Journal of NUCLEAR SCIENCE and TECHNOLOGY, Supplement 4, p. 447-450 (March 2004)

Doses Assessment for the Releases of the Inventories in Liquid and Gaseous Radwaste Systems at YGN 3 & 4

Joo Yeon KIM[1,*], Chang Ho SHIN[1], Jong Kyung KIM[1], Jai Ki LEE[1], Moosung JAE[1] and Yong Jib PARK[2]
[1] *Dept. of Nuclear Eng., Hanyang University, 17 Haengdang, Sungdong, Seoul 133-791, Korea*
[2] *Innovative Technology Center for Radiation Safety, Hanyang University, Seoul 133-791, Korea*

Inventory changes of the liquid and gaseous radwastes were analyzed by linear regression analysis on the basis of the operation histories of Yonggwang nuclear power plants (YGN) 3 & 4, and the future inventories were also predicted. Based on the evaluation results of the inventories, the annual doses for the resident were estimated using KDOSE60 code according to ages and pathways. The results show that the inventory changes increase linearly with progress in the operation histories, and the inventories released to environment are much lower than FSAR results. Linear regression analysis can be used to predict the future inventory if YGN 3 & 4 are continuously operated with the present pattern. It is noted that the inventories have been overestimated and this analysis can be applied to judge conservativeness for the future inventories. The annual doses for the resident were much lower than the FSAR results. The main pathways are ingestion of contaminated vegetables and inhalation for the release of radioactive gas, and fish ingestion for the release of radioactive liquid. In addition, future annual doses for the resident can be predicted using the future inventory. It is concluded that prediction of inventory and dose assessment will contribute to ensuring radiological integrity in NPPs.

KEY WORDS: NPP, FSAR, radwaste, inventory, linear regression analysis, annual dose, pathway

I. Introduction

When a nuclear power plant (NPP) is planned to construct, radiological assessments are carried out for assuring radiological integrity in NPP or environment. In the preparing stage of Final Safety Analysis Report (FSAR) [1], the expected inventories of radwastes and the expected resident doses due to the releases are presented. However, it is impossible to exactly evaluate the inventories and the resident dose until NPP will be actually operated. It is, therefore, necessary to investigate the inventory changes for the liquid and gaseous radwastes released from the actual operations, to assess the resident doses based on the inventories, and finally to guarantee that the inventories and the doses are satisfied within the estimated ones presented in FSAR for the establishment of radiological safety in operation.

In this study, inventory changes and its predictive values for the liquid radwaste system and the radioactive gas released in containment were analyzed by linear regression analysis on the basis of the operation histories of Yonggwang nuclear power plants (YGN) 3 & 4 in Korea. In addition, the annual doses for the resident were re-evaluated based on the actual inventory values.

II. Materials and Method

1. Application of linear regression analysis

Inventory data for the various systems presented in FSAR are described as the design requirements, which contain a sufficient margin from the viewpoint of conservative estimation. They offer the technical foundation for operation permission by meeting the criteria based on the estimation data resulted from other NPPs operation and testing operation. If fuels or U-tubes in steam generator lose their integrities and fission products leak to secondary system during plant operation, then there is a possibility that inventories in the systems can increase. Moreover, due to a tendency to extend the NPP operation time, inventories in the systems are highly expected to increase.

In order to investigate the relationship between inventories and operation histories, linear regression analysis[2] was, in this study, employed to see the characteristics of inventory changes. Furthermore, future inventories of the radwastes were predicted using the relationship between inventories and operation histories.

However, it exists a limit in predicting accurate inventory changes if there are scarce of data. YGN 3 & 4 were selected as the reference NPP in this study since there have been many survey data from testing operation up to now for the systems to estimate inventories.

2. Liquid radwaste system

The function of the liquid radwaste management system is to collect radioactive or potentially radioactive liquid wastes generated during plant operation, to process the liquid waste in order to remove radioactive isotopes, to accumulate radioactive isotopes for storage or disposal and to discharge the treated liquid to environment.

