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Scattered radiation survey of various radiological X-Ray units

Balwinder Kumar Thapa
Assistant Professor, Department of Radiology & Imaging Technology, University School of Allied Health Sciences, Rayat Bahra University, Mohali, Punjab, India

Abstract
This study of scattered radiation is focusing on its implications for patient, ooccupational/Radiation worker and general public. Scattered radiation is a biological product of the interaction between primary X-rays and matter, if not properly controlled can poses potential health risks. This survey was conducted in a Radiodiagnosis department by using dosimeters strategically placed in various locations to record radiation doses [1].

Aim and opjective: The goal of this study was to measure X-Ray radiations from various radiological units installed in the department of Radiodiagnosis (X-ray) in a tertiary Health Care Centre in North India in order to ensure that the Patient, ooccupational/Radiation worker and general public are safe and protected and are getting minimum radiation dose during radiological examinations.

Hence this survey was mainly done to measure the scattered radiation dose from various Radiological X-Ray units both for Occupational/Radiation worker and Member of public [2]

Methods and materials: Tests were performed on monthly basis for a period of six months from January, 2023 to June, 2023 on 10 Radiological X-Ray units/machines installed in the department of Radiodiagnosis with the help of:

1. Dosimeter (FLUKE 451, VICTOREEN) for measuring the doses and
2. Water Phantom (General/costume made) of 10 litres in place of patient to get the exposure and measure the scatter radiation by dosimetry [3-4].

Result: The maximum scattered radiation dose for radiation worker recorded was 9.37mR/week. (23.42%) and the minimum scattered radiation dose recorded was 3.08mR/week. (7.70%). The maximum scattered radiation dose for Member of public recorded was 1.87mR/week. (93.50%) and the minimum scattered radiation dose recorded was 0.05mR/week. (2.50%) [5-7].

Conclusion: The entire measured scattered radiation doses for radiation worker and Member of public were found to be within the permissible dose limits.

Keywords: Scattered, radiation, survey, radiodiagnosis, department, worker and public

Introduction

In response to awareness programs held in the country and abroad about the radiation protection and various regulatory bodies like; The International Commission on Radiological Protection (ICRP), The National Council on Radiation Protection (NCRP), The Atomic Energy Regulatory Board (AERB) etc. are mainly working on radiation protection for patient, staff and member of public while performing radiological examination. The radiation survey done in the department was compared with the data of other places on the bases of literature related to radiation survey in other part of the country. The main purpose of this survey was to measure the scattered radiation of various Radiological units installed in the department of radiodiagnosis (x-ray).

Radiation has benefits along with accompanying associated risks with it. The radiation must be restricted and protected against by the application of radiation safety standards. The purpose was to ensure that the Radiation worker and Member of public were safe and protected and were getting minimum radiation dose during radiological examinations.

The various radiological units surveyed in the department of Radiodiagnosis (X-Ray) were found to be working under high operational load and some of them were working round the clock. The x-ray equipment's were selected for scattered radiation survey on the bases of wherever there were chances of high scattered radiation.

Scatter radiation is the kind of unwanted x -radiation during a radiographic exposure is largely due to Compton scattering of the primary beam when hit the object. The scattered photons are deflected at a random course, result into unnecessary exposure to the Occupational/Radiation worker and General public. The scattered radiation survey conducted in the department to access whether the "scattered radiation doses" of various X-Ray units installed in the department of radiodiagnosis were within the permissible dose limits or not as per the guidelines of "The Atomic Energy Regulatory Board (AERB)" in India [8-12].

Methods and materials

This survey was performed strictly following the guidelines of AERB in India. All tables, permissible dose limits and applied formulas for dose calculations are according to AERB guidelines. The X-Ray equipment's were selected for radiation survey on the basis of where there were chances of high dose of scattered radiation. X-Ray parameters; Current (mA), Applied Voltage (Kv), Exposure time (sec) and Workload (KW) were recorded and used for calculations.

