Enhancement of Exposure Dose Prediction Reliability for Radiation Workers by Using Represented TLD/ADR Ratio

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Introduction

Exposure dose of workers of nuclear power plants in Korea is managed with TLD, a legal personal dosimeter. However, because TLDs are collected and read once a month due to its measurement principle, radiation workers are equipped with a supplementary dosimeter, ADR, to manage exposure dose on a real-time basis until TLD readings are provided. Dose readings may vary due to each dosimeter's specific characteristics, and these are overcome by using the previous year's TLD/ADR dose ratio in order to manage radiation-tasks that are performed actively. However, simple quoting of ADR/TLD ratio alone has its limitations fundamentally to effective exposure dose management for workers. Therefore, this study aims to obtain a more advanced represented ratio to address the aforementioned problem.

Materials & Methods

1. Current status

As can be seen from Fig. 1, which was included in a dissertation (Optimized Operation of External Dose Reading Facility) submitted to the Korean Association for Radiation Protection in 2008, the simple TLD/ADR ratio fluctuated drastically in the past, and although the level of fluctuation was reduced by applying TTP and fading optimization techniques from April 2007, the fluctuation nevertheless persisted. Therefore, it is difficult to ensure reliability of exposure dose management by simply quoting the existing or previous cycle's TLD/ADR ratio alone.

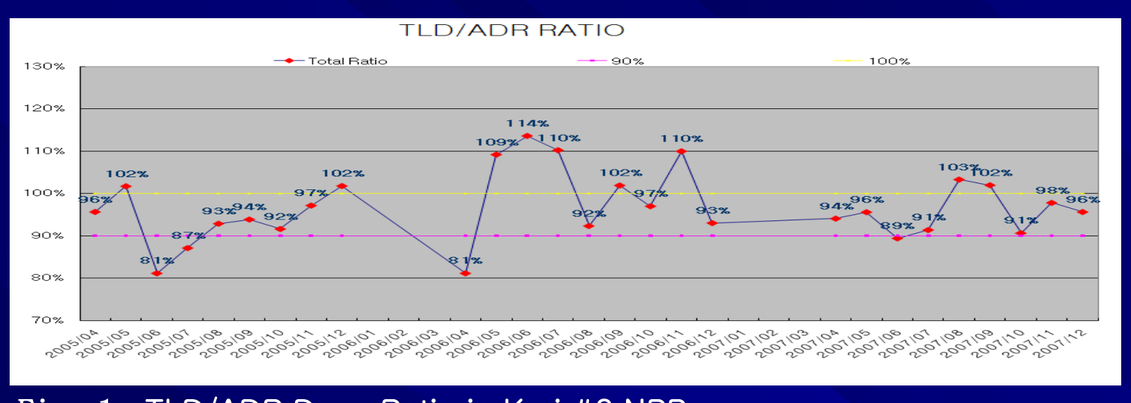

Fig. 1. TLD/ADR Dose Ratio in Kori #2 NPP

2. Analysis of radiation quality using TLD

Among approximately 60,000 TLDs supplied to workers at five nuclear power plants (Kori #2, Youngkwang #3, Uljin #1, Uljin #2 and Wolseong #2) in 2008 that use Harshaw reader systems, over 10,000 readings higher than the recording level were collected as raw data for this analysis, and a newly devised in-house emulator was used for effective analysis. The main characteristics of this emulator are that it can implement both algorithms provided by Harshaw (Win_Algorithm and DOELAP) simultaneously, and it allows users to view the type of exposure radiation quality and applied internal conversion factor. The analysis of dose radiation quality revealed that a high-energy photon field accounted for about 80% and, in particular, high-energy photons contributed 90% during O/H.

