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Analysis of external personal dosimetry for external exposure to medical radiation workers in radiotherapy and nuclear medicine departments between 2019 and 2022

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ABSTRACT

The National Cancer Institute from Chile possesses a wide variety of high-complexity equipment for cancer treatment and diagnosis that employs ionizing radiation with high and medium energy. Presently, the radiotherapy department is equipped with 5 clinical linear accelerators and one brachytherapy equipment, while the nuclear medicine department is equipped with a PET-CT, a single gamma camera, and a hospitalization room for betatherapy. A descriptive statistical analysis was conducted on the Personal Doses Equivalent Reports from medical radiation workers between 2019-2022. The analysis involved extracting Hp(10) and Hp(0.07) measurements from digital reports using the Python Pandas library, and a database was constructed. The annual set of data was selected for each department to describe their behavior concerning Hp(10) total since PD8 dosimeters had the highest circulation. Additionally, using the boxplot format for the Hp(10) and Hp(0.07) distributions, means, medians, minimums and maximums, interquartile ranges and outliers were analyzed. While Hp(10) measurements exhibited an increase, Hp(0.07) measurements remained constant or experienced a decrease. All reported measurements were less than international tolerances. Finally, this initial descriptive statistical analysis enables the radiation safety officers to evaluate the applicability of inferential statistical analysis with stronger evidence and in an objective manner.

Keywords : **Occupational radiation dose, radiation workers, radiation protection.**

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1. INTRODUCTION

The National Cancer Institute (Instituto Nacional del Cáncer, INC) from Chile is equipped with a wide range of high-complexity equipment dedicated to cancer treatment and diagnosis, utilizing ionizing radiation with high and medium energy. The INC facilities are divided between two locations in Santiago, Chile, known as North and South Headquarters (HQ). The radiotherapy department (RT dept.) at INC is equipped with 5 clinical linear accelerators for teletherapy, 3 of them with dual energy. Also, the department is equipped with a high dose rate remote afterloader brachytherapy equipment that uses Ir-192. Just 2021-2022 were low-dose rate ocular brachytherapy with I-125 performed in the RT dept. Additionally, the nuclear medicine department (NM dept.) is equipped with a PET-CT scanner employing F-18, a single gamma camera using Tc-99m, and a dedicated hospitalization room for betatherapy utilizing I-131.

The personal dose equivalent, Hp(d), is an operational quantity: the dose equivalent in soft tissue (commonly interpreted as the 'ICRU sphere') at an appropriate depth in milimeter, d, below a specified point on the human body. The unit of personal dose equivalent is joule per kilogram (J/kg) and its special name is Sievert (Sv). The specified point is usually given by the position where the individual's dosimeter is worn [1].

The aim of this study was to conduct an initial descriptive statistical analysis of the two-months Hp(d) Reports pertaining to Medical Radiation Workers (MRW) within the RT and NM Departments for the years 2019 to 2022.

2. MATERIALS AND METHODS

The institution acquired the External Personal Dosimetry Service provided by Nuclear Energy Commission of Chile (Comisión Chilena de Energía Nuclear, CCHEN). CCHEN provides Hp(d) measurements using *RADOS TL-Dosimeter* [2] with bimonthly reporting for each MRW from the RT and NM departments.

The Hp(10) and Hp(0.07) measurements were extracted from CCHEN digital reports (.pdf) with Python Pandas library. The database was built with data from 2019 to 2022. Table 1 summarizes the MRWs amount separated by their respective departments and profession, and Table 2 shows the RADOS dosimeters (PD8 dosimeters and ring-shaped dosimeters) amount reported from 2019 to 2022.

Table 1: MRW locations distribution within INC and their professions of the present study.

