Mathematical calculation of skin and soft- tissues radiation absorbed dose from Na^{22} ,Ba^{133} and Cd^{109} radiation source for persons working in nuclear research room.

الحساب الرياضي لجرعة الأشعة الممتصة للجلد والأنسجة الرخوة من المصادر المشعة Na^{22} , Ba^{133} و Cd^{109} للأشخاص الذي يعملون في البحوث النووية

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Abstract

Assessment of radiation absorbed dose in radiation contaminated area are of greater value in radiation protection field. In this project three radioactive source involved Na^{22} , Ba^{133} and Cd^{109} whose main emission are gamma ray. Calculation were done to compute the radiation absorbed dose by skin and soft-tissues using mathematical equation .The main parameters of this project are the distance from the radioactive source , activity and type of radiation sources. The results showed that the amount radiation absorbed dose at time considered didn't produce significant effect since it not reach 2 Gy where the highest values of skin dose was (0.001137187, 0.000285321and 0.000175802 mGy) for Na^{22}, Ba^{133} and Cd^{109} respectively and for soft-tissues was(0.001144353,0.00028630 and 0.000187827 mGy) for Na^{22},Ba^{133} and Cd^{109} respectively .

الخلاصــة

تقييم الجرعة الإشعاعية الممتصة في منطقة ملوثة بالإشعاع له أهمية كبيرة في حقل الوقاية من الإشعاع.في هذا البحث تم تضمين ثلاث عناصر مشعة وهي Na^{22} , Ba^{133} و Cd^{109} والتي تبعث أشعة كاما .عمليات حسابية تم إجراءها لحساب الجرعة الإشعاعية الممتصة من قبل الجلد والأنسجة الرخوة باستخدام معادلات رياضية.المعلمات الرئيسية الداخلة في البحث هي المسافة من المصدر المشع , فعالية و ونوعية المصدر المشع. أوضحت النتائج إن كمية الجرعة الإشعاعية الممتصة في الوقت الداخل في الاعتبار لم ينتج تأثير واضح لأنه لم يتجاوز او يصل الى 2mGy في حين اعلى مقدار تم الوصول له من الجرعة الممتصة بالجلد هو(0.001137187, 0.000285321and 0.000175802 mGy) للعناصر Na^{22} , Ba^{133} و Cd^{109}على التوالي وللأنسجة الرخوة(0.001144353,0.00028630 (0.000187827 mGy) للعناصر Na^{22} , Ba^{133} و Cd^{109} على التوالي.

Introduction

Radiation safety practice is a special aspect of the control of environmental hazards by engineering means. Radiation safety practice is divided between two principal categories: the safe use of sources of external radiation and prevention of personal contamination resulting from inhaled, ingested, or tactilely transmitted radioactivity[1].

In real life, radiation can affect human health. However, these effects are not always clear. At high doses, radiation can cause skin burns, make people vomit, and even cause death. At doses that are lower, although still much higher than most humans are normally exposed to, radiation can cause cancer. At those lower doses that people receive from nature and from medical radiation, it is not exactly certain how radiation affects human health, if it has any effects at all. But scientists do have a lot of information on these questions[2].

Radiation dosimetry is the branch of science that attempts to quantitatively relate specific measurements made in a radiation field to physical, chemical, and/or biological changes that the radiation would produce in a target. Dosimetry is essential for quantifying the incidence of various biological changes as a function of the amount of radiation received (dose–effect relationships). When radiation interacts with a target it produces excited and ionized atoms and molecules as well as large numbers of secondary electrons. The secondary electrons can produce additional ionizations and excitations until, finally, the energies of allelectrons fall below the threshold necessary for exciting the medium.[3].

The goal of any radiation safety program is to reduce exposure, whether internal or external, to a minimum. The external exposure reduction and control measures available are of primary importance.In order to be able to protect people from ionizing radiation ,it is to be obviously necessary to measure the radiation to which they may be exposed , and so quantity Exposure.[4].

