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Development of the Philippine National Dose Registry as a Tool for the Tracking and Assessment of Occupational Radiation Exposures and Risks in the Philippines

Kristine Marie D. Romallosa[1]*, **Christy Mae T. Betos**[1], **Elisha John W. Pascual**[2], **Camille U. Pineda**[1], **Marianna Lourdes Marie L. Grande**[1], **Ronald E. Piquero**[1], and **Angelo A. Panlaqui**[1]

[1]Radiation Protection Services Section,
[2]Management Information Services Section
Department of Science and Technology – Philippine Nuclear Research Institute,
Quezon City 1101 Philippines

The rise in the number of occupationally exposed workers in the Philippines has made tracking, monitoring, and assessment of occupational exposures more difficult. Over the years, other than the DOST-PNRI, various private companies have started providing individual monitoring services (IMS). Although these providers are duly recognized by the regulatory agencies, it has resulted in a decentralized database of occupational exposure records in the country. To help address this and as required by the International Atomic Energy Agency (IAEA), a web-based National Dose Registry (NDR) was developed to maintain a centralized dose repository of occupational external exposures in the country. The NDR can automatically record and track an individual's exposure history, provide an annual dose summary of the worker and facility, notify incidents of doses exceeding the regulatory limits, and allow regulatory agencies to have ready access to dose information, among others. The NDR also provides exposure profiles of workers according to the type of practices. The average annual doses due to external exposures received from various practices during 2013–2018 were evaluated in terms of personal dose equivalent $H_p(10)$. Results show that in conventional radiology practices, more than 70% of workers did not receive doses above the recording level. In industrial radiography (IR) and nuclear medicine (NM) practices, on the other hand, workers received the highest average annual doses of 1.02 mSv and 0.44 mSv, respectively – with incidents of doses exceeding the limit of 20 mSv/yr. Practices in IR and NM, thus, pose higher risks of occupational exposures to workers. The NDR, therefore, can be used in recording, tracking, and assessing occupational exposure profiles and risks. The NDR can also also be tool to aid in the development of better regulations and thereby help in strengthening radiation protection in the country.

Keywords: dose assessment, individual monitoring, national dose registry, occupational exposures, occupational radiation protection, radiation risks

*Corresponding Author: kmdromallosa@pnri.dost.gov.ph
kdromallosa@gmail.com

INTRODUCTION

Using radioactive materials and radiation generators that emit ionizing radiation can cause biological effects to the body. Individuals who work in these facilities are thus at risk due to potential occupational exposures. It is therefore essential to monitor activities involving ionizing radiation to help control and protect those that are exposed to it.

Ionizing radiation and nuclear technology have many beneficial applications. In present-day medical practices, radiology and medical imaging [*e.g.*, X-ray and computed tomography (CT) scan] have become a vital tool in the diagnosis of diseases or injury, while nuclear medicine and radiotherapy are widely used in therapeutic procedures in treating illnesses. Irradiation, specifically using gamma radiation, is used in sterilizing various equipment to destroy microbes incurred in them. Food irradiation is a technique wherein food products are exposed to certain levels of ionizing radiation to improve the hygiene and extend the shelf life of foods by reducing or eliminating insects and microorganisms without compromising the quality, taste, texture, appearance, and nutritional value of the products. There are many applications involving the use of radioactive materials in the industry as well, widely for quality control and assurance. Radiation is used as nuclear gauges to measure thickness of papers, metals, and plastics; and monitor density of a material, among others. Nuclear technology has also contributed a lot to research and development in different fields of science such as agriculture and environmental science (Bennett 2002).

Occupational Exposure Monitoring in the Philippines

Despite its beneficial applications, nuclear and radiation technologies are a source of exposure to ionizing radiation, which – if not controlled – may cause risk of deterministic and stochastic effects to the body. It is, therefore, necessary to protect the workers against occupational exposures by keeping the magnitude of doses they receive as low as reasonably achievable while still harnessing its benefits (Bennett 2002, IAEA 2014).

It is required under Philippine radiation safety regulations that occupational exposure is monitored and controlled. Occupational dose exposure limits are also set in place to minimize the risks of potential health effects to the worker. According to regulations (CDRRHR 2004, DOST-PNRI 2004), every radiation worker in the Philippines must wear personnel monitoring devices at prescribed frequencies or monitoring period in order to measure the total accumulated radiation doses received in the workplace. The regulations also state that occupational exposure of workers shall be controlled so that the following limits will not be exceeded: 1) an effective dose of 20 mSv per year averaged over five consecutive years, and 2) an effective dose of 50 mSv in any single year. In addition, the licensed facility shall maintain exposure records of workers and/or make arrangements if the facility ceases its operations using ionizing radiation.

Personnel monitoring devices or dosimeters measure the amount of accumulated radiation dose to which an individual is exposed. In the Philippines, there are two types of passive dosimeter systems used to measure external exposures: the optically stimulated luminescence (OSL) dosimeters and thermoluminescence dosimeters (TLD). TLDs and OSL dosimeters contain crystalline materials that luminescence when subject to heat and light, respectively. When exposed to radiation the crystalline material in the dosimeter will trap electrons. To measure the amount of absorbed dose, the trapped electrons in the material are subject to excitation by a stimulant – heat for TLDs and light (*e.g.*, laser or LED) for OSL dosimeters – and, in the process, light is released. The amount of radiation dose absorbed is related to the number of electrons trapped in the material and, hence, to the intensity of the light released.

