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Assessment of Radiation Dose for Non-Radiation Workers in the Medical Field Practices

Huda M. Al-Naemi

Hamad Medical Corporation, Occupational Health and Safety, Doha, Qatar
Email: dhudanaimi@hotmail.com

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Abstract

Radiation protection programs aims to reduce the radiation dose to the lowest possible level under the Dose Limit (DL) limit by the national or international laws, while the dose monitoring programs working as scale used to evaluating the efficiency of these programs and tools. In this study, the average of the annual E_{ff} dose for the intensive care units at Hamad General Hospital (HGH) is less than the 50% of DL. It was aiming also to evaluate the efficiency of the radiation safety requirements (especially the shielding Adequacy) for the non radiation workers at oncology centers, hence several monitors were installed in chosen locations outside the radiation treatment machine from 2007 to 2011.

Keywords

Annual Effective Dose, Radiation Dose Monitoring, Occupational Dose, Non-Radiation Workers

1. Objectives

This study intends to assess the radiation doses for the Non Radiation Workers (NRW) over the last five years in different medical applications within several hospitals belong to Hamad Medical Corporation (HMC). And to compare dose levels with limits permitted locally and internationally, in addition to verify the efficiency of radiation protection programs and requirements at HMC, aiming to reduce Personnel Radiation Doses (PRD).

2. Introduction

Radiation monitoring definition; generally the observation of the levels of radiation I a given area for the purpose of assuring that they have not exceeded prescribed amounts, or in the case of radiation already present in the area

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for the purpose of assuring that the levels have returned to those meeting acceptable safety standards either by measuring continuously or at intervals [1] [2].

So, the licensees were forced (by the regulatory law) to providing programs for the individual dose monitoring to the radiation-workers, which is very expensive, especially for the large organizations which involving a complex and overlapping applications while the problem of NRW Stand out clearly. Those large numbers of the rotatable staff (compared to the RW) makes service of Individual dose monitoring impractical. At the same time they have much concern regarding the adequacy of the radiation safety for them.

The NRW can be classified to two groups:

1) Medical staff needs to do the routine work in parallel to using the radiation (outside radiology department), such as intensive care units and Operating theater, etc.

2) Those who are working (technical or administrative) in nearby locations to the radiation workplaces (diagnosis and treatment, etc.), such as the reception staff in radiology or radiotherapy departments and workers in the blood laboratories which included irradiator unit. And to avoid difficulties arising from providing individual monitoring service for the NRW and to reassure them that they are not exposed to harmful levels of radiation, the radiation monitors (Area Monitors (AM)) have been installed in those locations which using the radiation outside the radiology department (1^{st} category), and in sites nearby to the radiation sources (2nd category). International Basic Safety Standard and related guidance by IAEA in the Basic Safety Standards was recommended general Safety Requirements Part 3 (Interim), Appendix I (Occupational Exposure) [2]-[4]: Public exposure III-3. For public exposure, the dose limits are:

a) An effective dose of 1 mSv in a year;

b) In special circumstances, a higher value of effective dose in a single year could apply, provided that the average effective dose over five consecutive years does not exceed 1 mSv per year;

c) An equivalent dose to the lens of the eye of 15 mSv in a year;

d) An equivalent dose to the skin of 50 mSv in a year.

Ionizing radiation is a constant risk to exposed workers. In medicine, the most exposed professionals are among cardiologists, radiologists and orthopedic surgeons [5]. Recently, it was shown that the incidence of malignant diseases increased in an orthopedic hospital among the exposed personnel [6]. In the last decades, orthopedic surgeries became less invasive, because of the development of minimal-invasive techniques and implants. Therefore, the use of intra-operative fluoroscopy is indispensable in orthopedic procedures nowadays. For instance, it is commonly used for closed reductions, intramedullary nails, open reduction and internal fixations (ORIF), as well as dorsal vertebral stabilizations.

