Review on Adequacy of Skin Exposure Dose Evaluation Using Harshaw Algorithm

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Introduction

TLD reader systems used in nuclear power plants at home are either Panasonic or Harshaw, and among these, Harshaw reader systems use DOELAP (DOS) for its dose evaluation algorithm except for those at Kori Unit 2 and 3 that use Win-Algorithm (Windows). It came to our attention that the algorithm for skin dose evaluation based on beta energy was missing in Win_Algorithm (ALGM-W05-0908-001) provided initially by Harshaw. Upon our request for supplementation, Harshaw provided another algorithm (ALGM-W05-U-0908-003), and this study was launched to examine the adequacy of the new algorithm. Consequently, a completely new algorithm had to be developed as the one provided by Harshaw resulted in under-evaluation to a degree when it involved mixed beta field. We are planning to request to Harshaw to reflect the new algorithm, and we hope that such an effort will help enhance reliability of dose evaluation for workers at nuclear power plants while serving as a foundation to set a proper course in the development of a domestic algorithm.

Materials & Methods

1. Exposure to Tl-204 and Sr-90

For this study, Harshaw's 8814 holders and 7776 Type TLD cards for whole body exposure dose evaluation were prepared, and in order to increase the analysis' reliability, cards with less than 1% relative standard deviation were selected and then they underwent exposure at the Korea Atomic Energy Research Institute as specified in Table 1. Also, KINS performance inspection outcomes for 2009 were used to analyze single exposure to Sr-90.

Radiation source	Exposure dose (mSv)	TLD ID
Tl-204	0.5	9001036
Tl-204	1	9002364
Tl-204	1.5	9001974
Tl-204	2	9002942
Tl-204	4.21	9000922
Tl-204 + Sr-90	1 + 1	9004710
Tl-204 + Sr-90	1 + 2	9000984
Tl-204 + Sr-90	2 + 1	9003652
Tl-204 + Sr-90	1 + 3	9005014
Tl-204 + Sr-90	4.21 + 1	9003832

Table 1. TLD Exposure Dose for Algorithm Analysis

2. Analysis of radiation quality using TLD

With DOELAP, it is interpreted as being exposed to pure beta field when the L3/L1 fraction exceeds 15, and skin dose correction factor is calculated as below with the L3/L2 fraction, without beta energy classification.

$$r_{Shallow\ Dose\ Factor} = a_0 + a_1 \times \log(L_3 / L_2)$$

3. Win_Algorithm(ALGM-W05-U-0908-001)

With ALGM-W05-U-0908-001, it is interpreted as being exposed to pure beta field when the L3/L1 fraction exceeds 12, and the average of reactions to Tl-204 and Sr-90 is applied without beta energy classification.

$$r_{Shallow\ Dose\ Factor} = (r_{Tl\text{-}204} + r_{Sr\text{-}90})\ /\ 2$$

4. Win_Algorithm(ALGM-W05-U-0908-003)

As for ALGM-W05-U-0908-003, it is interpreted as being exposed to pure beta field when the L3/L1 fraction exceeds 12, and when the L1/L2 fraction is smaller than 0.22, it is classified as Sr-90 and when it is larger than 0.4, it is classified as Tl-204. All other cases are considered mixed beta ray of Sr-90 and Tl-204, and the average of each reaction is calculated as the skin dose correction factor.

5. New Algorithm

It is interpreted as being exposed to pure beta field when the L3/L1 fraction exceeds 12. The beta energy is classified with the L3/L2 fraction, and the skin dose correction factor is calculated as the same linear-log function as DOELAP.

Results & Discussion

As shown in Table 2, while Win_Algorithm can be used to distinguish beta for single energy, its ability to distinguish mixed beta energy is rather weak. This is because relative reaction to Tl-204 compared to Sr-90 is 1.74 times lower, and the L1/L2 fraction diminishes when the mix rate of high-energy beta increases. Therefore, classification of beta energy with photon energy fraction (L1/L2) is basically limited, and thus with the New Algorithm, classification is performed using the fraction of beta against low-energy photon (L3/L2), and as a result, adequate classification of radiation quality could be confirmed.

Type	Win Algorithm	NEW Algorithm
Tl-204(0.5mSv)	Tl Only	Tl Only
Tl-204(1mSv)	Tl Only	Tl Only
Tl-204(1.5mSv)	Tl Only	Tl Only
Tl-204(2mSv)	Tl Only	Tl Only
Tl-204(4.21mSv)	Tl Only	Tl Only
Tl-204+Sr-90(1+1mSv)	Sr Only	Tl+Sr
Tl-204+Sr-90(1+2mSv)	Sr Only	Sr Only
Tl-204+Sr-90(2+1mSv)	Sr Only	Tl Only
Tl-204+Sr-90(1+3mSv)	Sr Only	Sr Only
Tl-204+Sr-90(4.21+1mSv)	Sr Only	Tl Only
Sr-90(59mSv)	Sr Only	Sr Only
Sr-90(28mSv)	Sr Only	Sr Only
Sr-90(21mSv)	Sr Only	Sr Only
Sr-90(7.46mSv)	Sr Only	Sr Only
Sr-90(5.53mSv)	Sr Only	Sr Only
Sr-90(1.56mSv)	Sr Only	Sr Only

Table 2. Beta Energy Classification by Algorithm

Figure 1 illustrates standard deviation of skin exposure dose evaluation values for each algorithm in a radial chart. While it did not exceed 35% of deviation, which is the limit of performance inspection by the reader, it was confirmed with DOELAP that deviation increased with Tl-204 mix rate, and for Win_Algorithm, it was confirmed that accurate values are indicated in single energy other than mixed beta field. During the process of developing the new algorithm, limitations of L1/L2 fraction were considered and thus skin exposure dose correction factors were calculated with a linear-log function using the L3/L2 fraction as in the case of DOELAP, and deviation within 7% could be maintained as a result of correction after inducing adequate gradient and intercept.