The DOST-PNRI, through the Radiation Protection Services Section (RPSS), provides IMS to various licensed radiation facilities. The service is provided to monitor and assess doses received by workers from external exposures. The service is also one of the means of ensuring that workers' exposure does not exceed the regulatory dose limits and in verifying the effectiveness of radiation control practices in the workplaces (DOST-PNRI 2004). Then, in recent years, two additional private IMS providers have emerged and at least one private hospital has its own dosimeter system for the monitoring of its staff.

Arising Problems in the Monitoring of Occupational Exposures

The program for the monitoring of occupational exposures in the Philippines is already in place but the IMS is currently limited to the monitoring of external exposures only *i.e.*, the capabilities for internal dosimetry are not yet established. The maintenance of occupational exposure records, on the other hand, is the primary responsibility of the licensed facility and is made available only upon request by the regulators. When the facility ceases to operate using ionizing radiation and/or a worker leaves, arrangements are made with the regulators for the retention of exposure records.

However, the rise over the years in the use of radiation technology and, consequently, the population of monitored radiation workers have made tracking, monitoring, and assessment of radiation doses more difficult. For one, the two regulatory bodies for ensuring radiation safety – the DOST-PNRI which regulates users of radioisotopes and radioactive materials; and the Center for Device Regulation, Radiation Health, and Research CDRRHR which regulates the use radiation generators such as X-rays – has no harmonized system for reporting of doses. As different companies started to provide IMS, the database of workers and their occupational exposures has become decentralized. There is no tracking of cumulative doses, particularly of those who worked with different employers or when their facilities availed of the IMS from various providers. Although the current IMS providers are duly recognized, there are also no regulations yet on its certification and/or accreditation. As a result of these, there is no centralized repository of records, harmonized reporting of doses, and tracking and assessment of occupational exposures in the country.

The Need for an NDR

Considering the risks of exposure to ionizing radiation, this lack of a centralized registry could affect the following: 1) control of occupational exposures and development of better safety regulations, 2) capability for the assessment and evaluation of the country's exposure profiles, 3) timely notification of incidents of exposures exceeding the regulatory and safe limits, 4) generation of scientific knowledge on risks due to occupational exposures, and 5) access to information of workers and organizations on their exposure histories and the effectiveness of their radiation protection programs, among others.

An NDR is an information system that contains centralized radiation exposure records, such as occupational exposures, in the country. According to international radiation safety standards, arrangements for the retention of workers' records of occupational exposure should be put in place by the regulatory body or a state registry. The IAEA also highlights the importance of radiation dose tracking and encourages all member states to have an NDR system in line with the IAEA Safety Standards (IAEA 2014, 2016, 2018).

The Philippines has no dose registry system. There is no centralized record to assess the occupational exposure profiles and risks from various practices. In this study, a system for the NDR was developed. The registry is a web-based system that tracks occupational dose exposures (dose histories) of workers and the facilities they worked with. The doses reported are in terms of the following quantities: personal dose equivalent $H_p(10)$ and $H_p(0.07)$ due to external exposures from photon, beta, and neutron radiation in units of milli-Sievert (mSv). It also provides annual exposure history of an individual, registry of facilities and its workers, and incidence of doses exceeding the regulatory limits. The NDR can also generate occupational exposure profiles from various practices such as in medicine and industrial radiography and research. The system developed can, therefore, bridge the gaps in the current occupational exposure monitoring programs in the country and serve as a tool in helping strengthen radiation safety of workers and in the assessment of occupational risks.

MATERIALS AND METHODS

The NDR developed in this study is a web-based system that collects occupational external exposure data from the IMS providers and processes the received data to generate different reports (Figure 1). It was programmed using PHP, an open-source programming language used for web development. To promote stability and speed up the development process, a framework called CodeIgniter for PHP was used. CodeIgniter is a pre-built module that provides the basic structure for the application. Prototyping model was the development approach implemented for the development process of the software, where various prototypes were produced continuously until the registry's features met the requirements for the assessment of occupational exposure of radiation workers.

The registry contains occupational exposures in terms of personal dose equivalent quantities: a) $H_p(10)$ – dose equivalent at 10 mm depth; b) $H_p(0.07)$ – dose equivalent at 0.07 mm depth; and c) $H_p(3)$ – dose equivalent to the

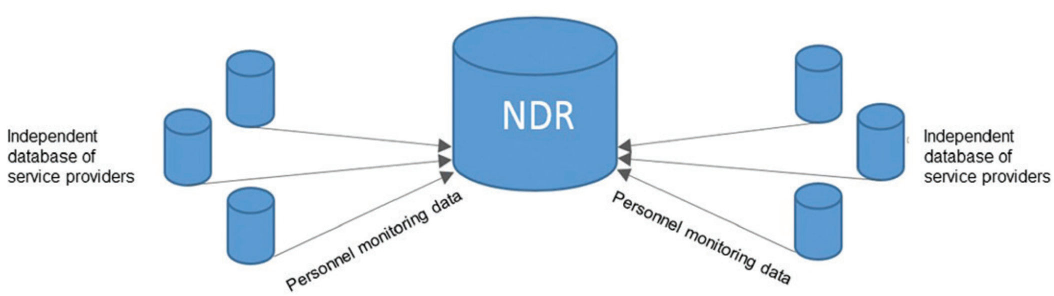


Figure 1. A diagram showing the main objective of the NDR.