3. Material and Methods

A list of abbreviation and acronym that are used in this study are shown in **Table 1**. The seven hospitals from HMC in the state of Qatar were included in this study and in the total of 16 locations dose monitoring was performed from 207-2011. The TLD-100 is fabricated from LiF elements assembled in bar-coded cards with the hars how model card holder has been installed different locations as shown in **Table 2** inside each radiation workplace (Portable X-ray users or/and radiation source location) to measure the cumulative radiation doses from each monitor in the workplace. TLDs distributed to the concerned department to be collected later for the evaluation of personnel dose equivalents. A single TLD badge is issued on a bimonthly. Though the evaluated H_p (10) value grossly overestimates the effective dose, it is entered as the dose of record without any corrections. Annual dose records for NRW were taken from the HIS (Health Information System) and exported to Excel 2010 (Microsoft Corp., Redmond, WA, USA) for analysis. The selected place under each hospital were selected where mobile x-ray machine are exist. Anterior-posterior (A/P) chest and abdominal radiographs are among the most common diagnostic imaging exams used in the NICU, CCU, PEC… etc.

4. Results & Discussion

The operational quantity for area monitoring defined in the ICRU sphere should retain their character of a point quantity and the property of additively. This is achieved by introducing the terms expanded and aligned radiation field in the definition of these quantities. For area monitoring of penetrating radiation the operational quantity is the ambient dose equivalent $H^*(d)$, with d = 10 mm. The ambient dose equivalent $H^*(d)$, at a point of interest in the real radiation field, Radiation field is the dose equivalent that would be produced by the produced by the

Table 1. List of abbreviations for the monitored area in HMC.

Abbreviation	Full name	Abbreviation	Full name
HMC	Hamad Medical Corporation	CCU	Cardiac Care Unit
HGH	Hamad General Hospital	SICU	Surgical Intensive Care Unit
RH	Rumailah Hospital	TICU	Trauma Intensive Care Unit
AAH	Al-Amal Hospital	MICU	Medical Intensive Care Unit
WH	Woman Hospital	PEC	Paediatric Emergency Care
AKH	Al-khor Hospital	PICU	Paediatric Intensive Care Unit
ROD	Radiation Occupational Dose	NICU	Neonatal Intensive Care Unit
NRW	Non-Radiation-Workers	AM	Area Monitors
DL	Dose Limit	IAEA	International Atomic Energy Agency
D_E	Full Body Effective Dose	BSS	Basic Safety Standard
PRD	Personnel Radiation Doses	ICRP	International Commission of Radiological Protection
TLD	Thermoluminescent Dosimeter	E_{ff}	Annual Effective Dose

Table 2. Illustrated the amount, locations and monitoring period for each department for the Monitored hospitals in HMC.

Hospital	Department	Location	Number of TLD/area	Monitoring period
HGH	Emergency	Trauma room	3	2007-2011
		Treatment clinics	6	2007-2011
	Blood bank	Irradiator room	1	2007-2011
		Administration room	1	2007-2011
	CCU	606	1	2007-2011
		607	1	2007-2011
		610	1	2007-2011
	SICU	Clinic area Patient beds	3	2007-2011
	TICU		6	2008-2011
	PICU		2	2007-2011
	MICU		2	2007-2011
	Surgery	Theater rooms	8	2007-2011
R H	Plastic surgery	Male	1	2008-2011
		Female	1	2008-2011
	Dental	Treatment rooms	8	2007-2011
	Ear Nose Throat	Clinic rooms	3	2008-2011
AK H	Surgery	Treatment rooms	4	2007-2011
		Day car unit	3	2007-2011
PEC	Clinic area	Inpatient	6	2010-2011
AA H	Oncology	Outside radiotherapy units	4	2009-2011
WH	NICU	Inpatient	14	2011
Aspetar	Surgery	Operation room	2	2011
		Recovery room	1	2011

corresponding aligned and expanded radiation field, in the ICRU sphere at a depth *d*, on the radius vector opposing the direction of radiation incidence. For penetrating radiation it is $d = 10$ mm and H*(*d*) is written H*(10). As a result of the imaginary alignment and expansion of the radiation field, the contribution of radiation from all directions add up. The value of H*(10) is therefore independent of the directional distribution of the radiation in the actual field. This means that the reading of an area dosimeter for the measurement of H*(10) should be independent of the directional distribution of the radiation—an ideal detector should have an isotropic fluence response. H*(10) should give a conservative estimate of the effective dose a person would receive when staying at this point. This is always the case for photons below 10 MeV in contrast to the formerly used free-in-air quantities air Kerma or exposure which are non-conservative in the photon energy range near 80 keV [7]-[9].