Liquid radwaste contains boric acid as well as particulate and ionic radioactive materials, and the radioactive materials are removed through filter and evaporator. Liquid,

* Corresponding author, Tel.+82-2-2290-1843, Fax.+82-2-2296-3690, E-Mail: jykim@rrl.hanyang.ac.kr

whose activity is almost removed, can be reused in a plant or released to environment through radiation monitoring systems.

Release of liquid radwaste is managed not to exceed the maximum permissible concentrations in water prescribed in the notice[3)] of *Ministry of Science and Technology* in Korea. The resident annual doses due to the release are also managed not to exceed those presented in FSAR.

3. Gaseous radwastes system

Release of radioactive gas in containment is carried out for pressure control in normal operation and delightful workplaces during overhaul. Radioactive material sampling in containment and their analysis are conducted under the conditions of two cases; (1) when a plant is shutdown or starts and (2) provided that a heat capacity is greater than 15 % point and, at the same time, either ^{131}I activity in coolant or activity of inert gases on the exhaust radioactive gas monitors is three times greater than normal operation condition.

Gas is released to environment through low volume exhaust fans and an air exhaustive facility, which remove the particles and radioactive iodine and is set up in the front side of the fans. During the release, gas is controlled through radiation monitors for surveillance of the exhaustive gas and environmental monitoring.

Release of gaseous radwaste is managed not to exceed the maximum permissible concentrations in air prescribed in the notice[3)] of *Ministry of Science and Technology* in Korea. The resident annual doses due to the release are also managed not to exceed those presented in FSAR.

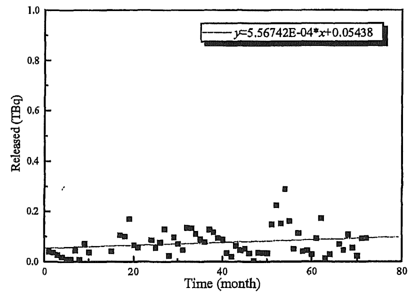
III. Results and Discussion

1. Characteristics of inventory changes

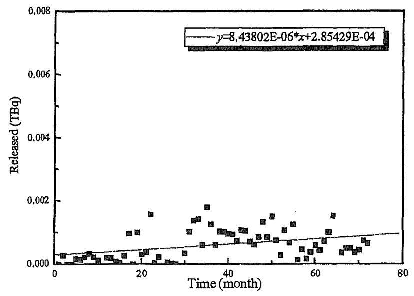
In order to investigate the characteristics of inventory changes for the radwaste, nuclides were divided into ^3H and gross β-γ nuclides by referring to the annual reports[4)] on radiation safety management. It was excluded that these values were under the lower limit of detection (LLD) as well as beyond 95 % confidence interval for deducing the exact characteristics of the inventory changes.

From **Fig. 1** and **Fig. 2,** it is noted that the inventory changes of the radwastes show a linear increase for the operation histories. These results mean that the future inventories can be predicted if YGN 3 & 4 are continuously operated with the present pattern. Based on **Fig. 1** and **Fig. 2**, the inventories for the operation histories of YGN 3 & 4 were predicted and the values were presented in **Table 1**.

The inventories for the gaseous radwaste system in FSAR are presented about 4.07 TBqy^{-1} for tritium and 172 TBqy^{-1} for gross β-γ when a NPP is operated. Those for the liquid radwaste system in FSAR are presented about 37.4 TBqy^{-1} for tritium and 16 GBqy^{-1} for gross β-γ likewise. It is noted that the inventories in FSAR has been overestimated when compared with the inventories data in **Fig. 1** and **Fig. 2**.