Exposure is the third of the important fundamental nonstochastic quantities with which we are concerned in radiological physics , Exposure is symbolized by X, and is defined by the ICRU (1980) as "the quotient of dQ by dm, where the value of dQ is the absolute value of the total charge of the ions of one sign produced in air when all the electrons (negatrons and positrons) liberated by photons in air of mass *dm* are completely stopped in air. " Thus

$$\mathbf{X= dQ/dm}$$

The exposure rate at a point **p** and time **t** is

$$\dot{\mathbf{X}} = \mathbf{dx/dt} \qquad [5].$$

Also the exposure X is defined only for photons and measures the energy fluence of the photon beam. It is the amount of ionization (total charge of one sign) produced per unit mass of dry air when all of the electrons and positrons liberated in a small mass of air are completely stopped in air, the units are coulomb per kilogram. Since the average amount of energy required to produce an ion pair is well defined, exposure is closely related to collision kerma in air.[6]

The most fundamental definition of the quantity absorbed dose is given in ICRU 60.1 According to ICRU 60, the absorbed dose D is defined by:

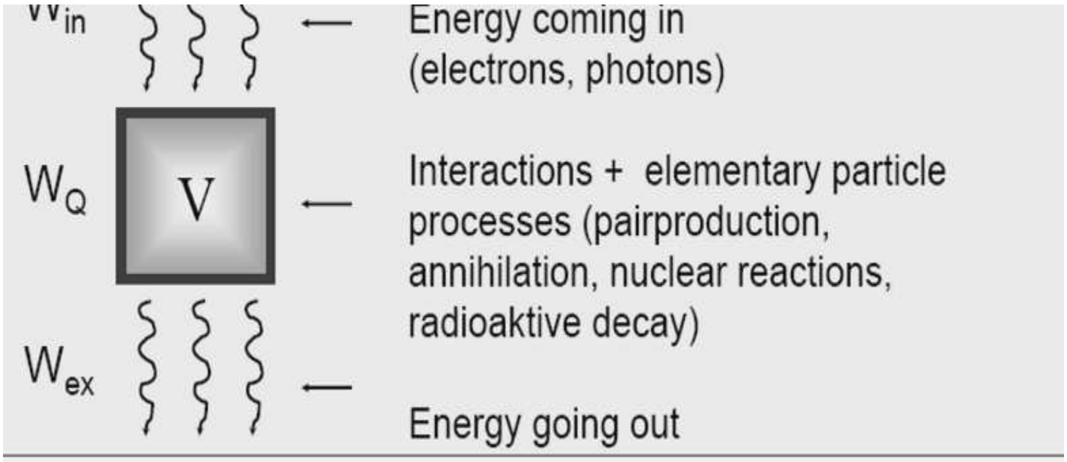
$$\mathbf{D = d\varepsilon/dm}$$

where:

dε is the mean energy imparted to matter of mass

dm is a small (infinitesimal) element of mass

The unit of absorbed dose is joule per kilogram (J/kg), the special name for this unit is gray [Gy] where the old unit of dose is the rad where 1 rad = 0.01 J/kg (Gy) = 100 erg /g .The term "energy imparted" as used in the definition above is the radiation energy absorbed in a volume V. Therefore, the term "absorbed dose" refers to an exactly defined volume and only to the volume V. Furthermore, the term "absorbed dose" refers to the material contained in this volume[7] .



Fig(1)Absorbed dose being the energy imparted to matter within a volume V.

Three main factors determine the radiation-induced damage that might be caused to living tissue, the number of radioactive nuclei that are present, the rate at which they give off energy, and the effectiveness of energy transfer to the host medium, i.e., how the radiation interacts with the tissue.[8]

Aim of project :

To calculate skin and soft tissues radiation absorbed dose for the persons who are working in the nuclear research room. and to study the effects of the distance from radioactive sources, exposure time and activity of radioactive source on skin and soft tissues radiation absorbed dose in absence of proper dosimeters .

Method of calculation:

*Three radioactive sources were used in this study are (Na^{22}) which emits gamma ray photons of(1.274 MeV)with the activity of(1 μCi) and (Ba^{133}) which emits photon (0.3633 MeV) with activity of(1 μCi) and Cd^{109} which emits photon(0.003179 MeV). The three sources that which used in this study of disk shape of 2 cm diameter and 1 cm thickness.

* The radiation Exposure can be obtained using equation(1):[9]

$$\dot{X} = \Gamma \frac{A}{D^2} \text{.................}(1)$$

where :

: Exposure rate(R/h) . $\dot{X}$

Γ : Specific gamma ray constant (**Γ** for Cs^{-137} =0.333 R. m^2/ h. Ci ;

Γ for Na^{22} =$1.188*10^{+1}$ R.cm^2/ h. mCi.