There have been several studies to investigate the radiation for the surgeon and the operating staff [10]-[12]. Müller *et al*. performed 41 intramedullary nailing of the femur and the tibia. The surgeons as well as the first assistant wore ring dosimeters on the dominant index finger during the operations. The mean radiation time was 4.6 minutes (min). The mean radiation dose for one intervention was 1.27 mSv for the surgeon and 1.19 mSv for his first assistant.

The strength of our study is that it was planned in a more pragmatic way—apart from bedside radiological procedures, we also took into account the radiation exposure to ICU, PIC, NICU and all the studied areas residents, nurses and all NRW accompanying the patient to radiological suites for diagnostic and therapeutic procedures. Ionizing radiation from fluoroscopy in the CT scan or interventional radiology suites may be significant and were not considered in this study. We also tried to measure the amount of scattered radiation within the mentioned units, which contributes to overall radiation exposure. Even after taking these additional sources of radiation exposure into account, we found that the cumulative radiation exposure was negligible. Similarly, another study looked into the radiation exposure to ICU nurses and found that the exposure was well below the permissible level [13]. The findings of our study have reiterated the results of these previous studies.

The total mean doses were estimated and compared against the public maximum permissible doses (DL = 1 mSv in a year) this may be increased to 5 mSv in a single year provided that the average over 5 consecutive years is 1 mSv per year as illustrated in **Table 3**. An equivalent dose to the lens of the eye of 15 mSv in a year and the equivalent dose to the extremities or skin of 50 mSv in a year [3].

4.1. Hamad General Hospital

It is the largest hospital within HMC, where all types of applications (medical & radiation) are includes and with highest workload.

By this study 9 medical applications were involved as shown in **Table 4**. As shown **Figure 1** the values of the Annual E_{ff} Doses during the monitoring periods (Year/workplace) in HGH compared with DL.

4.1.1. For Surgery Department

It is noticed in **Figure 2** that the doses values during the periods of 2009-2010 for Room (5) was more than the rest surgery rooms! (slightly less than the DL), because It was dedicated for orthopedic and facial surgeries (heaviest radiation use in surgery), and in 2011 starting to use the new extension rooms and redistribute the radiation workload on more than one room, Which explains the reduction of the dose values in 2011 for Room 5 and other rooms in general.

4.1.2. Blood-Bank

The semi-linear reductions on dose levels for blood-bank mostly come as result of source decay.

The analysis of the intensive care units results **Figure 3** shown (as expected) that the radiation workload in

Table 3. Maximum permissible doses for occupational and non-worker or public (msv/year).

Organ, tissue	Occupational dose (mSv/year)	Non radiation worker or public (mSv/year)
Whole body	20	1
Lens of the eye	20	15
Shallow dose (skin and extremities)	500	50

Table 4. The values of the Annual Cumulative Radiation Doses per workplace in each department/hospital during the monitoring periods.

Hospital	Department	D_E (mSv/Y)				(Cumulative E_{ff} Dose)	
		2007	2008	2009	2010	2011	D_E (Average)
HGH	Emergency	0.67	0.64	0.57	0.55	0.60	0.6
	Blood bank	0.74	0.69	0.65	0.61	0.57	0.65
	CCU	0.61	0.52	0.44	0.37	0.43	0.5
	SICU	0.56	0.54	0.59	0.41	0.42	0.5
	TICU		0.57	0.65	0.54	0.60	0.6
	PICU	0.46	0.43	0.51	0.31	0.40	0.4
	MICU	0.46	0.50	0.50	0.35	0.33	0.4
	Theater Rooms (1,2,3,4,6,7 & 8)	0.56	0.64	0.56	0.44	0.34	0.5
	Theater Rooms (5) (orthopedic + facial surgery)	0.68	0.83	0.92	0.94	0.59	0.8
RH	Plastic surgery		0.40	0.57	0.44	0.47	0.5
	Dental	0.55	0.58	0.57	0.42	0.42	0.5
	Ear Nose Throat		0.40	0.55	0.43	0.36	0.4
AKH	Theater Rooms		0.62	0.63	0.45	0.62	0.6
	Day car unit		0.52	0.62	0.45	0.45	0.5
PEC	Clinic area				0.41	0.58	**0.5**
AAH	Oncology			0.39	0.46	0.41	**0.4**
WH	NICU				0.18	0.38	**0.3**
Aspetar	Theater Rooms					0.38	**0.4**
	Recovery					0.44	**0.4**