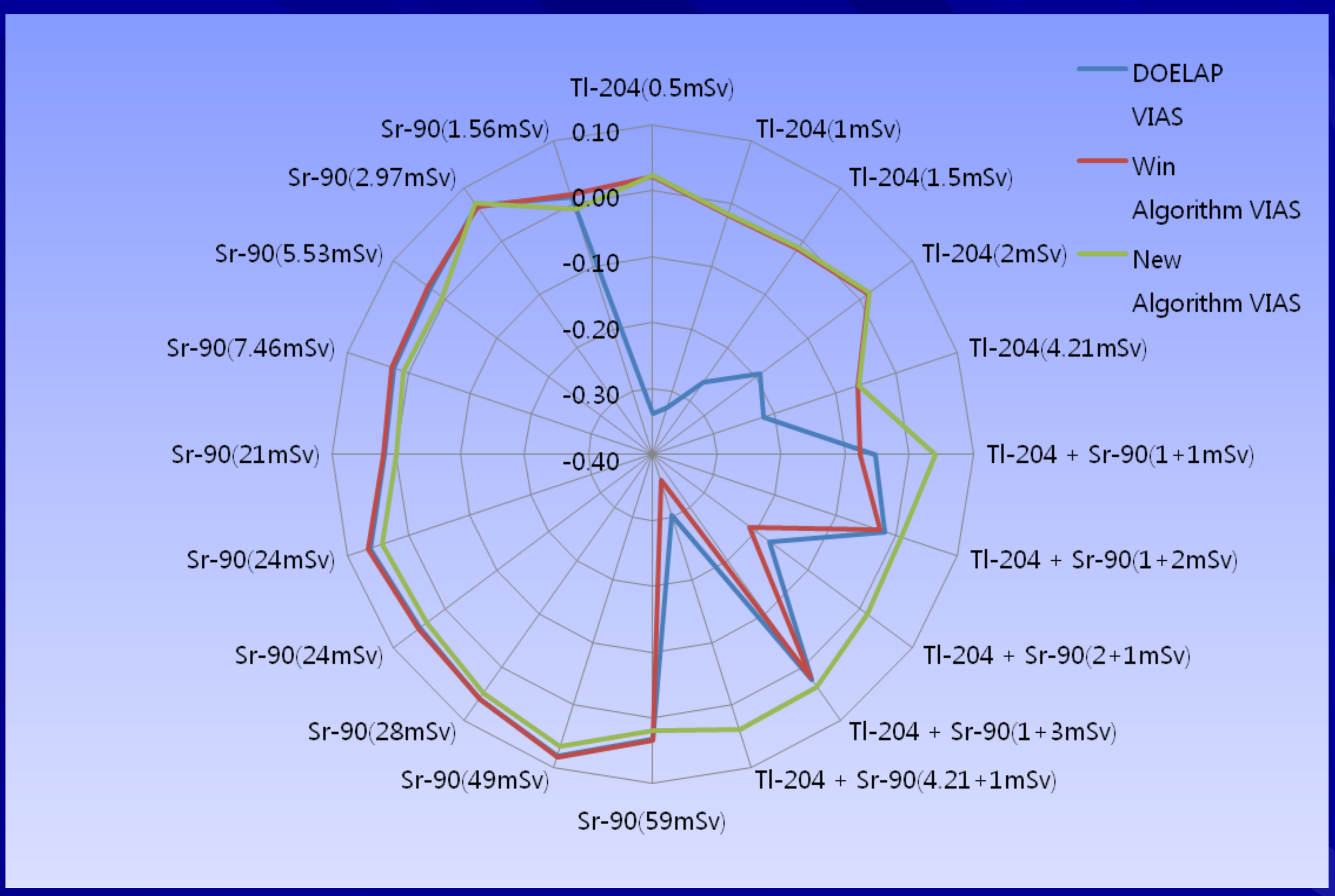

Fig. 1. Deviation of Skin Exposure Dose by Algorithm

Conclusions

In this study, the advantages and disadvantage of the existing algorithm were examined, and a method to distinguish beta energy as well as skin exposure dose correction factors was developed. Also devised is a positive alternative to performance inspection of low energy beta field of ANSI N13.11-2009, which will be applied in the future. When this method of analysis for special environments is applied, characteristics of exposure radiation quality and radiation dosimeter reaction can be confirmed, which is expected to greatly contribute to optimizing protection management in consideration of radiation quality and to reducing exposure.