eyes at 3 mm depth from external exposures to photon, beta, and neutron radiation in mSv. Exposures were also categorized according to the nature of the application. In medical applications, the practices are 1) nuclear medicine (NM); 2) conventional diagnostic radiology (CR) which consists of endoscopy, mammography, CT scan, urology, and dental radiography; 3) interventional procedures such as cardiac catheterization (SC); and 4) radiotherapy (RT). For industrial applications, there are IR and industrial gauges (IG). Nuclear services (NS) which comprises of educational, service, and research purposes– are one also of the categories.

Personnel monitoring data ranging from 2013 to 2018 were collected from two IMS providers: the PNRI-TLD and PNRI-OSL. The data consists of the names of the workers, the facility where they worked, the IMS provider and the monitoring period, among others. The data gathered were put in the Microsoft Excel template readable by the system and is then uploaded into the registry. Test reports were generated to check the accuracy of results such as calculation of annual doses received and type of radiation the worker was exposed to. Security features were later added, such as login alerts and e-mail notifications, before finally installing the system in a Linux powered server and made accessible to the internet. To protect the confidentiality of the data, all staff who worked with the development and maintenance of the NDR have signed a confidentiality and non-disclosure agreement.

The NDR also generates information on the radiological occupational exposure profiles, as per prescribed online platform of the United Nations Scientific Committee of Ionizing Radiation (UNSCEAR), shown in Figure 2. The UNSCEAR online platform is a tool used by governments and international organizations to provide national and regional data on the use of radiation in medical diagnosis and treatment for the Global Survey of Medical Radiation Usage and Exposure and the Global Survey of Occupational Exposure. The platform consists of the following: a) the number of workers exposed certain dose intervals *i.e.*, below minimum detectable limit of the dosimeter (< MDL), MDL–1 mSv, > 1–5 mSv, > 5–10 mSv, > 10–15 mSv, > 15–20 mSv, > 20–30 mSv, > 30–50, and > 50 mSv); b) the average effective dose of that interval; and c) collective dose (man-Sv) for each type of practice.

RESULTS

The NDR developed can now be accessed through the address https://services.pnri.dost.gov.ph/registry/. Figure 3 shows the dashboard. It illustrates at a glance the total number of facilities, the number of workers, the personal dose equivalent quantities monitored, and the percentage of workers per type of practice, among others. It also has a feature that allows online requests for occupational exposure history.

In addition, the NDR has the following features:

1. Generates reports on the occupational exposure history of an individual. The report contains the unique identification for the worker, its employer/s, effective and equivalent dose histories, and annual dose summary. A sample report is shown in Figure 4.
2. Generates an annual dose summary of a facility containing all of its monitored workers and the doses they received per monitoring period.
3. Provides a registry of facilities, type of practices, and other information such as name, address, *etc.*
4. Lists incidents of doses exceeding the regulatory limits and sends a notification to the regulatory agencies and the radiation safety officers of the concerned facility.
5. Provides an assessment of occupational exposure profiles per year in the prescribed platform of UNSCEAR.

Figure 5 shows the number of occupationally-exposed workers currently stored in the NDR since 2013 that is monitored by the IMS providers PNRI-TLD and PNRI-OSL. Radiation workers come from both private and government agencies all over the country. There are about 14,000 workers that have been monitored in 2018, more than 70% of which are from conventional diagnostic radiology applications. The total number of workers being monitored are estimated to be about 24,000–26,000 *i.e.*, private IMS providers monitor about 10,000–12,000 workers. The number of radiation workers monitored is also shown to increase over the years.

Table 1, on the other hand, shows the maximum and average annual doses received by workers due to external exposures according to the type of practice. Results show that IR had the highest maximum and average annual doses recorded. In medical applications, NM had the highest average. All average annual doses recorded are found to be lower than the regulatory dose limits of 20 mSv per year averaged over five years. However, practices in IR, SC, and CR have an incidence of exposures exceeding the regulatory dose limits.

The range of doses received from various practices was also generated from the NDR. Figure 6 shows the results of the annual dose intervals of various practices (IR, CR, NM, and SC) for the year 2017. The range of doses received by workers depends on the practice. For all practices, at least 50% of the radiation worker population received annual doses below MDL. Similar trends were also found for the other years.