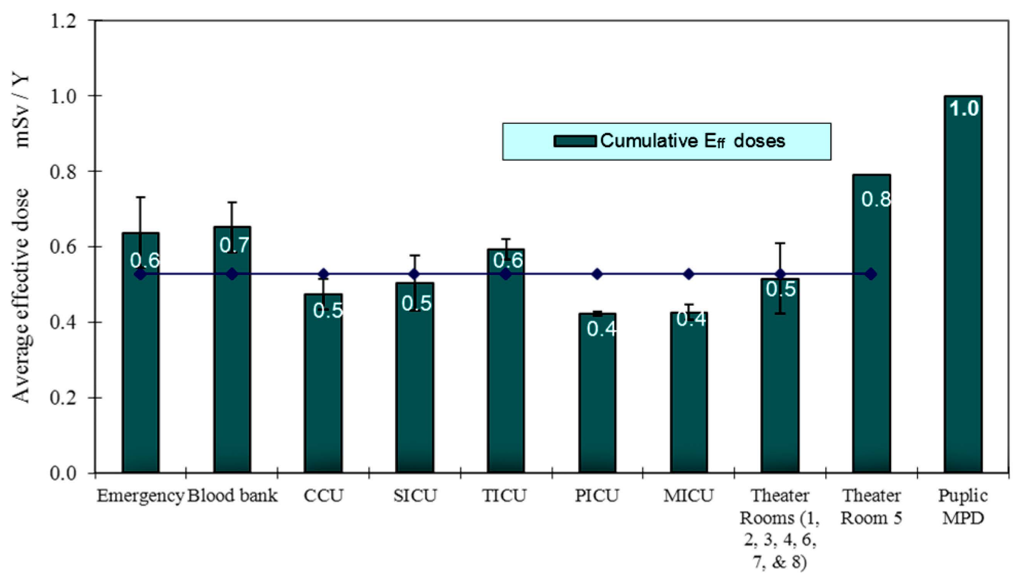

Figure 1. Max cumulative effective doses during the monitoring period for different department in HGH.

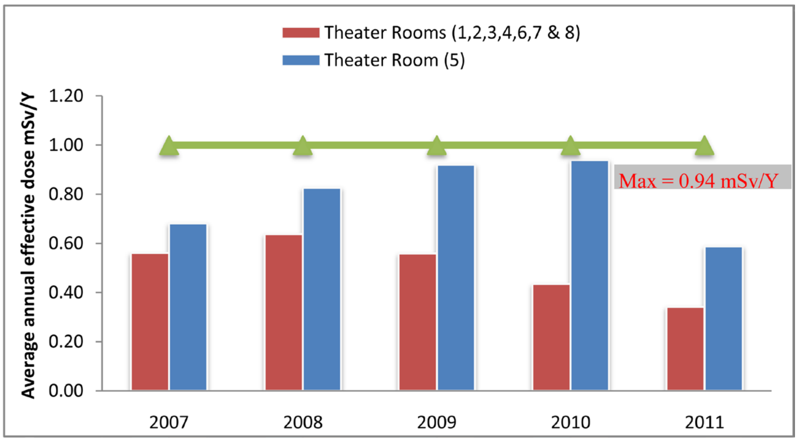

Figure 2. Annual E_{ff} dose values for HGH—Theater rooms periods compare with DL.