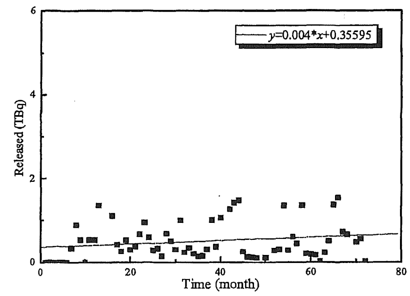


(a) tritium

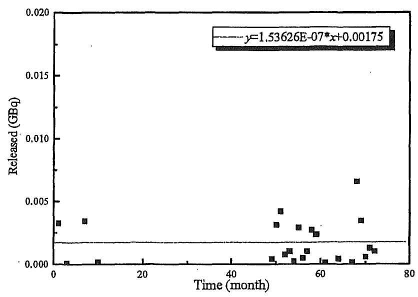


(b) gross β-γ

Fig. 1 Inventories changes in gaseous radwaste



(a) tritium



(b) gross β-γ

Fig. 2 Inventories changes in liquid radwaste

Table 1 The predictive values according to the operation histories for YGN 3 & 4

System	Type	10 y	20 y	30 y
Liquid	gross β-γ (GBq)	1.77×10^{-3}	1.79×10^{-3}	1.81×10^{-3}
	tritium (TBq)	0.84	1.32	1.80
Gaseous	gross β-γ (TBq)	1.30×10^{-3}	2.31×10^{-3}	3.32×10^{-3}
	tritium (TBq)	0.12	0.19	0.26

2. Assessment of the resident dose

According to FSAR, inventories are evaluated for each system under assuming 1 % of fuel damage using PWR-GALE code and the expected doses for the resident are also estimated for the release of their inventories to environment. Since considerable conservativeness is expected in the FSAR dose results, the resident doses were, in this study, estimated based on the actual inventory releases to environment. The annual whole body doses for the resident were calculated according to ages and pathways by KDOSE60 code[5,6] developed in Korea Hydro and Nuclear Power Company.

The inventories of the gaseous and liquid wastes are presented as many data points for the operation histories in **Fig. 1** and **Fig. 2**. If a specific data point is used in the dose calculation, the results will be overestimated or underestimated, which is dependent of the used inventory. Therefore, calculation of the maximum and minimum doses corresponding to the releases of the maximum and minimum inventories to environment seems to be more reasonable than the dose calculation based on the release of a specific inventory.

Table 2 shows the maximum and minimum annual whole body doses for the resident. The annual doses for the release of radioactive gas mainly contribute to the total doses, and the annual doses for the release of liquid radwaste are below 1 % of those for the gaseous radwaste system. The doses for whole body in FSAR are presented to be 1.93×10^{-2} μSvy^{-1} for adult, 2.85×10^{-2} μSvy^{-1} for teen and 4.66×10^{-2} μSvy^{-1} for child resulted from the release of radioactive liquid when a NPP is operated. The doses for the release of radioactive gas in FSAR are presented to be 2.55 μSvy^{-1} for adult, 8.04 μSvy^{-1} for teen, 4.39 μSvy^{-1} for child and 4.45 μSvy^{-1} for infant. It is noted that the doses in **Table 2** are significantly less than those in FSAR.

Figures 3 and **4** show the main pathways which have an effect on the maximum doses for each receptor. In case of the release of radioactive gas, the main pathways are ingestion of contaminated vegetables and inhalation. But, the main pathway for infant is the milk. This is resulted from dietary pattern of infant. Fish ingestion is the main pathway for the release of radioactive liquid. Especially, the residents in Yonggwang much ingest a yellow corvina, which is a special product in Yonggwang. So, we can predict that fish ingestion is one of the main pathways for the release of radioactive liquid. The main pathways are

Table 2 Annual whole body doses for the resident (μSvy^{-1})

	System	3 mon	5 y	15 y	Adult
Max. doses	Gaseous	4.73×10^{-1}	5.33×10^{-1}	4.38×10^{-1}	4.17×10^{-1}
	Liquid	0	1.79×10^{-3}	1.56×10^{-3}	1.30×10^{-3}
	Total	4.73×10^{-1}	5.35×10^{-1}	4.40×10^{-1}	4.18×10^{-1}
Min. doses	Gaseous	7.08×10^{-2}	7.98×10^{-2}	6.56×10^{-2}	6.23×10^{-2}
	Liquid	0	2.68×10^{-5}	2.43×10^{-5}	2.33×10^{-5}
	Total	7.08×10^{-2}	7.98×10^{-2}	6.56×10^{-2}	6.23×10^{-2}