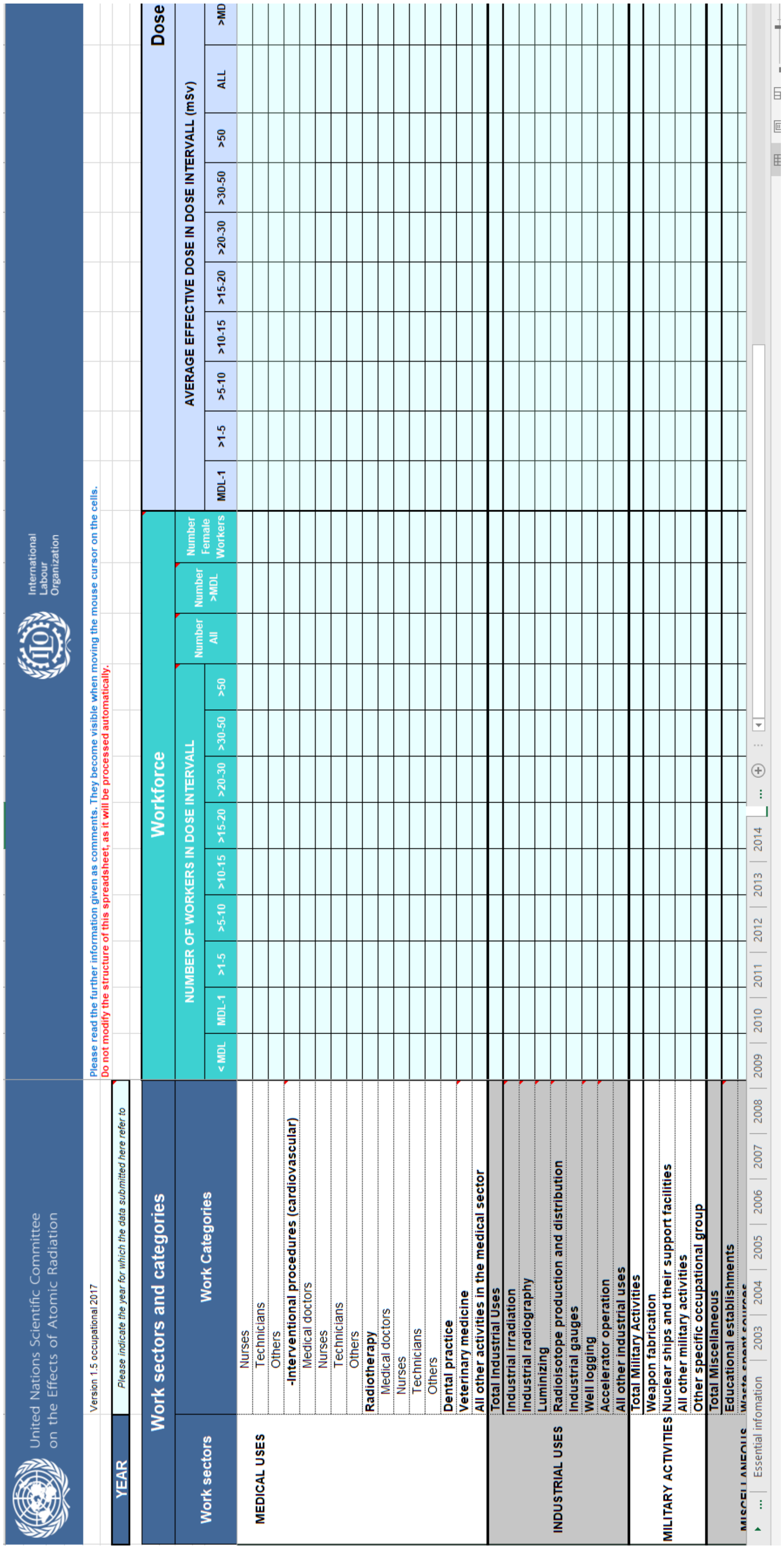


Figure 2. Dose assessment online platform for official submissions to UNSCEAR's Global Survey of Radiation Exposure.