Γ for Ba^{133} = 2.981 R.cm^2/ h. mCi

Γ for Cd^{109} = 1.59 R.cm^2/ h. mCi

A : Activity of the radioactive source .

D : The distance from the radioactive source(cm).):[9]

* The radiation dose in air can be obtained using the following conversion factor(2)[10]

1 Roentgen = 8.7 mGy……(2)

[Exposure (J/kg) = 2.58 C 10–4 C/kg C 33.97 J/C = 8.764 C 10–3 J/kg R].

* Absorbed dose can be calculated in different material by using the equation (3)

$$D_{Mediuem} = D_{Air} \frac{\mu_m(Medium)}{\mu_m(Air)} \text{.............}(3)$$

where : μ_m: the mass absorption coefficient which is equal:

$$\mu_m = \frac{\mu}{\rho} \text{................}(4)$$

μ**:** the linear absorbed coefficient , ρ**:** density of material.[11]

Results

*The exposure rate(R/h) and dose rate(mGy/h) was calculated to air relative to the
*the exposure rate and dose rate plotted in figure (1) and (2) for comparison purposes for three radioactive sources relative to the distance(cm)
*The dose rate was calculated for skin and soft tissues of the person for three radioactive sources as shown in table(2).
*The does rate for skin and soft tissues plotted relative to the distance from radioactive sources for comparison purposes as shown in figure(3) and (4).

Table(1):

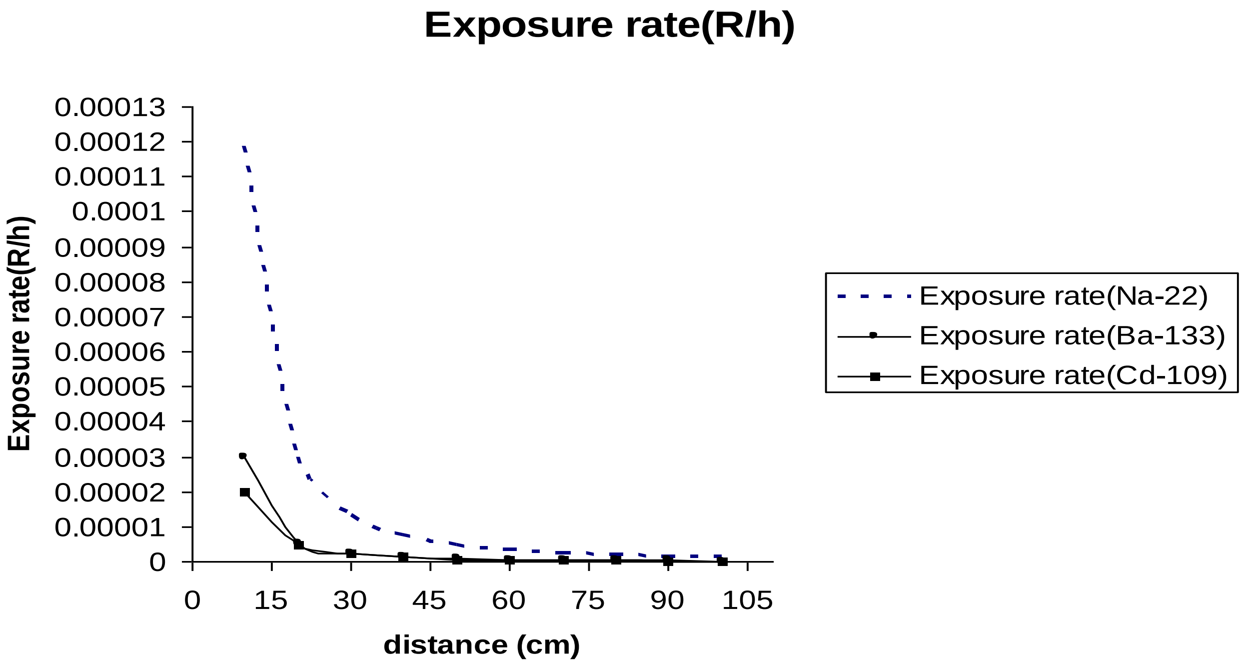
The values of exposure rate and dose rate calculated for air relative to distance from the radioactive sources(Na^{22},Ba^{133} and Cd^{109} respectively).