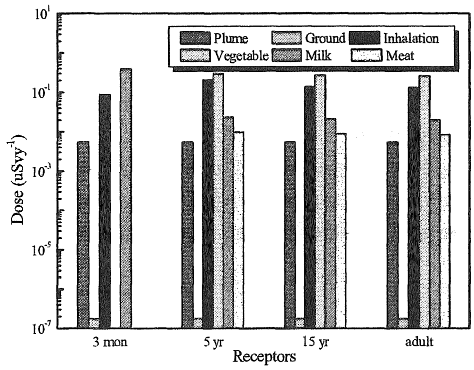


Fig. 3 Pathways contributing to maximum doses for the release of radioactive gas

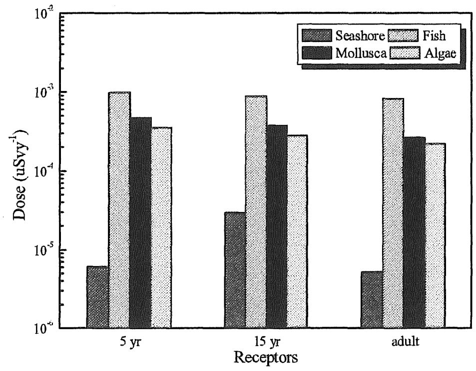


Fig. 4 Pathways contributing to maximum doses for the release of radioactive liquid

closely connected with activity standards and dietary life pattern of each receptor. It is noted that the inventories and the annual doses for the resident have been underestimated when compared with FSAR results.

IV. Conclusion

As NPPs in Korea are operated with an aim of radwastes reduction, it is necessary to investigate the inventory changes for the radwaste systems and to estimate the resident doses taking into account the actual operation histories. In this study, inventory changes on the basis of the operation histories of YGN 3 & 4 were analyzed by linear regression analysis for the liquid and gaseous radwaste system, and the resident doses resulted from their releases to environment were estimated. The inventory changes of the radwastes show a linear increase for the operation histories. Linear regression analysis can be used to predict the future inventory if YGN 3 & 4 are continuously operated with the present pattern. It is noted that the inventories have been overestimated and this analysis can be applied to judge conservativeness for the future inventories. The annual doses for the resident were much lower than the FSAR results. This study shows that future annual doses for the resident can be predicted using the future inventory. It is concluded that prediction of inventory and dose assessment will contribute to ensuring radiological integrity in NPPs.

Acknowledgement

This study was performed under the long-term nuclear research and development program sponsored by Ministry of Science and Technology of Korea and supported by the Innovative Technology Center for Radiation Safety (iTRS) and Korea Hydro and Nuclear Power Company (KHNP).

References

1) Korea Electric Power Corporation, *Yonggwang Units 3 & 4 Final Safety Analysis Report, Chapter 11*.
2) Bilal M. Ayyub, Richard H.McCuen, *Probability, Statistics, and Reliability for Engineers and Scientists, 2nd ed.*, Chapman & Hall/CRC Press LLC, Boca Raton, (2003).
3) Ministry of Science and Technology, *MOST Notice 2002-23*, (2003), [in Korean].
4) Korea Hydro and Nuclear Power Company, *Annual Report on Radiation Management*, (1995 - 2001), [in Korean].
5) H. S. Kim, J. K. Son, K. D. Kim, J. H. Ha, "Estimation of Off-Site Dose and Release Concentration of Radioactive Liquid Effluents from Radwaste Treatment System in Kori 3 & 4," *Proc. of the First iTRS International Symposium on Radiation Safety and Detection Technology*, Seoul, Korea, July 18-19, 2001, 196 (2001).
6) Korea Electric Power Corporation, *KDOSE60 : **KEPCO** Off-site **DOSE** Calculation Program based on ICRP-**60** for Normal Operation of Nuclear Power Plants*, (2000).