Average readings of scattered radiation were taken for two levels:

a. Maximum radiation level/week (mR/week) for radiation worker.
b. Maximum radiation level/week (mR/week) for Member of Public.

As per AERB guidelines, exposures from different locations on water Phantom were taken (Figure-1) and corresponding reading were recorded on dosimetry. The maximum scattered radiation dose calculated and compared with the permissible dose limits recommended as per the (AERB) guidelines [3-4, 12-13].

Table 1: list of x-rays equipment

Sr no.	Type of equipment	Model name	Name of the manufacturer
1	Digital radiography (DR)	RADIOTAX	SHIMADZU
2	Digital radiography (DR)	DEFINIUM 8000	GE MEDICAL SYSTEM
3	Digital radiography (DR)	OPTIMAS-50KW	PHILIPS
4	Digital radiography (DR)	SONALVISION G-4	SHIMADZU
5	Digital radiography (DR)	RADIOTAX	SHIMADZU
6	Digital radiography (DR)	MARS-80	ALLENGERS
7	Digital radiography (DR)	SONALVISION G-4	SHIMADZU
8	Digital radiography (DR)	AERO DR	KONIKA
9	Digital radiography (DR)	RADIOTAX	SHIMADZU
10	Digital radiography (DR)	RADIOTAX	SHIMADZU

Scattered radiation survey

Table 2: The locations were:(6)

Sr. No.	The locations
1	Control console (Operator Position) ---S1
2	Behind Window----------S2
3	Side door near operating console-------S3
4	Outside patient entrance door----------S4
5	patient waiting area door----------S5

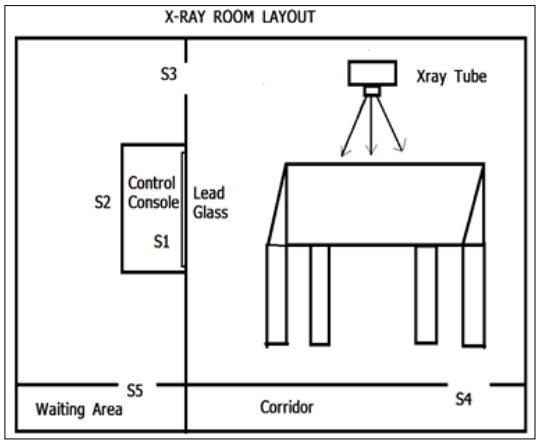

Fig 1

Table-2 & Figure.1-The readings were taken at the above mentioned '5' locations: At location S2 dosimeter kept behind the exposure window and at locations S1, S 3, S4, S5 dosimeter kept 1.0 meter away from the door. The 10 x-ray machines had different room layout plan and the locations were different for different machine. For example: Layout plain of Machine 1 and 2

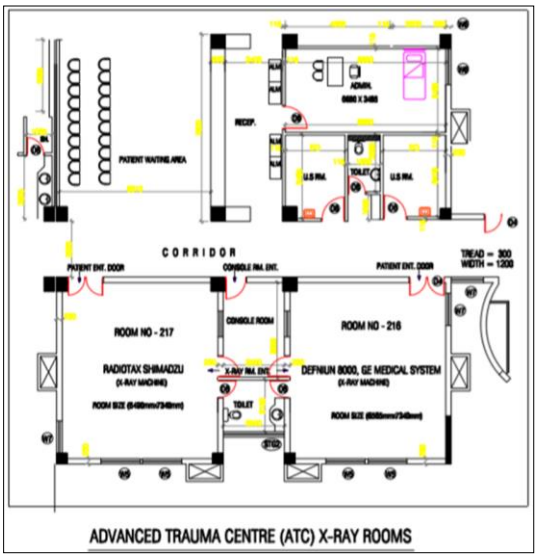

Fig 2: layout plan of Advanced Trauma Centre (ATC)