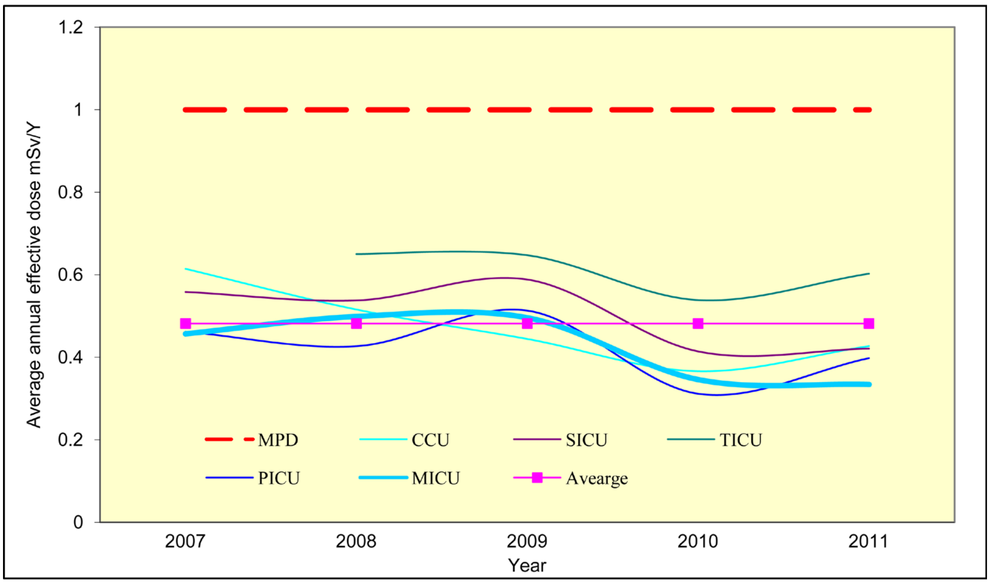

Figure 3. Values of the annual E_{ff} doses during the monitoring periods (Year/workplace) in HGH/Intensive care units, compare with DL.

TICU while remaining below the DL it is more than other applications of intensive care units' where these applications are similar in type of the radiological practice (conventional mobile x-ray) but varied in radiation workload, as required for the medical practice in each unit. The average of the annual E_{ff} dose for the intensive care units at HGH is less than the 50% of DL.

4.2. Rumailah Hospital (RH) Results

The workplace monitoring in RH was covered three applications (departments: dental, plastic surgery and Ear, nose & throat). As shown in **Figure 4** the significant decrease in the annual E_{ff} dose level for dental application starting in 2010 was due to the local instructions which was limited the x-ray use in clinics for special cases, and the rest cases (ordinary) are done in radiology section, where the protection conditions (construction) are better. For all applications at RH (dental, plastic surgery and Ear, nose & throat) maximum dose per monitoring years was less than the 50% of the DL for the public.

4.3. Al-Khor Hospital (AKH) Results

In surgical department the operations rooms and the day care unit, have been subjected to this study **Figure 5**.

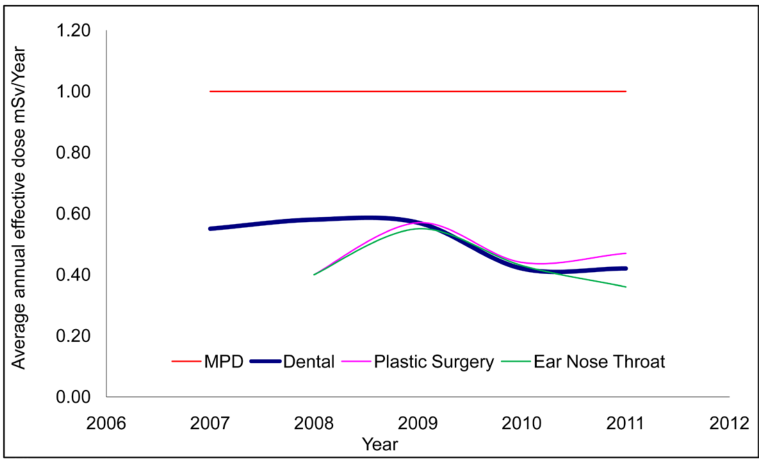

Figure 4. Values of the annual E_{ff} doses during the monitoring periods (Year/ workplace) in RH department, comparative with DL.