The Radioactive Source	Distance (cm)	Exposure Rate (Roentgen/h)	Dose rate in air(mGy/h)
Na^{22}	10	0.000118800	0.001033500
	20	0.000029700	0.000258390
	30	0.000013200	0.000114840
	40	0.000007425	0.000064597
	50	0.000004752	0.000041342
	60	0.000003300	0.000028710
	70	0.000002424	0.000021088
	80	0.000001856	0.000016147
	90	0.000001466	0.000012754
	100	0.000001188	0.000010335
Ba^{133}	10	0.00002981000	0.000259347
	20	0.000005002175	0.000043517
	30	0.000002222365	0.000019331
	40	0.000001249617	0.000010866
	50	0.000000799458	0.000006951
	60	0.0000005549737	0.000004819
	70	0.0000004075846	0.000003540
	80	0.0000003119413	0.000002705
	90	0.0000002463808	0.000002140
	100	0.0000001994945	0.000001731
Cd^{109}	10	0.00001966931	0.00017112
	20	0.000004889585	0.000042534
	30	0.000002160889	0.000018792
	40	0.000001208644	0.000010509
	50	0.000007691692	0.00000669
	60	0.0000005311328	0.000004619
	70	0.0000003880195	0.000003375
	80	0.0000002954023	0.000002566
	90	0.0000002320883	0.000002018
	100	0.0000001869316	0.000001618

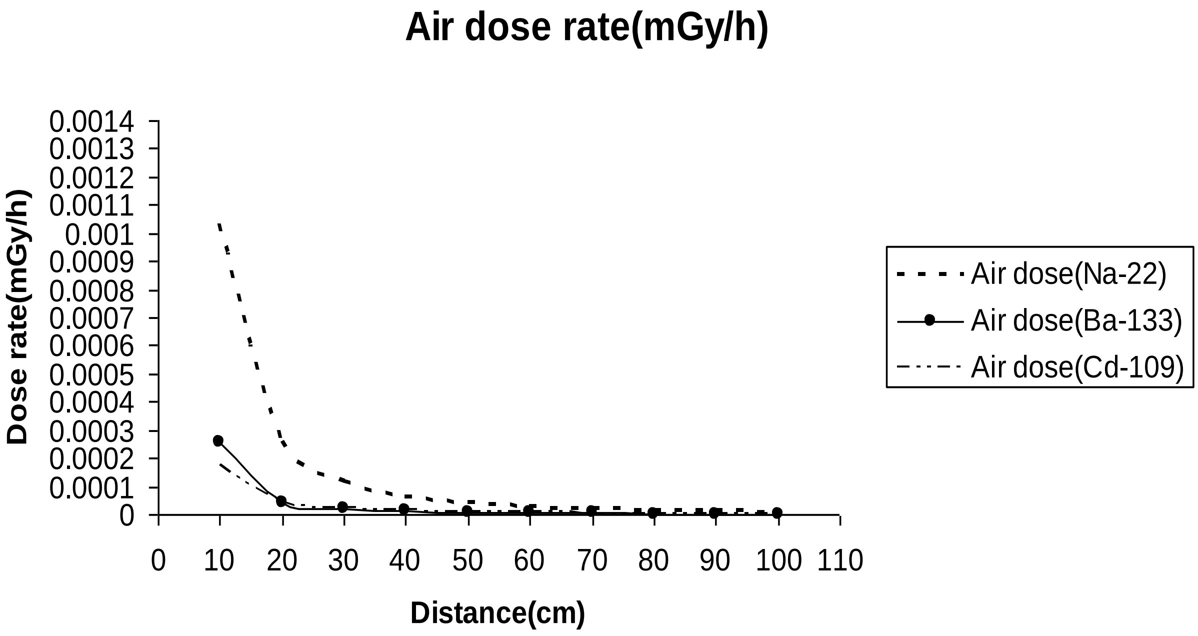
Table(2)

The values of exposure rate and dose rate calculated for air relative to distance from the radioactive sources(Na^{22},Ba^{133} and Cd^{109} respectively).

