kurth, Öko-Institut e.V. Darmstadt

Gerhard Schmidt, Öko-Institut e.V. Darmstadt

**Öko-Institut e.V.**

Büro Darmstadt
Elisabethenstraße 55-57
D-64283 Darmstadt
Tel.: 06151-8191-0

Geschäftsstelle Freiburg
Postfach 6226
D-79038 Freiburg
Tel.: 0761-4 52 95-0

Büro Berlin
Novalisstraße 10
D-10115 Berlin
Tel.: 030-28 04 86 80

Authors: Stephan Kurth, Gerhard Schmidt
Öko-Institut e.V., Elisabethenstrasse 55-57
D-64283 Darmstadt, Germany

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## Summary

As of March 4, 2004, Oeko-Institut was commissioned by the Korean Company KHNP to review an incident in NPP Yonggwang Unit 5.

Starting December 22, 2003, this incident lead to a contamination of a usually non-nuclear (clean) system of the plant, the Demineralized Water System, by contaminated reactor coolant in the Shutdown Cooling System. These two systems are usually separated by valves and check-valves. A high leakage rate of a valve was later identified by tests. The Leakage was caused by incomplete closure due to the deposition of foreign material inside the valve.

Because the Demi-Water System was not equipped with radiation monitoring systems at the time of the incident, the contamination in this system was not recognized immediately. The contamination spread to other piping and equipment, where demineralized water was used. Only after analysing an alert in a monitor for airborne activity, which was, by chance, activated by the gamma radiation of a nearby pipe, and identification of the real cause of this alert, was the contamination source finally identified and further spreading of activity through the Demineralized Water System stopped.

At this time, the spreading of contamination had already reached the water treatment plant, and a small part of the contamination had already been discharged to the hot cooling water channel and to the sea.

The causes of the incident were investigated by the operator and verified in our examination. Radiation measurements at the piping of the Demi-Water System showed the flow path of the contamination and led to an interface between the Shutdown Cooling System and Demi-Water System. The function of the isolation valves that should separate both systems was checked by valve leakage tests. An internal leakage caused by deposition of foreign material on the surface of the disc seating was found and confirmed by an internal inspection of the valve. After removing the foreign material and cleaning, the valve was found leak tight. However, the foreign material which was the root cause for the valve leakage was not analysed. Until now the origin and the consistence of the foreign material were not identified, so that a reoccurrence of a similar incident caused by the deposition of foreign material can not be excluded.

The investigation of the operation modes and conditions in the related systems showed that only during the shutdown cooling mode a flow of contaminated reactor coolant into the Demi-Water System was possible following the pressure gradient.

There was a weakness in the design of the solenoid isolation valves. This type of valve can only isolate in one flow direction. A reverse flow is possible when a certain value of the back pressure is exceeded, which was the case during the incident due to the leaking of one valve in the interface.

The sequence of actions that the operator had chosen to identify the cause of the radiation alarm was reviewed in order to evaluate whether this sequence was thorough and systematic and the response time appropriate.

As a result of our investigation we found four major reasons for the time lag between the start of the release and its stoppage:

a) At the time of the incident, no direct monitoring of the Demi-Water-System for contamination was installed. (This major cause of time delay between contamination of the system and its detection/stoppage is now avoided by direct monitoring of this system for contamination.)
b) The indirect signalling of the contamination by an aerosol monitor was misleading and pointed the response team in a false direction. This caused a delay of at least two days, because the reason for the alert was assumed to be aerosols. The necessary check for aerosols failed, but consumed extra time.
c) Only after aerosol detection with other equipment failed, did the response team have to assume that the installed monitor was defective. The check for a possible failure of the installed equipment consumed extra time (approx. one day).
d) Another factor to be considered is that the signalization of the aerosol monitor only reached the alert status. It did not reach the alarm status that would have required immediate actions to be taken.

The delays b) to d) are as such understandable. The actions taken by the response team were thorough and systematic at all points of the response sequence. Due to the missing detection equipment in the Demi-Water System, the response team had no opportunity to detect the source of the alert directly.

The main cause a) for the time delay has been addressed adequately and corrected by the measures discussed below.

