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Research Paper

ASSESSMENT OF REINFORCED CONCRETE BUILDINGS FOR ATTENUATION OF GAMMA RAY EMITTED FROM DIFFERENT SOURCES

Mohamed Abd El-Monem Farahat^{1*} and Ezzat Rady Atta²*Corresponding Author: Mohamed Abd El-Monem Farahat ✉ mfarahat100@yahoo.com

Most of the developed countries have used their buildings as domestic nuclear shelters in case of nuclear emergencies to protect their citizens from the dangerous effects of gamma ray. So, this work aims to study the possibility of using the reinforced concrete buildings to protect people from gamma ray hazards and determining the required safe distance to protect them. For this purpose a proposed building has been studied (consists of a basement, a ground storey and two typical stories) constructed of clay brick walls, reinforced concrete walls, reinforced concrete slabs and finishing's layers. (MCNP 5) code based on Monte Carlo technique was used to calculate the gamma doses that may reach to the hidden people inside this building. The doses have been estimated by $\mu\text{sv/h}$ at different heights from the sidewalk level (heights are - 0.30 m, 0.00 m, 2.95 m, 6.20 m and 9.45 m). Two types of investigated gamma ray sources were used; external exposure of industrial γ -source ^{192}Ir (20 Ci) and external exposure of fallout which contains radionuclides ^{131}I , ^{134}Cs and ^{89}Sr (their combined activities are 0.1 Ci, 0.01 Ci and 0.001 Ci). The results indicate that all gamma doses decrease with increasing the distance between the source and the measuring point, also the safe height of the domestic nuclear shelter space (safe stories) which can protect the hidden people from the dangerous effects of gamma ray is ≥ 2.95 m above the sidewalk level (radioactive source). The obtained gamma doses results of (MCNP 5) code are closed to the obtained results of the manual calculation formula. So, (MCNP 5) code is suitable for accurate calculations of gamma doses.

Keywords: Reinforced concrete buildings, Gamma ray, ^{192}Ir , ^{131}I , ^{134}Cs and ^{89}Sr , Radiation attenuation, Dose assessment

INTRODUCTION

The use of radiation sources of various types and activities is wide spread and led to dramatic advances in industry, medicine and agriculture

(Briesmeister, 1996). Although the other techniques of NDT (Non-Destructive Tests) methods have also been developed and widely implemented, the unique details of data obtained

¹ Assistant Professor, Department of Siting and Environment, Nuclear and Radiological Regulatory Authority, Egypt.

² Assistant Professor, Department of Safety of Fuel Cycle, Nuclear and Radiological Regulatory Authority, Egypt.

by radiography and the fingerprint as a film, have caused radiography to be more appreciated and preferred for the volumetric inspection of products (Whalen *et al.*, 1991).

Simplicity in application and accepted results of radiography using radiation sources is the major reason to consider these sources most predominant in Egypt.

A radiation accident is different from accidents in other fields as the effects of radiation are not immediately felt. Because of this insidious nature, a radiation accident can lead to very serious consequences. The likelihood of occurrence of an accident in industrial radiography is fairly high (IAEA Report, 2002), because majority of the radiography work is carried out in public domain, such as construction sites, workshop areas and inaccessible locations. The source activities used in industrial radiography are quiet high, hence in the event of an accident; there is the possibility of very high doses, even up to lethal doses in certain cases.

Accidents and consequent radiation exposure/injury during use happen mainly because of the following reasons (IAEA, 1993): Handling of sources by untrained persons, use of defective equipment and/or its failure, and failure to use radiation meter.

In a nuclear accident, such as that happened in Chernobyl reactor, individuals who do not seek protection inside shelters will die because of their exposure to gamma radiations radiating from fallout (Ormerod, 1993). Also, people die after exposure to infiltrating gamma radiations from nuclear reactors. Therefore, citizens must be protected against its possible consequences, and from radiating gamma radiations through hiding in nuclear shelters whether being domestic or

public shelters (Dumbleton, 2003). Nuclear shelters are equal in their importance to arming for protecting mankind from the destruction resulting from using the nuclear weapons (Chester and Zimmerman, 1987). Therefore, the buildings can also be used as protective structures in emergencies to protect citizens from dangers (Kearny, 1987).

INDUSTRIAL RADIOGRAPHY SOURCES AND DEVICES

The devices are generally small in terms of physical size, although they are usually heavy due to the shielding contained in them. The sources themselves are very small, less than 1 cm in diameter, and only a few cm long, and are attached to specially designed cables for their proper operation.