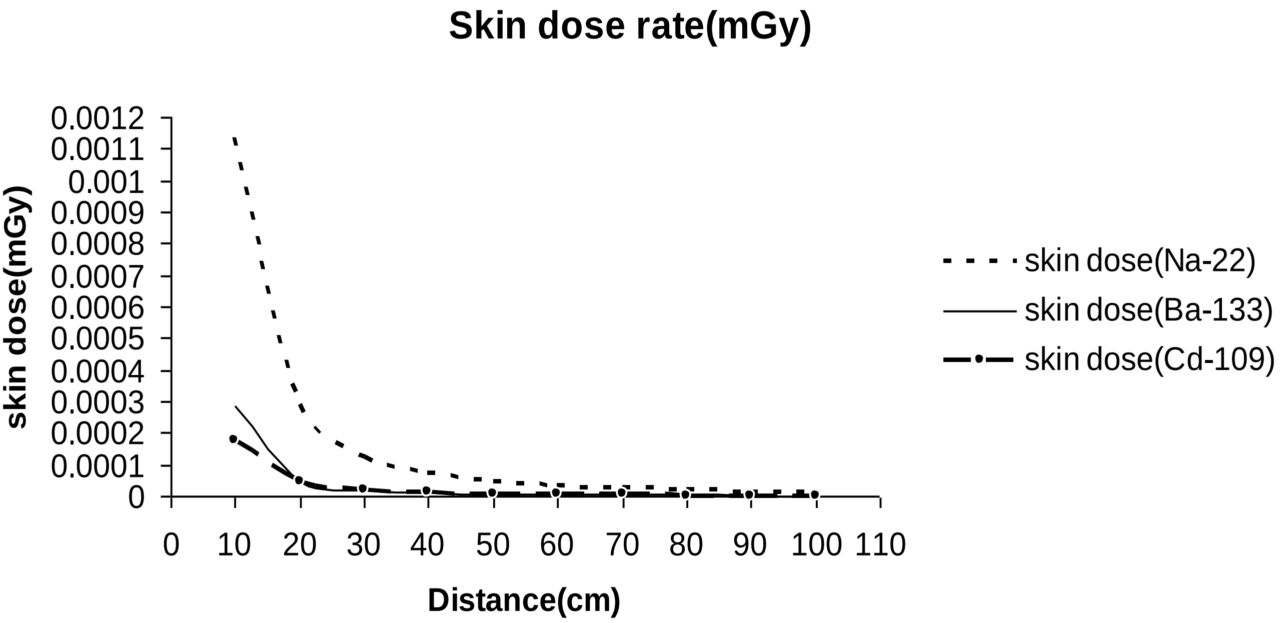
The Radioactive Source	Distance (cm)	Skin dose (mGy/h)	Soft tissue dose (mGy/h)
Na^{22}	10	0.001137187	0.001144353
	20	0.000284296	0.000286088
	30	0.000126354	0.00012715
	40	0.000071073	0.000071521
	50	0.000045487	0.000045773
	60	0.000031588	0.000031787
	70	0.000023202	0.000023348
	80	0.000017769	0.000017877
	90	0.000014032	0.000014121
	100	0.000011371	0.000011442
Ba^{133}	10	0.000285321	0.000286301
	20	0.000047875	0.000048039
	30	0.000021268	0.00002134
	40	0.000011954	0.000011995
	50	0.000007647	0.0000076673
	60	0.000005398	0.000005301
	70	0.000003905	0.000003907
	80	0.000003976	0.000002986
	90	0.000002354	0.000002362
	100	0.000001904	0.00000191
Cd^{109}	10	0.000175802	0.000187827
	20	0.000043697	0.000046686
	30	0.000019306	0.000020626
	40	0.000010796	0.000011535
	50	0.000006873	0.000007343
	60	0.000004745	0.000005069
	70	0.000003467	0.000003704
	80	0.000002636	0.000002816
	90	0.000002073	0.000002215
	100	0.000001662	0.000001775