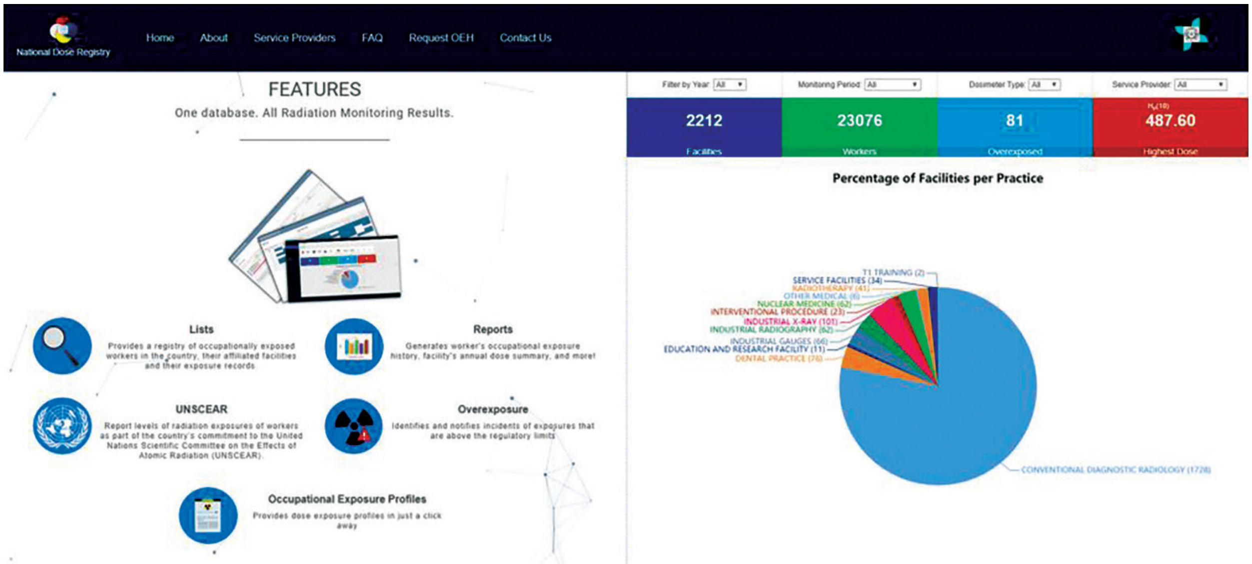
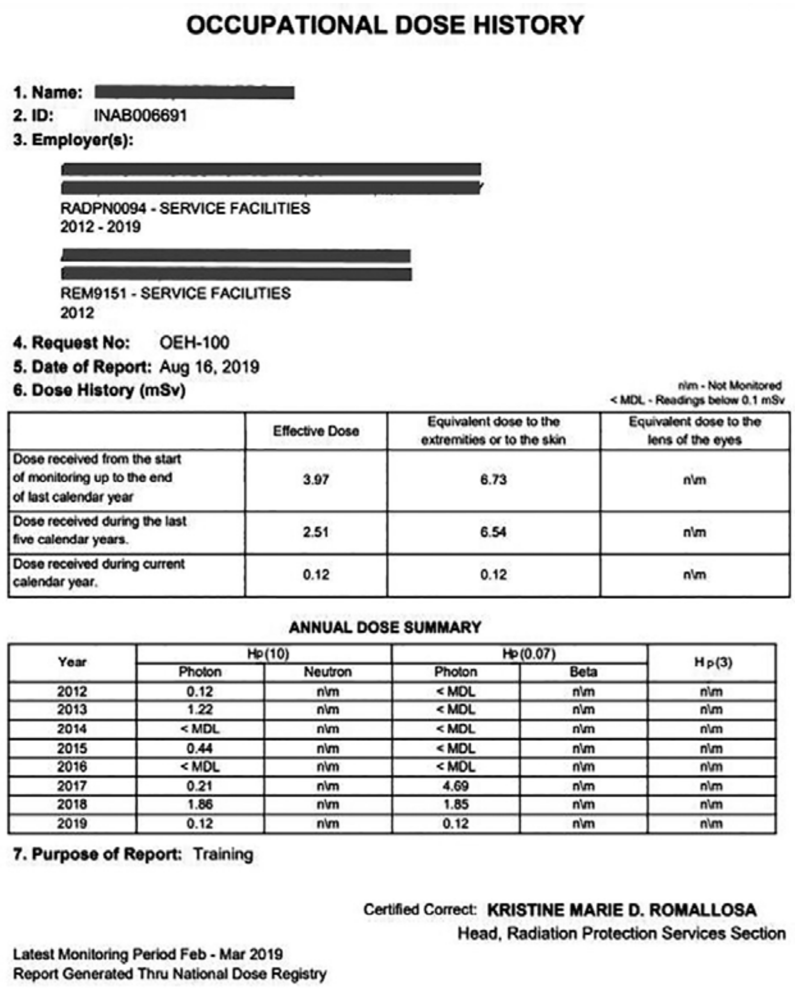


Figure 3. The NDR interface.



OCCUPATIONAL DOSE HISTORY

1. Name: [redacted]
2. ID: INAB006691
3. Employer(s):

[redacted]
RADPN0094 - SERVICE FACILITIES
2012 - 2019

[redacted]
REM9151 - SERVICE FACILITIES
2012

4. Request No: OEH-100
5. Date of Report: Aug 16, 2019
6. Dose History (mSv)

n\m - Not Monitored
< MDL - Readings below 0.1 mSv

	Effective Dose	Equivalent dose to the extremities or to the skin	Equivalent dose to the lens of the eyes
Dose received from the start of monitoring up to the end of last calendar year	3.97	6.73	n\m
Dose received during the last five calendar years.	2.51	6.54	n\m
Dose received during current calendar year.	0.12	0.12	n\m

ANNUAL DOSE SUMMARY

Year	Hp(10)		Hp(0.07)		Hp(3)
	Photon	Neutron	Photon	Beta	
2012	0.12	n\m	< MDL	n\m	n\m
2013	1.22	n\m	< MDL	n\m	n\m
2014	< MDL	n\m	< MDL	n\m	n\m
2015	0.44	n\m	< MDL	n\m	n\m
2016	< MDL	n\m	< MDL	n\m	n\m
2017	0.21	n\m	4.69	n\m	n\m
2018	1.86	n\m	1.85	n\m	n\m
2019	0.12	n\m	0.12	n\m	n\m

7. Purpose of Report: Training

Certified Correct: **KRISTINE MARIE D. ROMALLOSA**
Head, Radiation Protection Services Section

Latest Monitoring Period Feb - Mar 2019
Report Generated Thru National Dose Registry

Figure 4. Sample occupational dose history generated for a worker. The report shows the doses from external exposures received over the years by the worker from different employers in terms of personal dose equivalent $H_p(10)$, equivalent dose to skin $H_p(0.07)$, and equivalent dose lens of the eyes $H_p(3)$ in mSv.

