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Minimization of Risks from Occupationally Exposure to Radiation

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Abstract—*World has been developing through studying, quantification and application of physical phenomena which enhances life standard through invention of facilities such as power production, medical examination and therapy, mineral exploration, agricultural improvement, manufacturing consumer products, transportation and communication etc. by different professions among which some are unavoidably have to do with ionizing radiation or have to stay within its vicinity. The radiation may be naturally occurring or from man-made. The workers in such establishments unless if appropriate measures are taken are at higher risks due to the biological effects caused by the radiation than the general individuals. A practical radiography survey in Sharda Hospital radiology department, at 300mAs room, Siemens machine using dosimeter shows that a radiographer for morning session, for seven days may expose to radiation of 0.01085mR/week.*

This paper mentioned the radiation dose limits for different parts of the body for the occupational exposure. It also gives the applicable and effective concepts by which safety to occupationally radiation exposure might be maximized.

1. INTRODUCTION

Occupational exposure to radiation is the exposure of the people whose occupational work involves either the use of radioactive materials or stay repeatedly in naturally or artificially produced radiation.

1.1 Example of Occupationally Exposed People

This include the workers at

i- Nuclear power plants
ii- Mining and mineral processing industries
iii- Building/construction materials and paint producing companies
iv- Research laboratories
v- Nuclear medicine departments
vi- Radiognosis and radiotherapy departments
vii- Pilots and air crews
viii- Astronauts
ix- Food Irradiation Company
x- Isotopes production company

1.2 Examples of radiations exposed to are;

i- Gamma rays (in form of electromagnetic wave)
ii- X-ray (in form of electromagnetic wave)
iii- Beta radiation (in form of energetic electron)
iv- Proton (sub atomic particle)
v- Positron (an anti-electron)
vi- Neutron (sub atomic particle from radioactive materials)
vii- Alpha particle (nucleus of Helium atom)

1.3 The sources of the radiations are

i- Cosmic radiation which enters into earth from deep space at very high rate.
ii- Radioactive nuclei like Uranium-238, Thorium-232 present in Earth Crust and rocks and the clinically produced like Iodine-131, Carbon-11, Cobalt-60.
iii- X-ray production machines, among others.

2. EFFECTS OF IONIZING RADIATION

Interaction of radiation with human body causes excitation and ionization of the atoms in the body cells. The excitation do not cause a worrisome effect, however ionization causes effects whose resultant damage may take long time to show up as in the case of chronic exposure (low doses for long time) which consequently causes long time effect (**Stochastic Effects**). It usually involves occupational workers and people staying within the proximity of naturally occurring radiation in rocks, uranium reach lands etc or an immediate show up as the case is with the acute exposure (high dose/energy for a short time) which may involve the general individuals.

When ionizing radiation interacted with cellular components such as DNA, chromosomes, nucleus, etc, which are vital to the survival and full function of the cell it results in its inability to reproduce or produce abnormal cells or cells which will die shortly (**carcinoma**). This is called direct effect. On the other hand radiolysis of water which is the major component of the cell may take place resulting in fragmentation of the water molecules into radical ions (HYDRONIUM IONS) which may combine with themselves or with other substances to form toxic substances such as hydrogen peroxide (H_2O_2). This is called indirect effect.

$H_2O \rightarrow H_2O^{\cdot +} + e^-$

$H_2O^{\cdot +} + \rightarrow H^+ + HO^{\cdot}$

$HO^{\cdot} + HO^{\cdot} \rightarrow H_2O_2$

2.1 Low radiation dose

It categorically has 3 types of effects;

2.1.1 Genetic effect. The radiation causes mutation and chromosomal aberration (changing the genetic information) of the reproductive cells, like sperm and egg cells due to the damaged DNA structure. This effect is suffered by the offspring of the exposed person who may be unhealthy or sterile.

2.1.2 Somatic Effect. The radiation depending on its amount and the exposure time causes variety of damages such as cancer in the affected tissue/organ due to the damaged cells.

