Occupational Doses and the Contribution to the Population Dose in Korea

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1. Introduction

The exposure of radiation workers in occupational field includes medical radiology, industrial applications such as radiography, nuclear power, and some research activities. Occupational exposure from medical radiology practices includes the contributions from diagnostic x-ray procedures, dental radiography, nuclear medicine and radiation therapy.

The control of exposure for radiation workers, and the measures necessary to maintain radiation exposure as low as reasonably achievable (ALARA) are specified in Subparagraph 3 and Subparagraph 4 of Article 91 (1) of the Korea Nuclear Safety Act (KNSA), respectively [1]. Therefore, from a regulatory perspective, the exposure data of the workers are primarily for verification of the adequacy of the control of exposure, radiation protection and implementation of ALARA.

Furthermore, since the exposure of workers contributes to the effective collective dose of the entire population and hence to detriment in the population, thus, the level of exposure of radiation workers, the number exposed and the average exposure have been a matter of considerable general interest.

The purpose of this study is to evaluate the occupational exposure records in terms of the control of exposure for radiation workers and dose reduction. The study includes the estimates of the number of people exposed occupationally, the effective collective doses and mean doses to those exposed. In addition, the study includes an estimate of the contribution of occupational exposure to the Korean population dose.

2. Methods and Results

2.1 Utilization of Exposure Data

In Korea, occupational exposure data are accumulated in two separate national dose registry systems. One is the dose registry system of diagnostic radiology field (called "KCDC [1] registry") which is operated in accordance with 「Rules for Safety Management of Diagnostic Radiation Emitting Generator」(Health and Welfare Enforcement Ordinance 3, Published on January 6, 1995). Another one is the dose registry system of nuclear industrial field (called "NSSC[2] registry") which is implemented in accordance with Article 91 (Measure of Radiation Damage) of 「Enforcement Regulation of the Nuclear Safety Act」. The KCDC registry maintains dosimetry records for radiation workers, including diagnostic radiology physician, dentists, radiological technologists who work with diagnostic radiation devices. The NSSC registry serves a repository for exposure data for all nuclear and radiation workers who includes radiation therapy, industrial applications such as radiography, nuclear power, and some research activities. For the purpose of this study, the exposure record data from 2009 to 2013 from both of the KCDC and the NSSC registries were utilized for analyses, calculations and estimations of occupational doses. For simplification of data process, the workers were divided into two groups of medical workers and industrial workers. Thus, the medical workers were consisted of all the KCDC registry workers and radiation therapy workers from the NSSC registry. The industrial workers were consisted of all the NSSC registry workers except the radiation therapy workers. Personnel in aircraft were not included.

2.2 Collective Dose and Mean Dose

The collective dose is an extensive quantity that can apply to one person, to a population group or to the whole world population. If a measure of the radiation exposure in a population is desired, the collective effective dose can be calculated. This quantity is defined by ICRP [2] as follows:

$$S = \int_0^\infty E \frac{dN}{dE}\, dE \qquad (1)$$

where (d*N*/d*E*)d*E* is the number of individuals receiving an effective dose between *E* and *E*+d*E*

$$S = \sum_i \bar{E}_i N_i \qquad (2)$$

where $\bar{E}_i$ is the mean effective dose to population subgroup i.

The mean dose to an individual in the defined exposed group due to the source, called the *per caput* dose $\bar{D}$ from that source, can be calculated as

$$\bar{D} = \int_0^\infty E \frac{dN}{dE}\, dE \Big/ \int_0^\infty \frac{dN}{dE}\, dE \qquad (3)$$

[1] Korea Centers for Disease Control and Prevention

[2] Nuclear Safety and Security Commission

And since $\int_0^\infty \frac{dN}{dE}\, dE = N$, the total number of individuals in the defined group, it follows that $S = \bar{D}N$.

2.3 Occupational Doses for 2009-2013.

Using reported data, the annual changes of the number of radiation workers, taking into account of worker population size, N were evaluated. Fig. 1 shows total number of persons exposed occupationally during the period 2009 to 2013. As shown Fig. 1, the persons actually exposed were increased from the 85,428 persons for the year 2009 to the 108,275 persons for the year 2013 with annual increase rate of 3-9%. Additionally, Fig. shows that the annual numbers of medical workers were constantly more than twice those of industrial workers. Of the industrial workers, a principal workers group in number was nuclear power workers group followed by radiography workers group.