Department / MRW Professions	NM	RT				MRW total by profession
	North HQ	North HQ	South HQ	Medical Physic Service	Nursing Station	
AS_NM	3	-	-	-	-	3
CN_NM	3	-	-	-	-	3
MP_NM	2	-	-	-	-	2
MD_NM	6	-	-	-	-	6
SECY_NM	2	-	-	-	-	2
NT_NM	2	-	-	-	-	2
MT_NM	8	-	-	-	-	8
AS_RT	-	1	-	-	3	4
CN_RT	-	-	-	-	16	16
MP_RT	-	-	-	10	-	10
MD_RT	-	21	1	-	-	22
SECY_RT	-	1	2	-	-	3
NT_RT	-	17	13	-	19	49
MT_RT	-	22	10	-	-	32
MRW total by location	26	62	26	10	38	162

AS =Ancillary Staff; CN= College Nurse; MD = Medical Doctor; SECY = Secretary; NT= Nurse Technician; MT= Medical Technologist; MP = Medical Physicist

Table 2: MRW relative dosimeters distribution within INC of the present study.

Department		PD8	Ring	Total used dosimeters
NM	North HQ	64.6%	35.4%	381
RT	North HQ	98.7%	1.3%	820
	South HQ	100.0%	0.0%	709
	Medical Physic Service	94.3%	5.7%	280
	Nursing Station	100.0%	0.0%	359
Analyzed dosimeters		93.6%	6.4%	2549

To describes the behavior within the institution relative to total Hp(10), the annual data for each department was analyzed, considering the PD8 dosimeters' higher circulation (93.6% from table 2). Additionally, a statistical examination was performed using the boxplot format to analyze the distributions of Hp(10) and Hp(0.07), investigating measures such as means, medians, minimums, maximums, interquartile ranges (Q3 - Q1), and identification of outliers.

The occupational exposure limits are Effective dose (whole body): 20 mSv per year averaged over defined periods of five years (with the further provision that the effective dose should not exceed 50 mSv in any single year) [1]; Annual dose equivalent to the skin: 500 mSv per year [1]. Then, assuming E(50) = 0 and dividing the annual limit by six, the bimonthly limit for Hp(10) of 3.33 mSv per 2 months and for Hp(0.07) of 83.33 mSv per 2 months [3].

3. RESULTS

The contribution from each department to total Hp(10) between 2019-2022 using PD8 is described below. Figure 1 shows the contribution for each type of department to total Hp(10) and amount of analyzed dosimeters [4]. Table 3 shows Hp(10) means and standard deviations per departments between 2019-2022. Tables 4 and 5 shows percentages of Hp(10) per departments between 2019-2022 below 0.1 mSv/2_months and below 1.0 mSv/2_months, respectively. Finally, figure 2 shows boxplot distributions from both departments depending on the year and dosimeter used to analyze central tendency, dispersion, and whiskers.

Table 3: Hp(10) means and standard deviations per departments between 2019-2022.

Hp(10) (mSv/2_months)	**2019**	**2020**	**2021**	**2022**	**2019-2022**
RT dept.	0.09 ± 0.39	0.14 ± 0.04	0.20 ± 0.12	0.31 ± 0.11	0.17 ± 0.11
NM dept.	0.20 ± 0.17	0.25 ± 0.18	0.39 ± 0.26	0.67 ± 0.54	0.32 ± 0.31

Table 4: Percentages of Hp(10) below 0.1 mSv/2_months per departments between 2019-2022.

Hp(10) (mSv/2_months)	**2019**	**2020**	**2021**	**2022**	**2019-2022**
RT dept.	78.3%	20.2%	7.4%	0.0%	24.0%
NM dept.	61.4%	24.1%	7.6%	0.0%	21.0%

Table 5: Percentages of Hp(10) below 1.0 mSv/2_months per departments between 2019-2022.