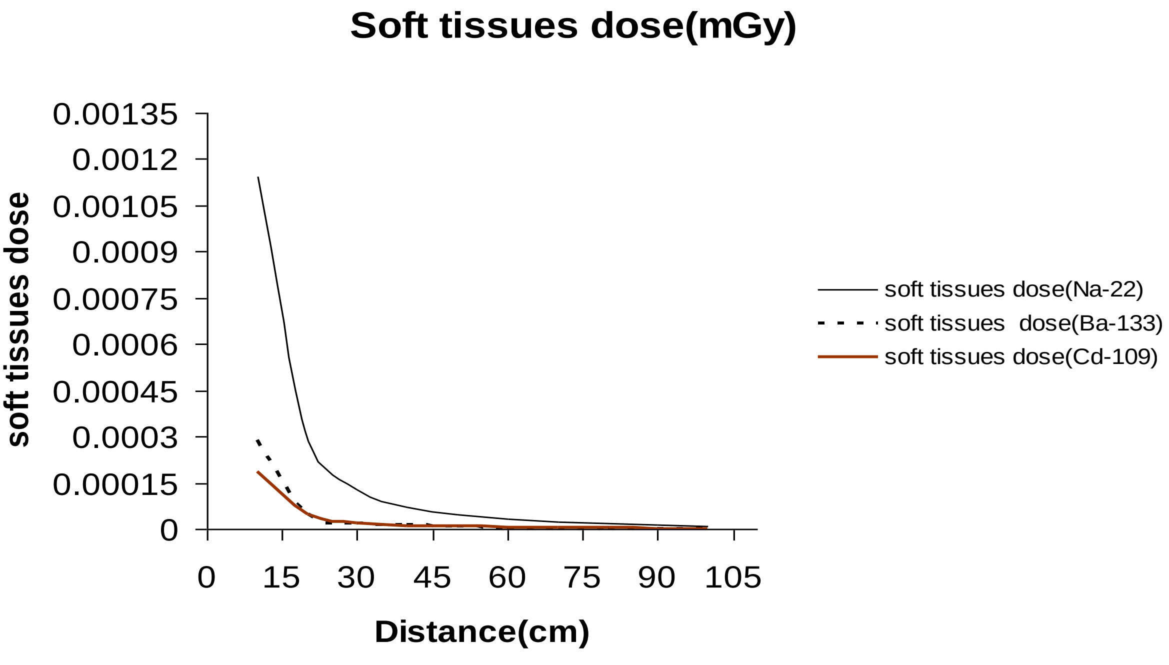
Fig(1) :**Show the exposure rate (R/h) relative to the distance (cm) from the radioactive sources(Na^{22},Ba^{133} and Cd^{109} respectively).**



Fig(2):**Show the dose rate in air (mGy/h) relative the distance(cm) from the radioactive sources (Na^{22},Ba^{133} and Cd^{109} respectively).**



Fig(3): Show the dose rate(mGy/h) calculated for skin of the person from the three radioactive sources(Na^{22},Ba^{133} and Cd^{109} respectively)relative to distance from radioactive sources..



Fig(4): Show the dose rate(mGy/h) calculated for soft tissues of the person from the three radioactive sources(Na^{22},Ba^{133} and Cd^{109} respectively)relative to distance from radioactive sources.

Discussion:

The external radiation dose calculation determines the radiation dose from shielded gamma ray source. The source can be appoint source , or a cylindrical volume source with an evenly distributed concentration of radionuclide[12].

challenge in radiation research related to human health is to predict the biological impact of exposure to low dose (0.1 Gy) ionizing radiation[13]

The results of this project show that the effect of the inverse square law on the both the exposure and the absorbed dose in air , skin and soft tissues was very significant so as the distance between the sources and the persons increase the exposure and the dose decrease proportionally and vice versa ,this parameter was studied by [13] as he was interested in the distance between the patient who are up taking radiopharmaceutical drug and considering the patient as portable radiation source .

The results of this project show that the values of dose rate and exposure rate in air for Na^{22} started at 10 cm with 0.000118800 and 0.001033500 and it's significantly greater than that for Ba^{133} and for Cd^{109} whose it's dose rate at 10cm0.00002981 ,
0.000259347(Ba^{133}) and 0.00001966931, 0.00017112(Cd^{109}) ,we think that belong to the higher gamma ray energy that emitted from the Na^{22} (1.274 MeV) while for Ba^{133} (0.3633 MeV) and for (Cd^{109}) was (0.003179 MeV).

Also the results show that the radiation absorbed dose by skin and soft tissues for persons working in nuclear research room were very close to each other because the mass absorption coefficient(μ_{en}/ρ) for the both(skin and soft tissues) are also very close from each other.(table2).