To prevent a reoccurrence of the incident, the following measures were taken to improve the isolation of clean and contaminated systems:

- At the PASS interface the connection to the Demi-Water System was cut. A Quick Disconnect Coupling was installed. The Demi-Water System will only be connected for a very limited time when it is required for the flushing of the sample line. Instructions for operation of the QDC were implemented in the procedures. If the procedure is followed thoroughly a contamination of the Demi-Water System will be prevented with high certainty.
- A systematic review of all possible flow paths from Primary Reactor Coolant to the Demi-Water System was performed by KHNP and verified during our

investigation. The results of the review are a suitable base for the development of measures to prevent a contamination of the Demi-Water System.

- Our investigation confirmed the weakness of the valve design. The existing solenoid isolation valves could only isolate in one flow direction and allowed a reverse flow. We welcome that KHNP plans to remove these valves by direct acting valves for bidirectional flow isolation.

The radioactivity monitoring over the complete flow path from the Demi-Water system to the environment was reviewed. The main question to be reviewed was whether a similar incident would be detected early enough to prevent a further spreading of contamination, and close enough to the contamination source to be able to enclose the contamination.

The detection time of a contamination in the Demi-Water System can be minimized by a continuous operation of measuring equipment directly in the system header. We therefore recommend the installation of such equipment at carefully selected locations of the header. This measure, accompanied by the already implemented monitoring program for the Demi-Water System, will detect contamination from every source or leakage flow path early in time, providing the opportunity to react to a contamination and to stop its further spreading very soon.

The review of the monitoring of the different water treatment facilities showed that this monitoring has been greatly improved after the incident. To complete the monitoring system, KHNP plans to install a continuous radiation detection system in its general water treatment plant. This system will automatically stop discharges of treated water when a certain activity level has been reached. We welcome these plans as an appropriate measure to enhance the prevention of unintended discharges and recommend its implementation. The monitoring of the sewage water treatment plant and the rainwater collection system have also been enhanced, so all three flow paths are now monitored for radioactivity.

The environmental monitoring inside and outside the premises has been evaluated as to whether it is appropriate for the detection of uncontrolled discharges over the water pathway. The sampling and measuring program would be able to detect relevant discharges. The results of samples that were taken after the incident did not show any signs of the activity released, because the amount discharged was too small to be detected (see below).

The review of KHNP's determination of the radionuclide inventory released to the environment showed that the calculation was based on conservative assumptions. The calculation is based on measured volumes of discharged wastewater and on measured concentrations of radionuclides in the two water treatment facilities. The activity levels were measured in samples taken after the discharges were stopped and

when the highest spreading of contamination had been reached. The highest of the two measured activity levels was selected for the calculation of the released inventory. The use of these values overestimates the released inventory.

In order to evaluate the environmental consequences of the incident, a simplified model calculation was used in this study. This simplified model is based on a number of very conservative assumptions, the resulting doses are certainly higher than those delivered by more realistic models. Based on this simplified model, a total dose of less than 1 µSv has been calculated. This is smaller by more than an order of magnitude than the precautionary value of 10 µSv/a and smaller by more than a factor of 1000 than limits for routine discharges from nuclear facilities (1 mSv/a). There is no general contradiction between our results and those calculated by KHNP. In both cases the environmental consequences of the incident are very small and below regulatory concern.

In our evaluation the following measures are recommended:

- The separation of contaminated and non-nuclear systems should be performed by isolation valves of high effectiveness and reliability.
- The inspection of systems and components should be extended and targetted on indications of pollution and suspended material on surfaces.
- In case of valve leakages caused by the deposition of foreign material, this material should be separated. The origin and the consistence of the material should be analysed.
- The design of the isolation valves in the PASS interface should be changed. The isolation function should be effective in both flow directions at all system conditions.
- A systematic review including all interfaces between contaminated and clean systems should be performed to ensure the effectiveness of the isolation function under the given system conditions.
- Before connecting the QDC the existing pressure indicators at the PASS pump should be read to make sure that the pressure level in the connected systems is correct.
- The planned installation of continuously working monitoring equipment to detect contamination in the Demi-Water System header should be implemented.
- The planned equipment for monitoring radioactivity in the general wastewater treatment plant and closure of discharges in case of an actuation should be installed.
- With respect to the sampling of water treatment facilities, we propose separate sampling for water and sludges to enhance the quality of the monitoring program.

- We propose the implementation in Unit 6 of all the changes that have been made or are planned for Yonggwang Unit 5, and of the recommended additional measures, as far as they are applicable in Unit 6.