The use of radiography sources and devices are very common, and their probability may make them susceptible to theft or loss. The small size of the source allows for unauthorized removal by an individual, and such a source may be placed into a pocket of a garment.

Industrial radiography may also be performed in fixed installations, either using the same small portable devices, or using larger machines that may appear to be similar to teletherapy units. Iridium-192 is ideal for radiography but other radionuclides can be used depending on the characteristics of the object material (Mushtaq, 2013).

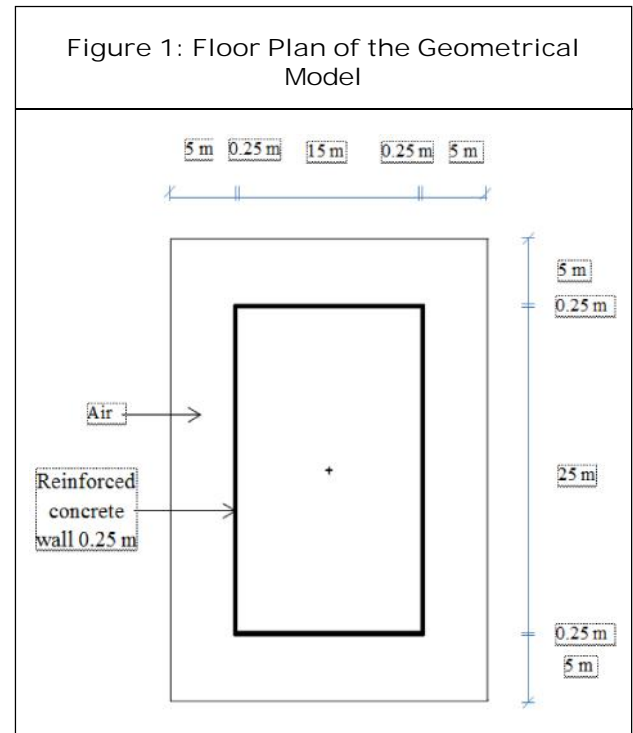
EFFECTS OF NUCLEAR WEAPONS

Modern weapon technology continuously develops more deadly and destructive weapons (Hanesalo and Hanesalo, 1997). Is there a chance for mankind to cope with these increasing threats?

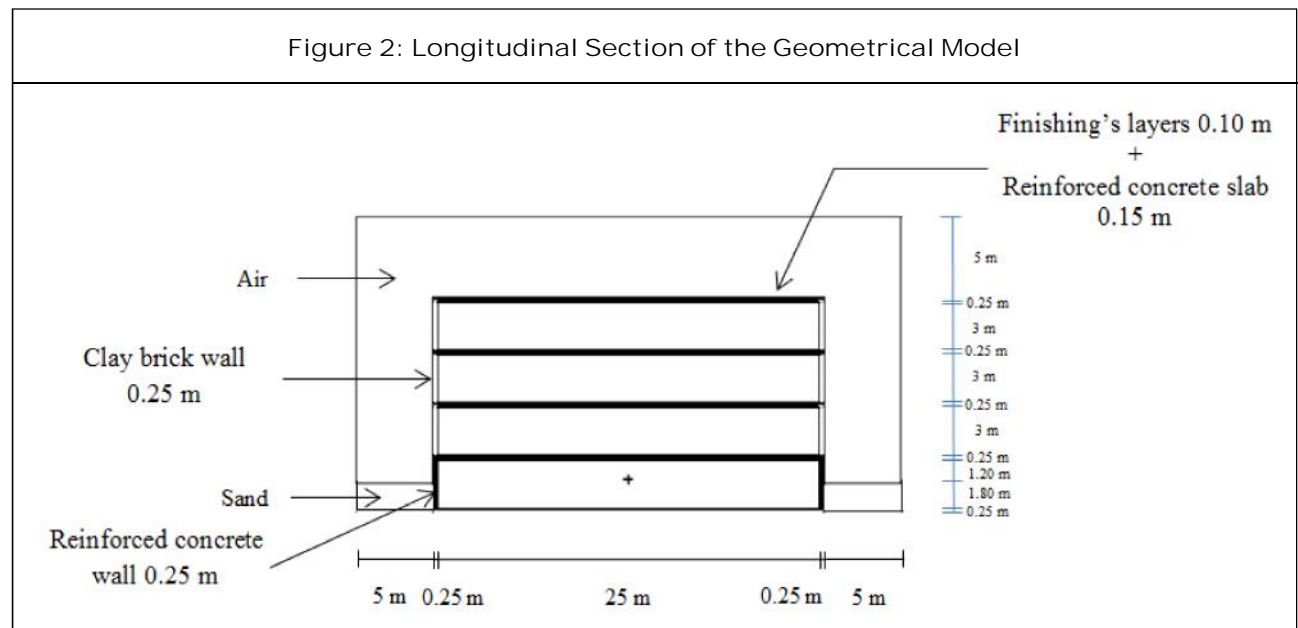
The answer is yes, if the protection is planned and produced in an effective way (Moore, 1980). This requires special knowledge about the weapons and long experience of the design of protective structures (nuclear shelters) (Gant and Halland, 1979). The walls and the slabs of any building reduce the effects of gamma rays (Sisson, 1980).