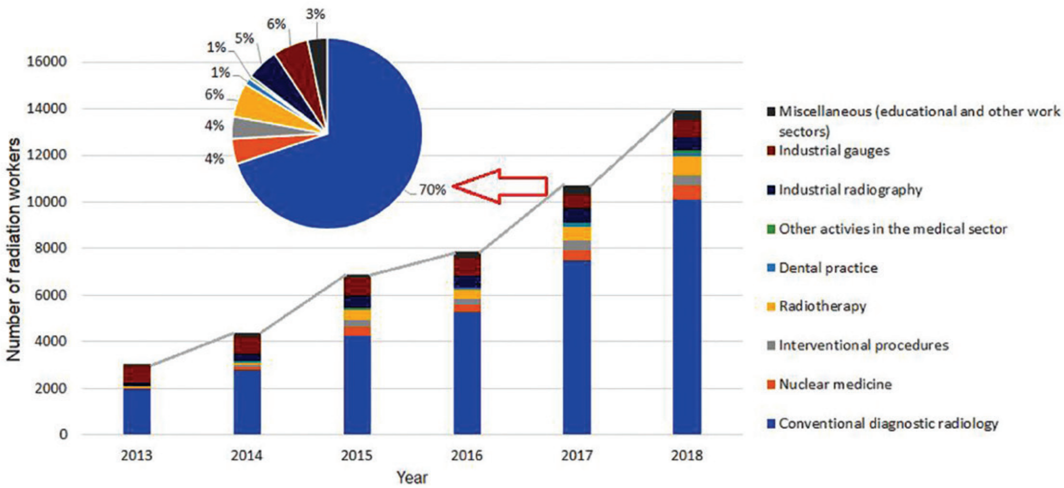


Figure 5. Total number of radiation workers individually monitored in 2013–2018 by PNRI-OSL and PNRI-TLD.

Table 1. Average and maximum annual occupational doses (in mSv) received by workers from according to type of practices.

Radiation practice		Annual dose received (mSv)					
		2013	2014	2015	2016	2017	2018
Nuclear medicine (NM)	Ave.	0.16	0.37	0.40	0.33	0.54	0.85
	Max	1.00	4.12	28.63	4.50	13.97	149
Conventional diagnostic radiology (CR)	Ave.	0.14	0.29	0.10	0.12	0.16	0.12
	Max	33.60	167.25	22.33	43.44	46.85	51.12
Interventional procedures (SC)	Ave.	0.07	0.78	0.25	0.27	0.36	0.17
	Max	0.37	24.96	24.47	21.03	8.35	9.48
Radiotherapy (RT)	Ave.	0.03	0.06	0.12	0.12	0.10	0.12
	Max	0.17	0.78	18.04	7.08	12.45	13.94
Dental practice (DP)	Ave.	0.02	0.03	0.05	0.07	0.07	0.30
	Max	0.10	0.19	0.46	0.69	1.52	14
Industrial radiography (IR)	Ave.	0.72	0.93	0.83	1.47	1.58	0.62
	Max	6.18	71.08	30.79	319.58	380.79	32.67
Industrial gauges (IG)	Ave.	0.11	0.17	0.33	0.09	0.08	0.07
	Max	14.16	33.52	101.25	23.93	3.06	19.03
Miscellaneous (educational, research, and manufacturing purposes)	Ave.	0.08	0.13	0.34	0.42	0.29	0.24
	Max	1.30	2.35	6.77	18.86	5.48	8.59

DISCUSSION

Dose registries have been used in countries like Switzerland, Canada, Spain, and the UK (Ashmore and Grogan 2017, Hernández *et al.* 2001, Moser 1995, Muirhead *et al.* 2009) for the tracking and assessment of occupational exposures. The NDR developed in this study can be used for the same purpose and thus be a tool in helping strengthen radiation protection in the country.

The exposures histories generated by the NDR can be used to evaluate the effectiveness of the facility's radiation protection program and their compliance with the regulatory dose limits. The exposure records, which are readily available upon request by the individual or facility, can also be used for personal, work planning, compensation, or litigation purposes.

Currently, the NDR contains the records monitored by PNRI-RPSS from 2013 to 2018. Although data from the other IMS providers are not yet included, the system is ready to accommodate their dose records. Arrangements are now being initiated by the DOST-PNRI to fully implement the NDR where: 1) the regulatory agencies can readily access the records and receive notifications; and 2) the exposure records from other IMS providers, estimated to be about 10,000–12,000 workers, are also incorporated.

The information in the NDR is presently limited to external exposures only. The system can, however, be expanded to include doses due internal exposures. The PNRI-RPSS is establishing a new facility for individual monitoring of internal exposures. Once the facility completed, the NDR can also be a repository of internal exposures records.

Assessment of Occupational Exposures of Workers in the Philippines

The NDR was also shown to be a tool to generate scientific knowledge on trends and assessment of occupational exposure profiles in the country. The increasing trend of workers over the years are shown in the NDR can be used to project the emerging radiation and nuclear applications. Figure 5 shows that majority of the radiation workers in country are involved in conventional radiology. For instance, in 2017, approximately 70% of all the radiation workers monitored were CR personnel. It is also found and as shown in Figure 6C that about 70% doses received are less than the MDL, while more than 95% of the workers received annual doses below 1 mSv. The fraction of workers from other practices receiving annual doses less than the MDL are 62% for IR, 50% for NM, and 54% for SC. The distributions are comparable with the patterns described by UNSCEAR, implying that most occupationally-exposed workers receive low doses and only few workers receive high doses (UNSCEAR 2008).