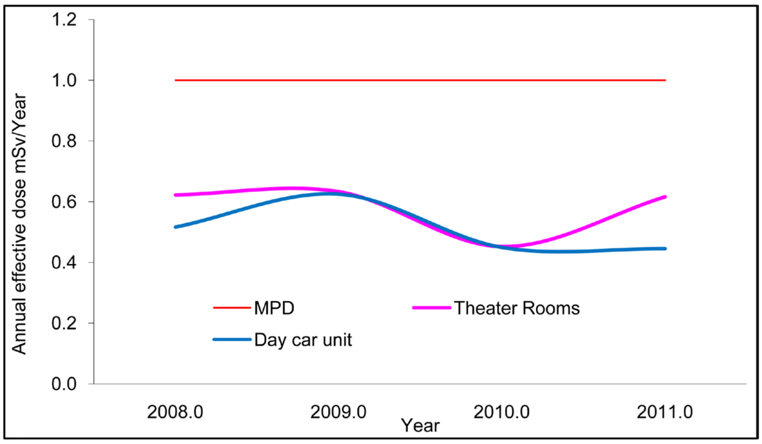

Figure 5. Values of the annual E_{ff} doses during the monitoring periods (Year/ workplace) in AKH compare with DL.

Annual E_{ff} Dose for day care unit is relatively less than operation rooms due to the lower radiation workload comparative to operation room's workload. In general at the NH (surgery department) the workspace monitoring proved that the annual E_{ff} dose (non radiation workers) is less than the DL for the public.

4.4. Paediatric Emergency Center

In some emergency cases there is a need to use the portable X-ray, which may expose medical staff and other patients to radiation doses, where the study shows

Figure 6 a slight increase at the level of annual dose (between 2010 & 2011) which reflecting the workload increase as a result to increase the number of population, as well as the study shows that the dose levels received by non-radiation workers and the general public during the years 2010 and 2011 is less than the allowable internationally and locally limit, as is clear from the graph, that the average of annual dose for the years 2010 and 2011, less than 50% of the annual limit allowed.

4.5. Al Amal Hospital

Aiming to evaluate the efficiency of the radiation safety requirements (especially the shielding Adequacy) for the non radiation workers at oncology centers, several monitors was installed in chosen locations outside the radiation treatment machine, Where the results **Figure 7** come to indicate that the exposure levels for non radiation workers are within the 50% of the permitted dose limits (general publics).

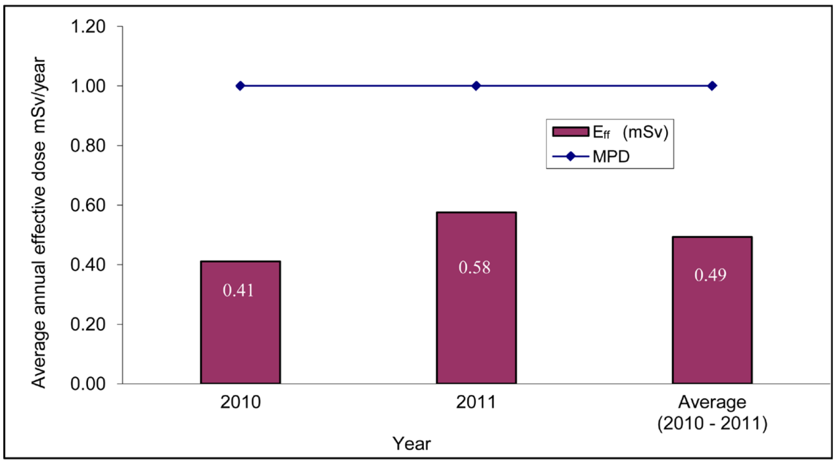

Figure 6. Values of the annual E_{ff} doses during the monitoring periods (Year/workplace) in PEC compare with DL.

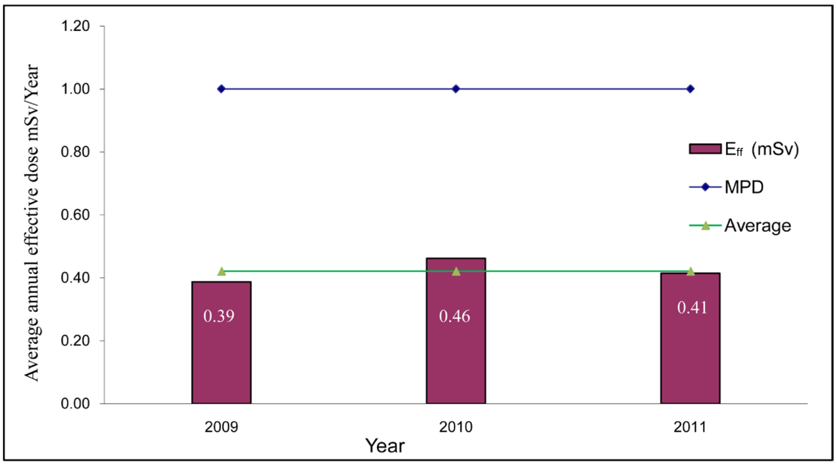

Figure 7. Values of the annual E_{ff} doses during the monitoring periods (Year/workplace) in AH, compare with DL.