Hp(10) (mSv/2_months)	**2019**	**2020**	**2021**	**2022**	**2019-2022**
RT dept.	100.0%	100.0%	100.0%	100.0%	100.0%
NM dept.	100.0%	100.0%	98.9%	74.2%	96.3%

Figure 1: *Total Hp(10) distributions from both departments and their locations between 2019 to 2022. The letter "n" represents the PD8 dosimeters amount.*

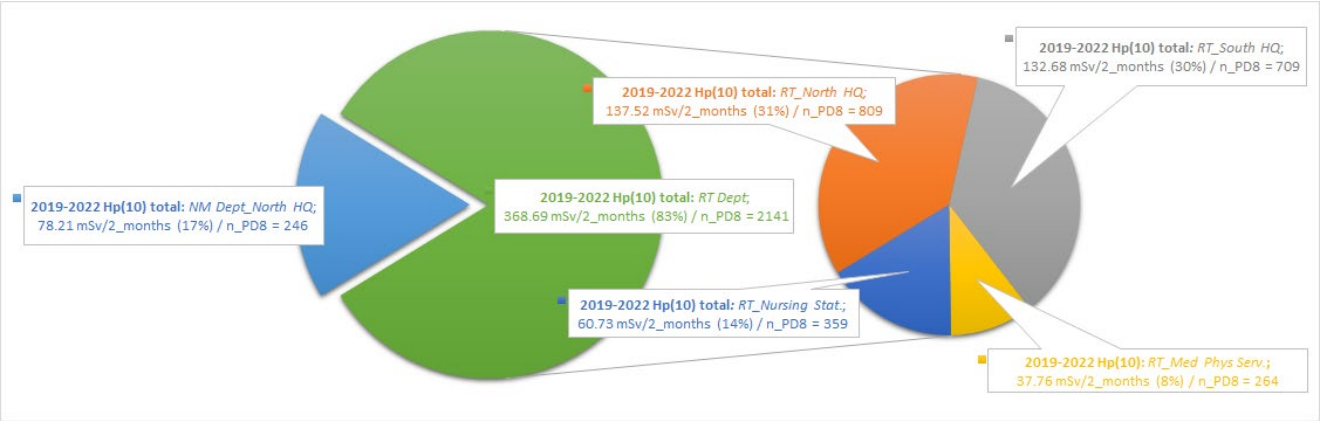
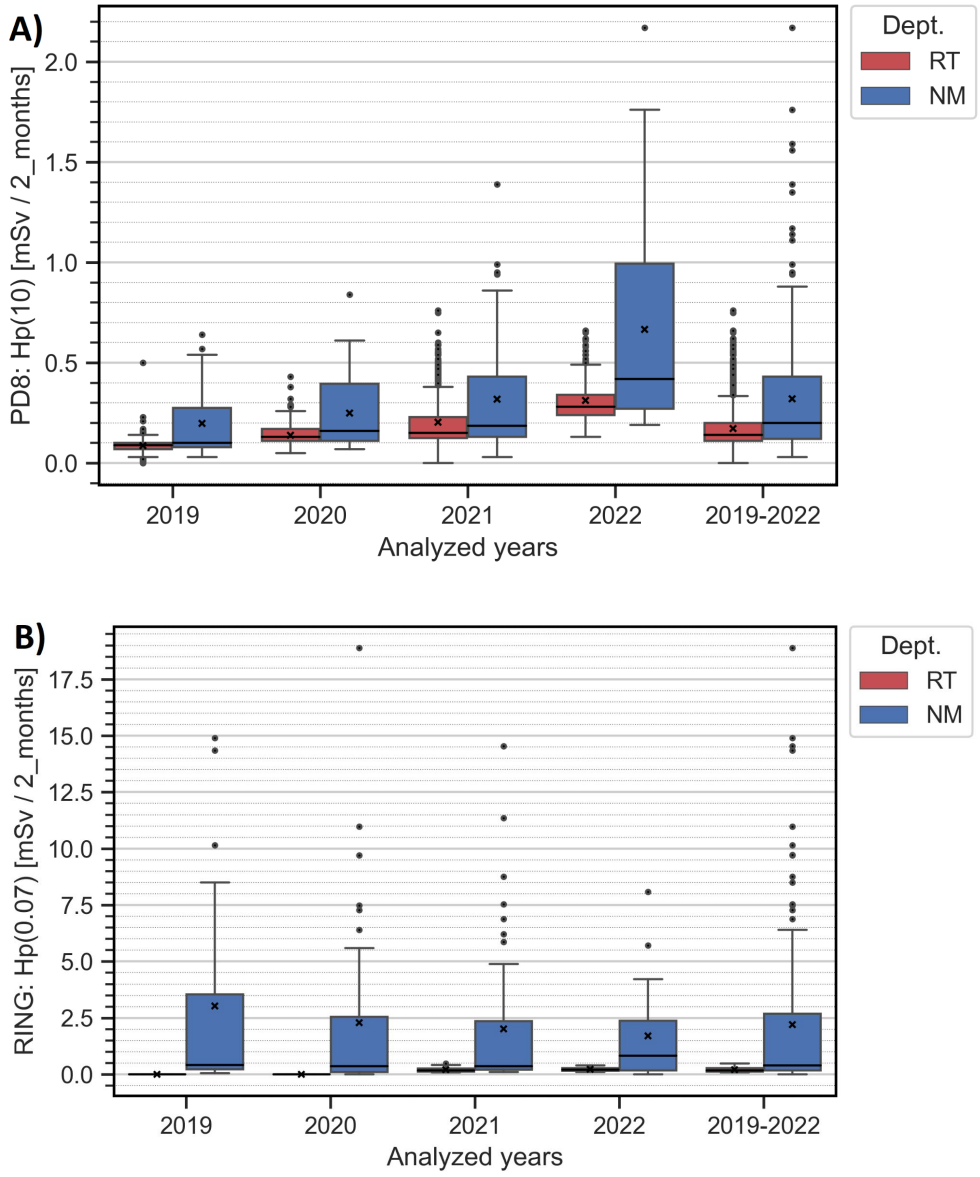