Certain practices, on the other hand, have higher risks of occupational exposures. In SC and IR applications in 2017, for instance, 2% and 1% of the total population received annual doses > 5 mSv, respectively (Figure 6). Annual doses for NM, SC, and IR are also higher compared to IG, CR, and RT. Particularly for IR, several incidents of doses exceeding the annual regulatory limits were found, some of which are greater than 50 mSv/yr.

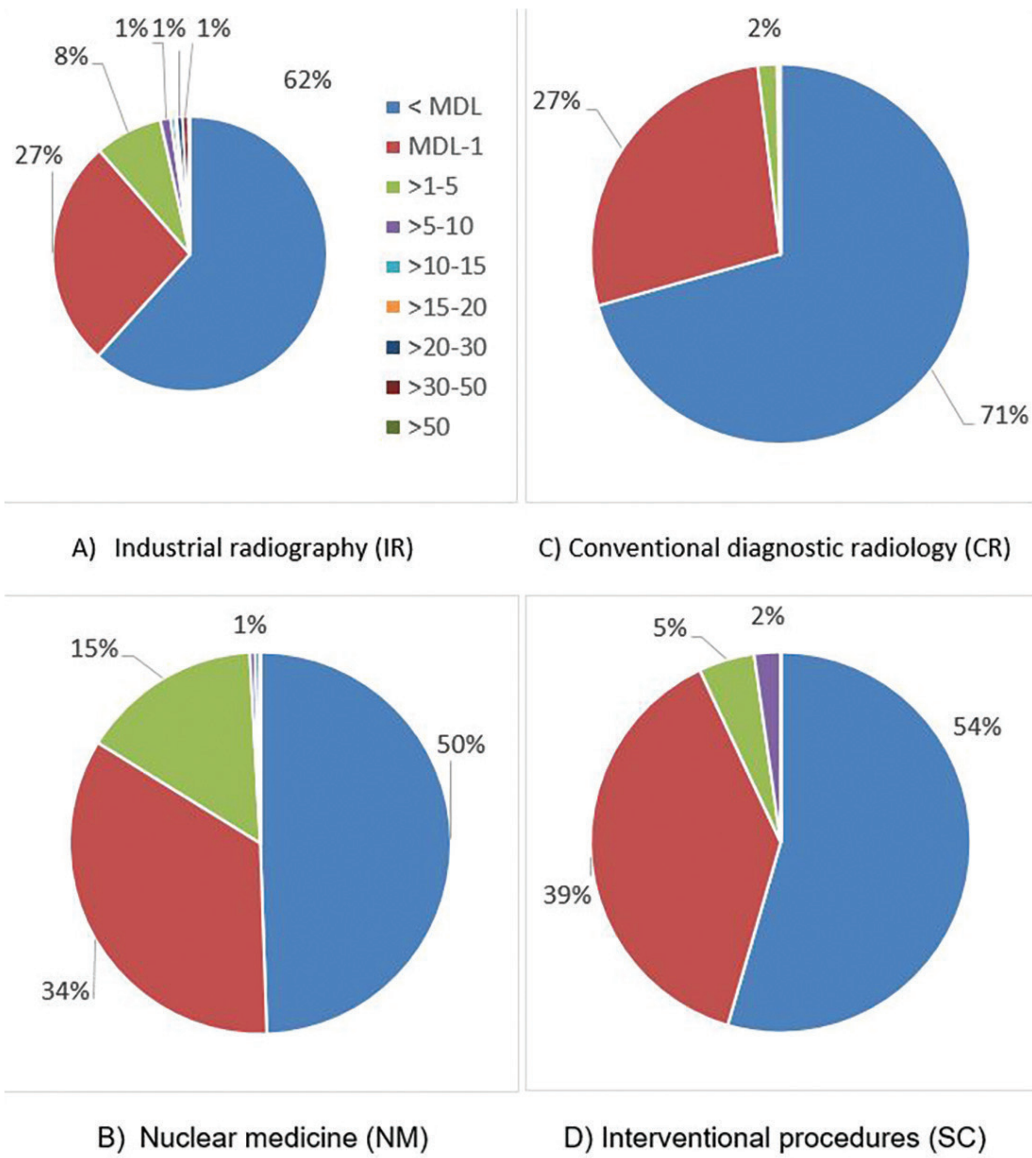


Figure 6. Occupational dose intervals (units in mSv) for 2017; minimum detectable limit (MDL) = 0.10 mSv.

IR had values of average occupational doses ranging 0.72–1.58 mSv. It is one of the most common non-destructive testing methods in the world. Higher annual average effective doses are commonly received by industrial radiographers; thus, they are considered as one of the most critical groups of radiation workers (UNSCEAR 2008). These high average doses recorded are similar with average doses recorded from other countries such as the USA, Canada, and China as presented in the UNSCEAR report (UNSCEAR 2000). For NM, the recorded average annual doses ranged 0.16–0.85 mSv. Workers in this field may also receive high annual doses ranging 1–50 mSv according to various studies (Martins *et al.* 2007, Mettler *et al.* 2008).

The NDR as a Tool for Regulators and National Authorities

The results of the assessment generated from the NDR can be used to aid the regulators in adopting a graded-approach in the optimization of radiation protection and safety requirements, particularly in individual dose monitoring.