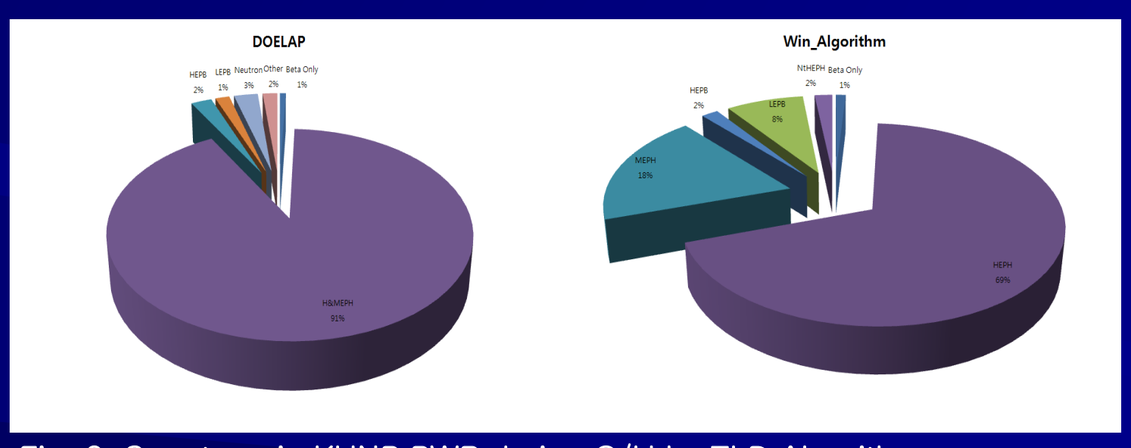

Fig. 2. Spectrum in KHNP PWR during O/H by TLD Algorithms

3. Dosimeter responses against radiation quality

In order to compare the reactivity of each personal dosimeter under conditions that are as similar as possible, induction points of the linear function were set at H150, H200, 137Cs, and 60Co. By reflecting the spectrum, which induces the average radiation of the primary coolant at light-water domestic nuclear power plants, as weighted energy, the reactivity of TLD and ADR (DMC 2000) elements was calculated to be 1.01 and 0.95, respectively. As TLD reading is performed once a month, its fading rate was set at 0.95. Also, the theoretical reactivity to the algorithm, DOELAP, based on deep dose can be determined as 0.90 (M150, H150, ^{137}Cs). Consequently, the TLD/ADR radiation ratio can be determined as 0.91.

Plant	Date	TLD Dose (man-mSv)	ADR Dose (man-mSV)	TLD /ADR	DOELAP	DEV
Y-3	200804	385	476	0.81	0.91	-10%
	200811	337	380	0.89	0.91	-2%
U-1	200809	336	356	0.94	0.91	3%
	200810	381	403	0.95	0.91	4%
K-2	200805	850	949	0.90	0.91	-1%
	200812	71	78	0.91	0.91	0%
U-2	200807	513	589	0.87	0.91	-4%

Table 1. Measured Ratio /DOELAP Ratio in KHNP PWR during O/H

4. Correlation between radiation and TLD/ADR

As shown in the above table, it can be confirmed that the TLD/ADR radiation ratio is 90% consistent with the theoretical ratio for O/H of each plant. This in turn verifies that the TLD/ADR dose ratio is related to exposure radiation quality while also confirming the reliability of the analysis.

5. Represented ratio for the new system

In order to determine the represented TLD/ADR ratio that is appropriate for the new reader system, ADR (EPD-G), which has been in use since December 2009, and the new algorithm, (Win_Algorithm) first introduced in July 2009, 1,080 readings over the recording level out of some 3,000 TLD supplied during O/H in November 2009 and May 2010 were used as raw data for our analysis. The reactivity of the newly introduced ADR (EPD-G) was determined as 0.96 by using the method shown in Chapter 2.3. Unlike the existing DOELAP algorithm, the new algorithm, Win_Algorithm, has its reactivity based on radiation quality set as a random variable (neutral network concepts) rather than a simple function, resulting in an internal conversion factor or probability distribution based on the quality of the exposed radiation. Therefore, in order to determine the represented TLD/ADR ratio, an uncertainty test was performed, which resulted in a represented TLD/ADR ratio of 0.8648. The uncertainty of the 95% confidence interval is 6%. Thus, when compared to observation values of 85% in November 2009 and 89% in May 2010, less than 1σ of confidence can be confirmed.

Results & Discussion

Exposure dose management for O/H of Kori #3 for the month of April 2011 was performed by applying the represented TLD/ADR ratio of 86%, and as a result, the TLD dose against ADR was measured as 90%, which was 4% over the estimated dose, but still within 95% of reliability. In addition, by determining the TLD/ADR ratio based on radiation quality (0.8956), it was confirmed that it nearly matched the observed ratio (90%), confirming once again the correlation between TLD/ADR ratio and radiation quality.

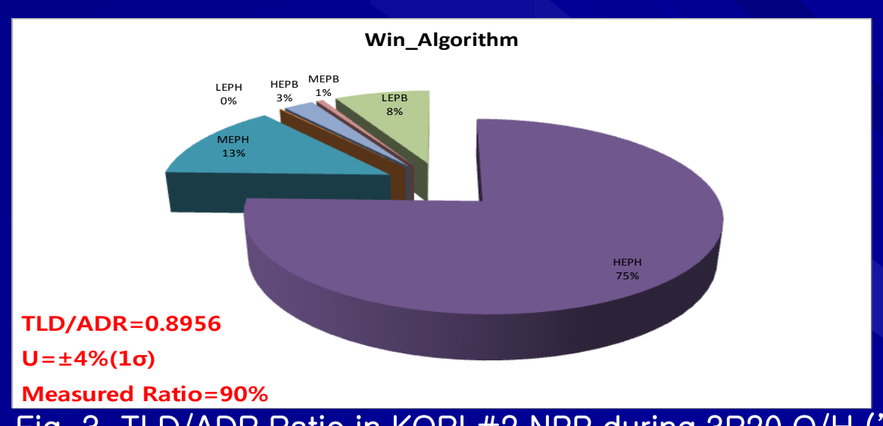

Fig. 3. TLD/ADR Ratio in KORI #2 NPP during 3R20 O/H ('11.4)

Conclusions

The radiation dose at Kori #3 during O/H in April 2011 was found to be 4% higher than estimated. The reason was that the radiation dose rates at major work sites were measured to be relatively higher than in the previous cycle. As a countermeasure, workers were asked to wear lead vests to reduce exposure dose, and our analysis found that during this process, radiation underwent a change in quality as it penetrated and was absorbed into the lead vests. Therefore, a decision was made to introduce a program in which TLD for analyzing radiation exposure quality is placed in advance when change in exposure quality of radiation is anticipated, so that its impact can be reflected in the represented TLD/ADR ratio.