4.6. Women Hospital

In NICU section (within the woman hospital), the medical staff (non radiation) needs to be direct in touch with the patient (sometimes or always) even during the x-ray exposures, The monitoring results in 2011 **Figure 8** have shown that the dose levels for this category of workers was less than 40% of the allowable limit.

4.7. Aspetar

The level of E_{ff} radiation dose resulting from the use of mobile X-ray equipment in operation rooms **Figure 9** confirms that the non radiation workers (in Operation Theater) didn't exposed to radiation doses exceeding 50% of the maximum Permissible dose for the public.

4.8. Comparing the Monitoring Results for the Similar Applications in Different Hospitals

First/Surgery applications (Operation Theater), the study involved **Figure 10** surgical departments at the following institutions:

Hamad general hospital (All surgical applications);
Rumailah Hospital (plastic surgery);
Al Khor Hospital (All surgical applications);

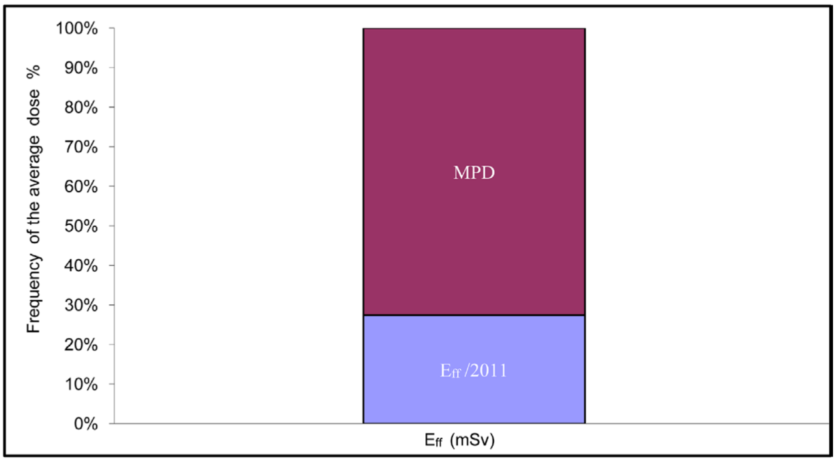

Figure 8. Values of the annual E_{ff} doses during the monitoring periods (Year/workplace) in WH, compare with DL.

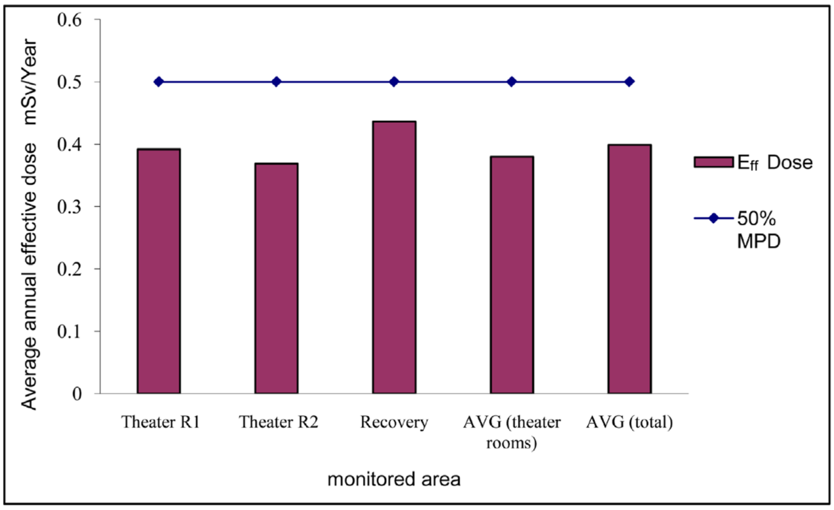

Figure 9. Values of the annual Eff doses during the monitoring periods (Year/workplace) in Aspetar (Surgery Department) compare with DL.