When we compare the results of our project with these previous literatures we found that[15] calculate the external radiation dose from Cs^{137} in unit of mGy /day using phantom mentioned below fig(3) using TLD dosimeters at different site and the

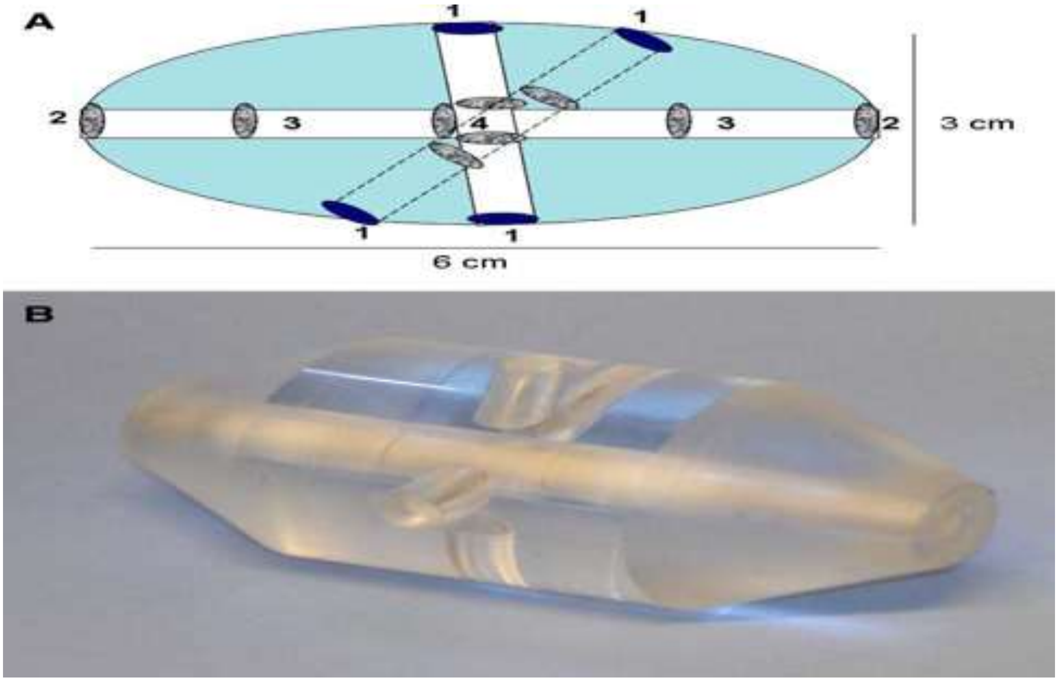


Fig3: Frog phantom constructed out of PMMA (6 × 3 × 3 cm) with one hole drilled along the major axis and two holes along the minor axes.

measured dose was ranged from 0.026 mGy/day to 0.00237 mGy/day while it higher than our calculated dose for the three sources.

Other work[16] calculate the dose rate from gamma ray source inside the room using TLD(thermo luminescence dosimeters) with dose range from 31nGy/h to 130nGy/h calculated from gamma ray source of different building material, for comparison it's lower than our level(dose values).And [17] calculate the dose rate of gamma ray in Yazed province(Iran) with range from[20-200nGy/h] so it's alsolower than thses dose calculated from radioactive source considered.

Other had the same idea of our projects also calculate the effective dose(mSv) from point source (external photon beam)[18]

[19] calculate the dose rate for gamma ray emitted from naturally radioactive source and it was to be in range (0.011nGy/h to 51nGy/h with an overall mean value of 8.7 nGy /h,so it is very low compared with our results especially dose calculated for air(table 1).

Most of research regarding radiation doismetry concentrate on calculation of the exposure rate and dose rate in air , but in our research we expand our calculation to include the skin and soft tissues(table 2) as it is directly subjected to radiation rather than other human body organ mathematically as deep organdose required highly efficient software (Montecarlo software) as used by[20] to calculate the organ dose from radioactive source.[21] also measure the contribution of total body irradiation to the bone marrow using different radioactive source.

Similar research was done to estimate surface skin dose and deep skin dose using two method ,one of which using MCNP code (software) and practical method using phantom body from Co-60 source located at 10 cm and 30 cm[22]

Conclusion :

1.The highest absorbed dose that which calculated by this project was in the safe side for the worker as the dose threshold of 2 Gy(200 rad) for deterministic effects was not reached, [23].

2.The dose and the exposure increase as the distance decrease and vice versa .

3.The exposure time must be minimized as much as possible to avoid the cumulative dose from radioactive source for the workers in contaminated area.

4.The worker must be at least one meter away from the radioactive sources.

5. To determine the maximum permissible dose(MPD) in (rem) for radiation worker especially the staff who are exposed for long time to radiation relative to the age in (year) I suggest utilizing the following formula [MPD =5(N-18)] , N is the age in year.

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