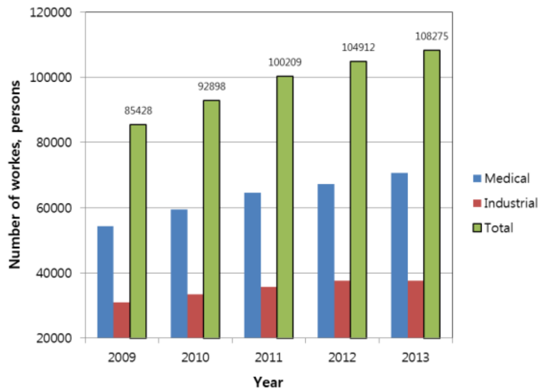

Fig. 1. Status of the numbers of radiation workers for 2009-2013.

2.4 Annual mean exposures

The annual mean doses calculated for medical workers and industrial workers over the period 2009 to 2013 are shown in Table 1. For the medical workers, the mean doses were in range of 0.68 mSv in 2009 to 0.49 mSv in 2013. These dose values were commonly low, respectively, compared to 0.87 mSv estimated by the previous study [3]. For the industrial workers, the mean doses were in range of 0.98 mSv in 2009 to 1.09 mSv in 2013. Similarly, these dose values also were slightly low, respectively, compared to the mean dose of 1.44 mSv estimated by the previous study [3].

Table 1. Summary of occupational exposure in Korea for 2009-2013.

Workers group		Year				
		2009	2010	2011	2012	2013
Medical workers	N, persons	54,408	59,444	64,552	67,300	70,647
	S, man-mSv	37,019	35,923	37,525	34,153	34,477
	$\bar{D}$, mSv	0.68	0.60	0.58	0.51	0.49
Industrial workers	N, persons	31,020	33,454	35,657	37,612	37,628
	S, man-mSv	30,333	32,202	27,513	34,957	40,899
	$\bar{D}$, mSv	0.98	0.96	0.77	0.92	1.09
Total	N, persons	85,428	92,898	100,209	104,912	108,275
	S, man-mSv	67,352	68,125	65,038	69,110	75,377
	$\bar{D}$, mSv	0.79	0.73	0.65	0.66	0.70

2.5 Annual collective doses

2.5.1 Medical workers

Fig. 2 shows annual collective doses calculated for medical workers during the period of 2009 to 2013. As shown in Fig., the annual collective doses varied with 37.5 man-Sv in 2011, 34.2 man-Sv in 2012, and 34.5 man-Sv in 2013. During the same period, however, the annual mean doses gradually decreased with 0.58 mSv in 2011, 0.51 mSv in 2012, and 0.49 mSv in 2013. From these data, the occupational medical doses were not regarded as maintaining likely to be ALARA. However, they showed two possible dose reductions slightly of about 3% and 9% in 2010 and 2012, respectively.

2.5.2 Industrial workers

The annual collective doses for industrial workers are listed in Table 1. It shows there were some gradual increases of the collective doses with increase of the number of workers during the period of 2011 to 2013, but not in 2011. This means there were unlikely any dose reduction efforts or ALARA in these workers group. For the annual collective doses of the nuclear power workers, Fig. 3 shows a distinct decreases of collective doses with increases of the number of workers during the 2009-2012. Therefore, these results demonstrate the nuclear power workers had been implemented likely dose reduction or ALARA during the same period.

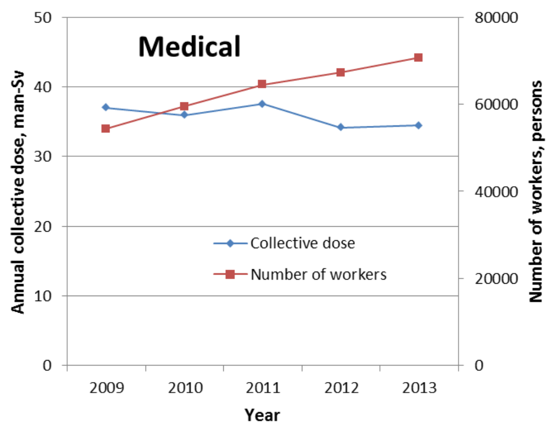

Fig. 2. Annual collective doses of medical workers for 2009-2013.