Operating parameters for 10 machines

Table 3: Operating parameters for 10 machines

Operating Parameters	Equipment Setting:	Applied Current (KV):	Applied Voltage (mA)	Exposure time(s)	Workload
For 1 to 4 machines	AP Position	100KV	250 mA	1Sec.	25KW
For 7-10 machines	AP Position	100KV	250 mA	1Sec.	25KW
For 5th machine	AP Position	100KV	125 mA	1Sec.	12.5KW
For 6th machine	AP Position	100KV	200 mA	1Sec.	200KW

The operating parameters were selected according to AERB guideline by putting more load on X-Ray tube of the machine as compare to usual operating load on X-Ray tube. On eight X-Ray units, the load on x-ray tube was 25KW and for other two was 20KW and 12.5KW respectively. The reason for putting the less load on 5th and 6th machine was according to their conditions [14].

During the survey; 6 Readings were taken from March, 2017 to August, 2017 for scattered radiation dose with the help of Dosimetry (FLUKE 451, VICTOREEN) on Water Phantom (General/ costumer made) of 10 litters litres in place of patient to get the exposure [3-4].

At the end of the survey, average readings of six months, at every location (S1 to S5) for all the 10 X-Ray unit/Machine were taken and readings from those location (S1 to S5) which recorded the maximum scattered radiation doses were used for calculations.

The scattered radiation doses were taken with dosimetry measured in Microsievert (µSv) which was converted into Milliroentgen (mR) with the help of radiation unit's conversion chart. For example: scattered radiation reading for radiation worker at "S1" (Control console) was 3.53 Microsievert (µSv) which is converted to 0.4025 Milliroentgen (mR) and for member of public at "S5" **(**patient waiting area door) was 0. 2219 Microsievert (µSv) which was converted to 0.0253 Milliroentgen (mR) [15].

The same radiation unit's conversion chart used for all other readings in all the x-ray machines during the whole survey and readings for scattered radiation doses mentioned in the table below: (table-4)

Table 4

Machine No.	Scatter radiation test				
	Maximum radiation level (mR/hr) of six months				
	i) Readings for radiation worker				ii) Readings for member of Public
	S1	S2	-4S3	S4	S5
1	0.4025	1.8130	2.1730	1.9950	0.0253
2	0.5060	1.6530	1.9040	1.8650	0.9008
3	1.0830	0.8970	1.6450	0.2705	0.1635
4	0.5750	1.4490	1.0580	1.551	0.0638
5	1.3340	1.6560	2.2540	0.4715	0.4140
6	0.6021	0.4370	1.1870	1.6050	0.4830
7	0.6325	1.4600	1.7830	0.9315	0.2645
8	0.4715	0.7820	1.4840	0.9549	0.4255
9	2.1510	1.8750	1.9320	0.9315	0.5290
10	1.4370	1.7370	2.1280	0.9440	0.6440

Shielding during radiation survey

The radiation protection action taken related to shielding that certain materials (concrete, lead) were placed between the source of radiation while the scattered radiation survey carried out. The wall of X-Ray room was made of high-density concrete blocks and lead glass window was present in front of the radiation worker during radiation exposure. Radiation worker kept himself behind the lead glass window during exposure.

Patient waiting room had a lead lined door with hydraulic mechanism to ensure that door was closed during exposure and X-Ray warning Lights displayed outside the door. And instructed the Member of Public to stayed behind the red line marked at the exposure door [16-17].

The formulas and tables used for calculation are taken from AERB guidelines and results compared with the permissible doses of AERB which are given below:

Scattered radiations formula

$$\text{Maximum Radiation level/week (mR/wk)} = \frac{\text{mAmin/week X --Max. Radiation level (mR/hr)}}{\text{60 X -----mA used for measurement}}$$

Permissible limit

For location of Radiatio Worker: 20 mSv in a year (40mR/week)

For Location of Member of Public: 1 mSv in a year (2mR/week) [18]

Results of machine-1

RADIOTAX SHIMADZU ROOM NO. 216 IN ATC:

The Maximum radiation dose for Radiation worker was at location S3=2.1730 mR/hr and Member of public at S5=0.0253

Work load 650 mAmin in one week (12). This 650mAmin work load in one week was same for all 10 X-Ray units.