2.1.3 In Utero Effect. The radiation affects the developing fetus of a pregnant woman.

2.2 High radiation dose

It tends to kill many cells that the whole tissues or organ may damage. This results in what is called Acute Radiation Syndrome (ARS). The symptoms showing ARS include drop in white blood cells count for semi clinical range of exposure (25-50Rem), vomiting, nausea, fatigue, loss of appetite and redness of skin for Therapeutic range (100-200Rem), more severe nausea and vomiting, internal haemorrhaging, hair loss for Lethal range (above 200Rem). Small percentage will die within 30 days for exposure to high dose up to 600Rem and higher percentage for more than 600Rem, while for exposure to more than 1000Rem results in definite death of the victim.

Other high dose effects are cataract (cloudiness on an eye), erythema, acute ulceration (peeling of outer skin cells), dermal atrophy (thinning of skin tissue), dry desquamation (hardening of skin), moist desquamation (loss of skin) etc.

3. EFFECTIVE MEASURES TO MINIMIZE OCCUPATIONAL RADIATION DOSE

International Commission on Radiological Protection (ICRP)-Recommendations (2007) has set effective dose limits for occupationally exposed people as 100mSv (10Rem) in5 consecutive years, not exceeding 50mSv (5Rem) in a single year, for skin, hands and feet 500mSv (50Rem) for a single year and for eye lens 150mSv (15Rem). These regulatory limits are same for men and women except pregnant women. Once pregnancy is declared equivalent dose limit for the surface of her abdomen shall not exceed 2mSv (0.2Rem) for the remainder of the pregnancy in order to protect the fetus, and intake of radionuclide materials shall be limited to 1/20 of ALI (Annual Limit Intake; 1 ALI=5Rem).

The major factor responsible for protecting workers from reaching the above limits is the proper adjustment and following radiation protection rules on three things; time, distance and shielding (TDS Rule) or (cardinal rule).

3.1 Time

The less the time worker spends in exposure to ionizing radiation the less his total dose.

$$\text{Dose} = \text{dose rate} \times \text{time}$$

3.2 Distance

Even a very short distance from the source of radiation matters in reducing the radiation dose. The dose rate is related to the distance of a worker from the source by inverse square law;

$$\text{Dose } \alpha \ \frac{1}{r2}$$

Where;

r; the distance from the source

3.3 Shielding

Is the physical barrier placed around or wore against the radiation source to reduce the exposure to a safer level. Charged particles are absorbed due to columbic interactions with the electrons or nucleus of the shielding material while neutrons are stopped due to elastic and inelastic collisions. Some component of the radiation will be scattered and some component will be transmitted.

The effectiveness of the shielding is related to some factors;

3.3.1 Atomic Number. Elements with high atomic number (like lead, Iron, Tin etc) are best for more energetic radiations like gamma-rays while low-atomic-number elements are sufficient for neutrons.

3.3.2 Thickness. The more the thickness of the shielding the more it absorbs the radiation (attenuation), thus the less the intensity of the transmitted radiation.

3.3.3 Area. The cross sectional area for absorption and scattering for shadowing shielding reduces the amount of radiation transmitted to the protected region. Unlike closed shield which surrounds the source.

3.3.4 Distance from the Source. This helps due to the geometric divergence of the radiation; the closer the shadowing shielding to the radiation source the more the area it covers.

In order to maximize the protection i.e to minimize the radiation dose for occupational workers, the policy of ALARA (As Low as Reasonably Achievable) has to be adopted. This principle does not only helps not to exceed the regulatory limits, but also to keep the statistical probability of cancer (stochastic effects) far less than the permitted dose levels and to eliminate the deterministic effect like skin reddening or cataracts. This policy is based on the principle that no matter how small radiation exposure is, it increases the chances of biological effects such as cancer and the chances of the effects increases with the cumulative lifetime dose. These ideas combined together to form Linear No-Threshold model.