Figure 2: *Hp(d) boxplot distributions from both departments depending on analyzed year and the used dosimeter.* ***A)*** *PD8 dosimeter bimonthly measurements. Bimonthly Hp(10) limit: 3.33 mSv/2_months* ***B)*** *Ring shaped dosimeter bimonthly measurements. Bimonthly Hp(0.07) limit: 83.33 mSv/2_months.*

Symbols: means (x), medians (—), outliers (•), minimum and maximum (whiskers).



4. CONCLUSION

The first database with Hp(d) measurements for each MRW since 2019 has been created. For Radiotherapy and Nuclear Medicine Departments, the mean Hp(10) between 2019 to 2022 was 0.17 ± 0.11 mSv/2_months and 0.32 ± 0.31 mSv/2_months, respectively.

Regardless of its contribution to total Hp(10) from INC, means, medians, and dispersion from Hp(10) measurements of both departments have been raised since 2019. On the other hand, the behavior occurred for Hp(0.07) where they were constant or even decreased. Also, percentages of Hp(10) below 1.0 mSv per two months per departments between 2019-2022 remained almost constant, but percentages of Hp(10) below 0.1 mSv were decreased. There was suspicion of a change in the methodology of PD8 result delivery, where instrumental background subtraction is not performed. Finally, for all cases analyzed, the readings recorded were lesser than calculated bimonthly international tolerances.

This initial descriptive statistical analysis allows radiation safety officers from INC evaluate applicability of inferential statistical analysis (parametric or non-parametric) with better evidence and in an already manner. Finally, this will allow:

• Evaluate the normality of the reported data for each department.

• Detects and investigates atypical Hp(d) values from INC.

• Reports Hp(d) temporary trend for a specific MRW.

• Detects and investigates significant differences in Hp(d) between years and periods from INC, department, headquarters and/or MRW workflow.

5. REFERENCES

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