Calculations of scattered radiation survey

i) Maximum Radiation level/week (mR/wk) for Radiation worker=650x2.1730=1412.45 =0.094mR/hr 60x250 15000
Maximum Radiation level/week (mR/wk) =Hour x days x mR/week =8x6x0.094=4.51mR/week
This is below the permissible limit: 20 mSv in a year (40 mR/week)=4.51mR/week
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ii) Maximum Radiation level/week (mR/wk) for Member of public=650x0.0253 =16.44 =0.001mR/hr 60x250 15000
Maximum Radiation level/week (mR/wk)=Hour x days x mR/week =8x6x0.001= 0.05mR/week
This is below the permissible limit: 1 mSv in a year (2mR/week) =0.05 mR/week

Sr. No.	Result	
1	Maximum Radiation level/week (mR/week) for Radiation worker	4.51
2	Maximum Radiation level/week (mR/week) for Member of public	0.05

In the same way by using the above formula and calculations, the results of other 9 X-ray machine were calculated and compared the results;

Result of 10 machines

Table 5: Result of 10 machines showing for Maximum Radiation level/week (mR/wk) for radiation worker and Member of public

Machine No	Generator power (KW) applied	Maximum Radiation level/week (mR/wk) for Radiation worker	Maximum Radiation level/week (mR/wk) for Member of public
1	25KW	4.51mR/wk	0.05 mR/wk
2	25KW	3.96mR/wk	1.87 mR/wk
3	25KW	3.42mR/wk	0.34 mR/wk
4	25KW	3.22mR/wk	0.13mR/wk
5	12.5KW	9.37mR/wk	1.72mR/wk
6	20KW	4.17 mR/wk	1.25 mR/wk
7	25KW	3.70 mR/wk	0.55mR/wk
8	25KW	3.08 mR/wk	0.88 mR/wk
9	25KW	4.47 mR/wk	1.10 mR/wk
10	25KW	4.42vmR/wk	1.33 mR/wk