Fig. 4 shows annual collective doses calculated for radiography workers for 2009 to 2013. In Fig., the annual collective doses increased from 12.8 man-Sv in 2009 to 26.7 man-Sv in 2013. For the mean doses, they were gradually increased from 2.23 mSv in 2009 to 3.72 mSv in 2013. Further, the mean dose of 2013 was approximately 45% high, compared to 2.55 mSv in year 2002 [3].

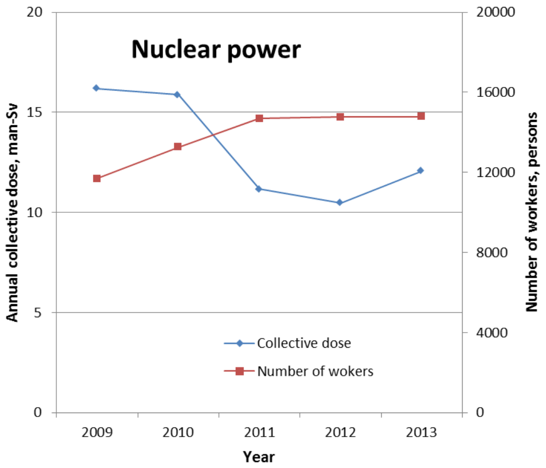

Fig. 3. Annual collective doses of nuclear power workers for 2009-2013.

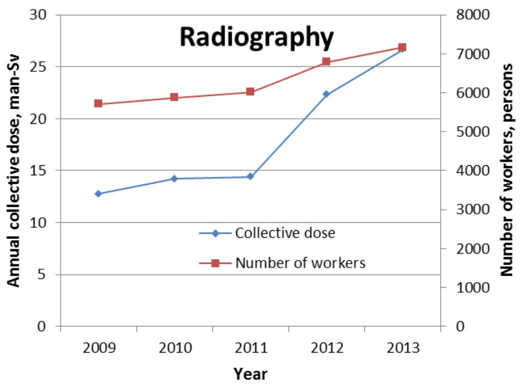

Fig. 4. Annual collective doses of radiography workers for 2009 to 2013.

As a result, this analysis shows the radiography workers were not likely kept to be ALARA during the period 2009 to 2013. Since these workers doses were combined with the doses of nuclear power workers, the doses of industrial workers were shown to increase continuously, although nuclear power workers made an efforts their doses ALARA as demonstrated in Fig. 3.

2.6 Korean population doses from occupational Exposure

The contribution of occupational exposure for Korean population was estimated based on the annual population data from the resident status for 2009-2013 published by the Ministry of Public Administration and Security (MOPAS). As a result, the contributions of the effective dose of exposed workers to the effective dose per member of Korean population are given in Table 2. In Table, the total estimated annual effective doses were from 0.0014 mSv in 2009 to 0.0015 mSv in 2013. These dose values were found to be almost similar, compared to 0.002 mSv estimated in year 2002 [3]. Further, these values were very low, compared to 0.009 mSv in the U.S. population for 1980-1982 [4] and to 0.005 mSv in the world population [5], respectively.

Table 2. Estimated annual effective doses to Korean population from occupational exposure (mSv).

	Year				
	2009	2010	2011	2012	2013
Medical	0.0008 (0.0001)*	0.0007 (0.0001)	0.0007 (0.0001)	0.0007 (0.0001)	0.0007 (0.0001)
Industrial	0.0006 (0.0003)**	0.0006 (0.0003)	0.0005 (0.0003)	0.0007 (0.0004)	0.0008 (0.0005)
Total	0.0014	0.0013	0.0012	0.0014	0.0015

* Population dose from exposure of dental practice
** Population dose from exposure of radiography practice

3. Conclusions

In this study, the number of people exposed occupationally, the effective collective doses and mean doses to those exposed, and average effective doses from occupational exposure during the period of 2009 to 2013 have been evaluated. In general, radiation workers were increasing in number annually, but the mean doses for those exposed each year showed the control of exposures were mostly considered met within the dose limit in KNSA. Nevertheless, it was shown that the continuous efforts would be needed to reduce doses and thus to implement ALARA regulatory requirements. In radiation occupations, the application of ICRP radiation protection principles will ensure good practice and decreasing exposures. Over the period of 5 years, the contributions of the annual effective dose from occupational exposure to the annual effective dose for Korean population were identified less than 0.002 mSv. This contribution of occupational exposures for the whole population is only a small source of detriment to society as a whole, but occupational exposures are unquestionably important to the individuals involved and to the fields in which these exposures occur.

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