The principles that helps achieved that are;

i- **Justification**; Any use of ionizing radiation must be avoided unless if the dose produces sufficient benefit that can justify the risk.
ii- **Limitation**; Any individual must be held within the general public dose limits.
iii- **Optimization**; The radiation doses from any particular source of radiation must be kept as low as reasonably achievable.

Occupationally exposed person should also employ personal protection materials such as lead apron, hand gloves, protection glass, dose assessment dosimeter etc.

4. METHODOLOGY

The experiment to determine the weekly radiation dose from which the approximate annual dose may be calculated for a worker who attends the radiation unit only on morning duty (9:00-12:00am), stays a distance away from the x-ray tube and stays behind a shielding during radiography was conducted at Sharda Hospital Radiology Unit, at 300mA x-ray room, using Siemens machine. The x-ray machine control unit was placed behind a shielding made from lead has a height 187 cm and width 120 cm place at a distance 260 cm from the x-ray tube. The kVp used is in the range (55-81), using low exposure time (0.10-0.60s). We noted down the mAs used for different parts of the examination body for 31 patients from 9:00am to 12:00am (half day). We used the data to calculate the weekly Work Load in form of grand total mAs/week which we converted to mA-min/week. We used handheld survey meter (dosimeter) to detect the radiation dose rate in micro Sievert per hour at various locations the radiographer deals with; at chest stand position when the radiographer was making the patient to stand upright for posterior to anterior (PA) radiography, at control panel behind the shielding material during the x-ray exposure, at the x-ray tube as the radiographer adjust it for next radiography, at the door where the radiographer exit, and at the wall where the radiographer stands before the next patient enters. The experiment was repeated for two more days, the average values were calculated. The dose rates measured in micro Sievert per hour were converted to milliRem per hour. The total dose rate in milliRem per hour was calculated and used in the formular for the determination of weekly dose.

The formular we used was;

Weekly dose= $\frac{weekly\ \ dose\ \ rate\ \ (mR/h)\times work\ \ load\ (mA-\min/\text{week})}{mA\ \times 60min\ \times 1\ week}$

5. RESULTS

Table 1: Weekly work load

Examination part	No of experiment per day	Average mAs/experiment	No of days/week	Total mAs/week
Abdominal	2	60	7	840
Cervical	1	26	7	182
Chest	25	19	7	3325
Elbow	1	38	7	266
Shoulder	2	19	7	266
Total mAs/week				4879

Table 1. Displaying the values of mAs used for different body parts

Table 2: The dose rates for various locations

Location	Dose rate (mSv/h)	Dose rate (mRem)
Control Panel	1.7	0.17
X-ray tube	0.97	0.097
Door	0.46	0.046
Wall	0.6	0.060
chest stand	0.65	0.065
total dose rate	4.38	0.438

Table 2. The table displaying the dose rates for various locations in the x-ray room and their total

6. CALCULATIONS

6.1 Total weekly mA-min $=\frac{\mathbf{4879}}{\mathbf{60}}$ = 81.32mA-min/week

6.2 Weekly dose=$\frac{\mathbf{0.438\times81.32}}{\mathbf{50\times60\times1}}$ =0.01187mR/week

6.3 Annual dose=0.01187$\times$ **52** =0.6174mR/annum

7. DISCUSSION

Due to the application of the previously mentioned principles for radiation dose minimization; lead shielding at the control panel, distance away from the x-ray tube during the radiography (2.6m from the x-ray tube) and non stay within the x-ray room except when on duty (9:00-12:00am) only, the weekly radiation dose was found to be very far less than the regulatory limit. Comparing the annual dose limit **10Rem i.e. 10,000mRem for 5 years** with the annual dose obtained **0.6174mR/year** or **0.6174×5= 3.087mR for five years**. by taken a year with 52 weeks, if the radiographer works all the days of a whole year, his occupationally absorbed dose is approximately 0.0**31%** of the occupational dose limit. This shows a great achievement of minimizing occupational dose limit which agrees with the policy of ALARA.

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