Probabilistic Assessment of Dose to Workers due to Radiological Emergency Situation

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1. Introduction

Industrial radiography workers commonly use high radioactivity source and carry out the work in poor conditions such as working in a field with difficult shielding and working at night. Thus, when the event of an unexpected accident occurrs, workers are more likely to be exposed to high doses. From 2013 to 2016, a total of 25 workers were exposed beyond the legal annual dose limit, 24 of whom were industrial radiographic testing workers [1].

Korea Institute of Nuclear Safety performs dose assessment to the workers in the event of an unexpected radiation accident by field investigation, interviews with workers, colleagues and reproducible experiments. In most cases, the circumstances of an accident are reconstructed based on a statement of the worker. Because the worker's memory of the accident is not clear, uncertainties arising from the reconstruction of the accident are very large.

Parameters necessary for dose assessment include stay time near the radiation source, distance from the source and surrounding structure, etc. When these variables are applied at a single value, the results are not considered for such uncertainties and are overestimated or underestimated.

In this study, we derived possible accident scenario by reconstructing from the actual accident case in industrial radiography field, and performed evaluating dose for the scenario by applying probabilistic approach.

2. Materials and Methods

In this section some of the dose assessment methods were described. Results were verified with overexposed case in industry radiography field.

2.1 Dose Assessment Methods

When evaluating a radiological accident, it is necessary to use all the available essential information at the moment. Process should be repetitive and dynamic, providing for a review of the response strategy as full information is received. The use of the IAEA-recommended method IAEA-TECDOC-1162 [2] allows for rapid engineering calculations of dose loads per person from sources of beta and gamma radiation of the simplest geometry (point, linear, disk) at various distances from the source. In this study, to estimate the effective dose from a point source was used. To calculate the effective dose at a certain distance from the point source, the formula below should be used.

$$E_{ext} = \frac{A * CF_6 * T_e * (0.5)^{\frac{d}{d_{1/2}}}}{X^2}$$

Where, E_{ext} = effective dose from a point source [mSv], A = source activity [kBq], T_e= exposure duration [h], CF_6 = conversion factor [(mSv/h)/(kBq)], X = distance from the point source [m], $d_{1/2}$ = half value layer [cm], and d = shielding thickness [cm][2].

2.2 Probabilistic Dose Assessment

Probabilistic approaches allow the use of distributions instead of single values and also allow quantification of variations and uncertainties. The distribution describes the range of possible values and shows which values within the range are most likely.

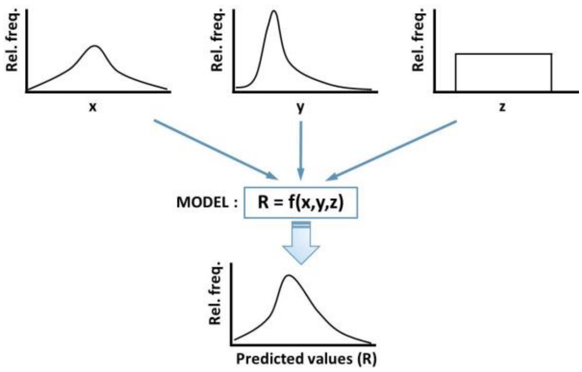

Fig. 1. Scheme of probabilistic analysis

Fig. 1 shows the scheme of probabilistic approach, which derive the results as a type of new probability distribution function by combining uncertain variables. In cases where parameter values are provided as a probabilistic distribution, the values were sampled according to the probability and substituted into the formula. Statistically sufficient number of results were derived after performing repeated calculations. The results of calculation is also presented with a form of probabilistic distribution. In this study, variables such as time(T_e) and distance(X) were assumed to be normally distributed.

2.3 Accident Scenario for Overexposed Worker

In this study, a hypothetical radiological exposure scenario was derived based on actual accident in industrial radiography field. We assumed that a radiographer finished performing radiography exposure then entered a radiographic test room without recognizing that radioactive source is still present in the room and exposed from the radioactive material. Statements from the worker about the situation at that time are shown in Table 1.

Table I: Summary of exposed situation

Source nuclide	Co-60
Source activity	72.45 Ci
Time stayed in the room	10 - 60 sec
Distance from source to worker	1 - 2.5 m
Shielding material	Lead
Shielding thickness	1.1 cm

3. Results

The variables which have uncertainty such as time, distance were assumed normally distributed and the 5th and 95th percentile values were set to the minimum and the maximum value of the variables. Hence, the value of T_e was set to $N(35, 17.5^2)$. In the same way, the value of X was set to $N(1.75, 0.38^2)$.

The source activity, conversion factor, and half-value layer are single value. The point source conversion factor at 1 m from the source of Co-60 and half value layer of Co-60 were referred from the Table E1 and E2, respectively in IAEA-TECDOC-1162 [2].

With a thousand times of iteration, the thousands of result was obtained. A histogram of 1000 estimated dose results is shown in Fig. 2.

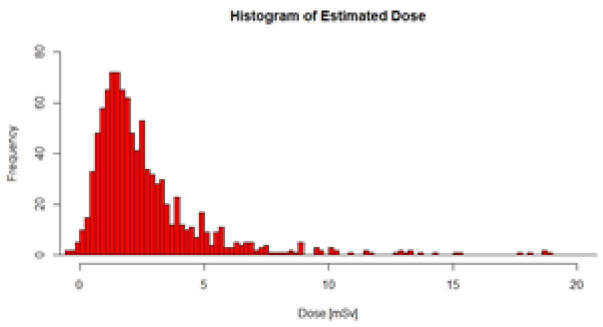

Fig. 2. Histogram of the estimated dose

Statistics derived from the results of the newly obtained form of probability distribution are shown in Table 2.

Table II: Statistics of the results

Mean	1.30
Median	0.94
Standard Deviation	1.74
5th percentile value	0.20
95th percentile value	3.40

From the probabilistic assessment of dose, the exposed dose of maximum likelihood was 1.30 mSv, the most conservative result was 3.40 mSv. In this case, it might be decided that the worker is highly unlikely to have been exposed beyond the dose limit. However, if, in some cases, the higher area of the dose range exceeds the dose limit, a more accurate dose assessment needs to be performed using various other methods.

4. Discussion

In the actual accident case, the variables for calculating dose such as time, distance, shielding are not sure and it has high uncertainty. Hence, a probabilistic approach for estimating dose is meaningful in that valuable information can be obtained to provide appropriate radiation safety protection and management, such as assessing exposure dose and taking measures in an accident scenario. Methodology of this study could not only be applied in accident of radiation worker but also radiological terror for public.

REFERENCES

[1] 2016 Nuclear Safety Yearbook, Nuclear Safety and Security Commission, 2017.
[2] Generic procedures for assessment and response during a radiological emergency, IAEA-TECDOC-1162, International Atomic Energy Agency, p. 85, 2000.