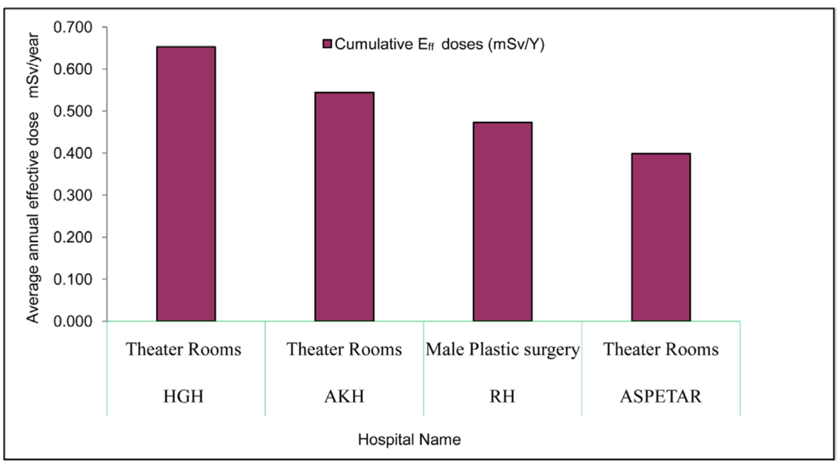

Figure 10. Compare the average annual E_{ff} dose levels for several surgery applications in different institutions.

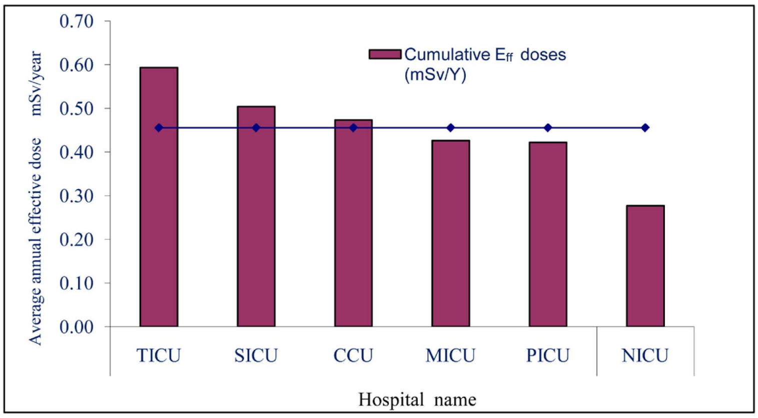

Figure 11. Comparing the average annual E_{ff} for portable X-ray users In different institutions.

Aspetar (Orthopaedic Surgery).

Dose levels of annual E_{ff} doses are well below the DL limit for all instetutions. On the other hand, the decreasing manner shows by the graph came as a result of the different in the workloads.

Second/departments using portapel X-ray, This involoved following user:

Hamad general hospital (CCU, SICU, TICU, PICU & MICU);

Women's Hospital (Neonatal Intensive Care Unit (NICU);

The graph shows the good practice in the WH/NICU, also as expected, the relatively high doses HGH (TICU, SICU), due to the presence of a large volume of work of radioactivity, While all results for all users are much lower than the permissible limits (The total-average dose is less than 50% of DL as shown in **Figure 11**. It is also illustrated that the average annual effective dose in NICU is the lowest compared with all the monitored workplace in all HMC which reflect that cumulative radiograph doses received in the ICU seem low with regard to environmental exposure and international recommendations which is 67% less than the public effective dose per year.

5. Conclusions

Based on the current findings, Annual accumulative Radiation Doses for all non radiation workers groups in different application in all institutions are well below public maximum permissible doses setup in the ICRP/IAEA safety standards.

Except for new applications, there is no need to continue monitoring procedures (area monitoring and personal monitoring for NRW) for applications which the monitoring results for three consecutive years proved to be less than the DL for the public.

As a essential tool, the Monitoring of the workplace can be used to realize the efficiency of the safety Requirements which was provided for the working environment

System of the workplace monitoring should consist of measurements and analysis of the doses levels to get safety assessment in order to control the hazards of the radiation exposure.

The level of protection of HMC staff is adequate and that the approved radiation safety programme efficient at both: facilities shielding and staff monitoring levels.

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