Summary and comparision charts

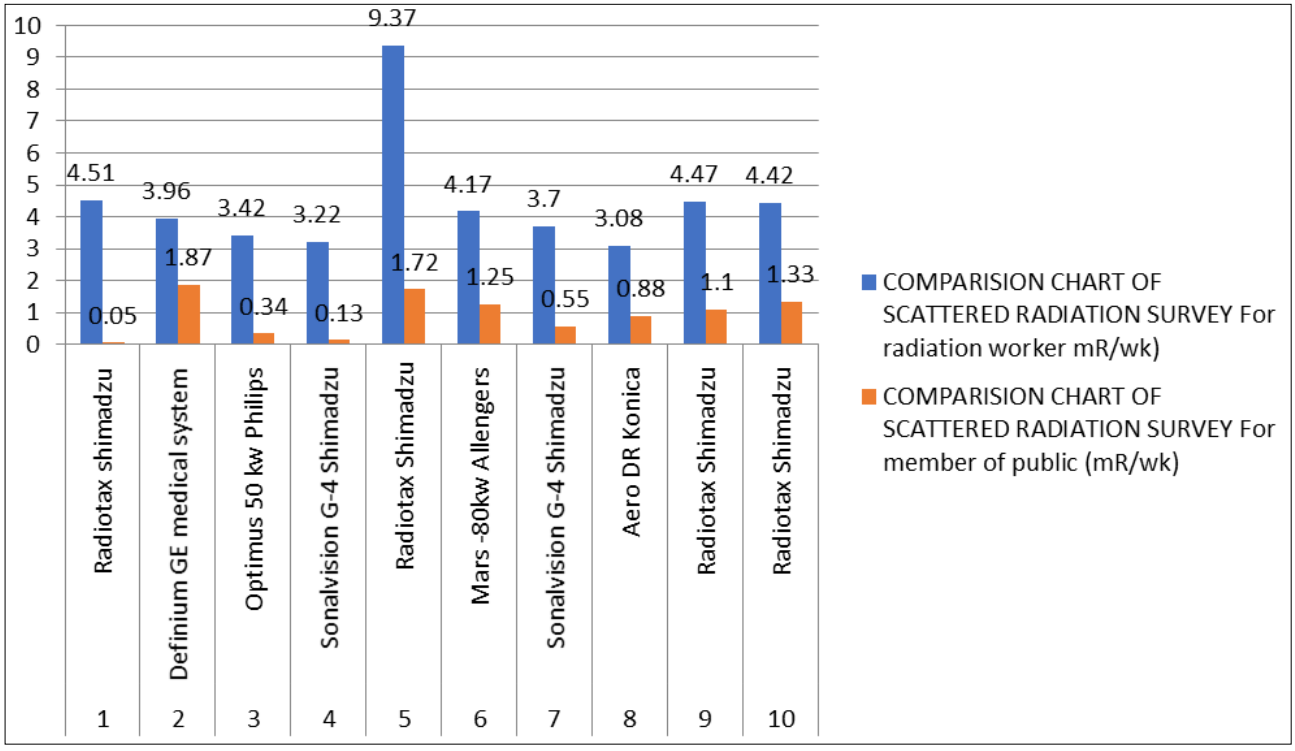

Fig 3: Comparison chart of scattered radiation survey for radiation worker and member of public [19]

Results

Result of scattered radiation survey by the column chart

From the above column chart: the numerical values of scattered radiation doses for radiation worker determined from the first X-Ray machine was 4.51mR/week, then it was gradually decreased up to the machine no. 4 i.e. 3.22mR/week and then it was sharply inclined to the highest from (RADIOTAX SHIMADZU), the 5th no. X-Ray unit i.e. 9.37mR/week. After that it was sharply declined to the lowest i.e. 3.08mR/week from (AREO DR KONIKA), the 8th no. X-Ray unit.

Whereas, the scattered radiation dose for member of public the radiation exposure was recorded lowest i.e. 0.05mR/week from (RADIOTAX SHIMADZU), the 1^{2st} X-Ray unit and then it was sharply inclined to the highest from DEFINIUM 8000 GE MEDICAL SYSTEM the 2nd X-Ray unit i.e. 1.87mR/week. After that it was sharply declined from machine-3 i.e.0.13mR/week with ups and downs by keeping average values at the 10th X-Ray unit i.e.1.33mR/week [20].

Discussion

During this study it has been found that the maximum scattered radiation exposure for Radiation Worker was recorded 9.37mR/week (23.42%), from (RADIOTAX SHIMADZU), the 5th no. X-Ray unit and the minimum scattered radiation exposure was recorded 3.08mR/week (7.70**%)**, from (AREO DR KONIKA), the 8th no. X-Ray unit. The numerical values and percentage of the other X-Ray units lies between 9.37mR/week and 3.08mR/week (23.42% and 7.70%). All were less than the permissible dose limits for Radiation Worker: that was 20 mSv in a year (40 mR/week) AERB recommendation.

On the other hand, during survey the scattered radiation exposure for Member of public from all 10 radiological units, the maximum scattered radiation exposure was recorded 1.87mR/week (93.50%) from DEFINIUM 8000 GE MEDICAL SYSTEM the 2nd X-Ray unit and the minimum scattered radiation exposure was recorded 0.05mR/week (2.50%), from (RADIOTAX SHIMADZU), the 1st X-Ray unit [21].

The numerical values and percentage of the other X-Ray units lies between 1.87mR/week and 0.05mR/week (93.50% and 2.50%). These were less than the permissible dose limits for Member of Public: that is 1 mSv in a year (2mR/week) as per AERB recommendation.

Conclusion

It has been found during the scattered radiation survey that the all the above 10 X-Ray units have been performing within the permissible dose limits as per AERB guidelines [22].

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