The primary justification for the monitoring and assessment of exposures is to help achieve and demonstrate adequate protection and safety of the practice including among others compliance with regulatory requirements. It also aims to determine the radiological conditions in the workplace; provide information to the workers of how, when, and where they are exposed; and provide data on the risk-benefit analysis of practices (IAEA 2018).

Based on the results of assessment of the exposure profiles, most of the workers are engaged in CR. However, it has the lowest risks of occupational exposures among the practices. NM, SC, and IR – although comprising only about 7% of the total facilities – have higher average annual doses and risk of receiving doses that exceeds the regulatory limits.

Existing regulations and standards for individual monitoring may, therefore, need to be revisited to determine whether the nature of practice and application of a graded-approach have been taken into account. That is, in updating and developing practice-specific requirements, due considerations should be given on the distributions of exposures of workers in different practices, probability, and magnitude of potential exposures, and the likelihood of exposures exceeding the limits, among others.

CONCLUSION

In this paper, the development of the Philippine NDR as a tool for the tracking and assessment of occupational radiation exposure profiles and risks in the Philippines was presented. The NDR developed was shown to be a centralized web-based information system that contains radiation dose records from external exposures of workers in the country. It can also be used as a tool in improving the assessment of the country's exposure profiles and in the determination of practices that have higher risks of occupational exposures. It will allow workers and facilities to have access to their own exposure histories. It can also bridge the gap in the maintenance and tracking of the exposure records of individuals 1) working in multiple facilities and with various radiation sources, 2) even if their facilities ceases to operate, and 3) who availed of IMS from various providers. Its web-based feature makes it readily accessible to the regulatory bodies for oversight and control of occupational exposures. Finally, it can provide an indication of the level of radiation hazards among different practices and thereby aid in the development of better radiation safety regulations for the protection of the workers in the Philippines.

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REFERENCES

ASHMORE JP, GROGAN D. 1985. The National Dose Registry for Radiation Workers in Canada. Radiation Protection Dosimetry 11(2): 95–100. https://doi.org/10.1093/oxfordjournals.rpd.a079450

BENNETT GF. 2002. International basic safety standards for protection against ionizing radiation and for the safety of radiation sources. Journal of Hazardous Materials 54(1–2): 134–135. https://doi.org/10.1016/s0304-3894(97)89416-2

[CDRRHR] Center for Device Regulation, Radiation Health, and Research. 2004. Administrative Order 149: Basic Standards on Radiation Protection and Safety Governing the Authorization for the Introduction and Conduct of Practices Involving X-Ray Sources in the Philippines. Muntinlupa, Philippines.

HERNÁNDEZ A, MARTÍN A, VILLANUEVA I, AMOR I, BUTRAGUEO JL. 2001. The Spanish National Dose Registry and Spanish radiation passbooks. Radiation Protection Dosimetry 96(1–3): 277–280. https://doi.org/10.1093/oxfordjournals.rpd.a006601

[IAEA] International Atomic Energy Agency. 2014. Basic Safety Standards. IAEA Safety Standards Series No.

GSR Part 3. 471p. https://doi.org/STI/PUB/1578

[IAEA] International Atomic Energy Agency. 2016. Governmental, Legal and Regulatory Framework for Safety. IAEA Safety Standards Series No. GSR Part 1 (Rev. 1).

[IAEA] International Atomic Energy Agency. 2018. Occupational Radiation Protection. IAEA Safety Standards General Safety Guide No. 7. 360p. Retrieved from http://www-ns.iaea.org/standards/

MARTINS MB, ALVES JG, ABRANTES JN, RODA AR. 2007. Occupational exposure in nuclear medicine in Portugal in the 1999–2003 period. Radiation Protection Dosimetry 125: 130–134. https://doi.org/10.1093/rpd/ncl564

METTLER FA, BHARGAVAN M, THOMADSEN BR, GILLEY DB, LIPOTI JA, MAHESH M, MCCROHAN J, YOSHIZUMI TT. 2008. Nuclear Medicine Exposure in the United States, 2005–2007: Preliminary Results. Seminars in Nuclear Medicine 38(5): 384–391. https://doi.org/10.1053/j.semnuclmed.2008.05.004

MOSER M. 1995. The national dose registry for radiation workers in Switzerland. Health Physics 69(6): 979–986. https://doi.org/10.1097/00004032-199512000-00016

MUIRHEAD CR, O'HAGAN JA, HAYLOCK RGE, PHILLIPSON MA, WILLCOCK T, BERRIDGE GLC, ZHANG W. 2009. Third Analysis of the National Registry for Radiation Workers: Occupational Exposure to Ionising Radiation in Relation to Mortality and Cancer Incidence. Human Studies 256(2): 2002–2004.

[DOST-PNRI] Department of Science and Technology – Philippine Nuclear Research Institute. 2004. CPR Part 3: Standards for Protection Against Radiation (Vol. 100) Quezon City, Philippines.

[UNSCEAR] United Nations Scientific Committee on the Effects of Atomic Radiation. 2000. Report of the United Nations Scientific Committee on the Effects of Atomic Radiation to the General Assembly [UNSCEAR Report Vol. II]. New York. 17p.

[UNSCEAR] United Nations Scientific Committee on the Effects of Atomic Radiation. 2008. Effects of Ionizing Radiation, Annex E: Occupational Radiation Exposures [UNSCEAR Report Vol. I]. New York. 472p.