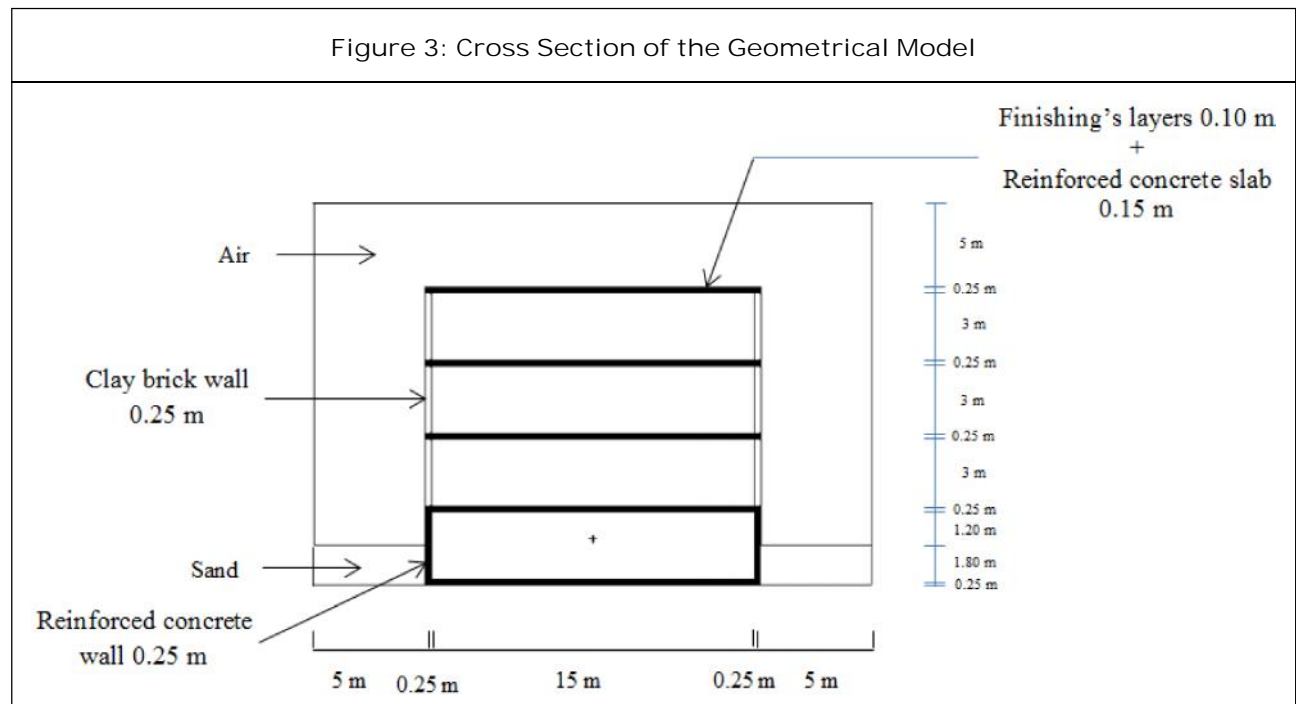
Assumed Building

The assumed area of each storey (floor) of the assumed building is (Length) 25 m x (Width) 15 m = 375 m² (Figure 1). The assumed height of each story of the assumed building is 3 m. The assumed building consists of four stories (floors). These stories are basement, ground, first and second stories (Figure 2). The roofs (slabs) of these stories consist of reinforced concrete layer and finishing's layers. The assumed thickness of the reinforced concrete layer is 0.15 m. The assumed thickness of the finishing's layers is 0.10 m. The walls of the ground, first and second stories consist of clay bricks. The assumed thickness of the clay bricks wall is 0.25 m. The walls of the basement storey consist of reinforced



concrete. The assumed thickness of the reinforced concrete wall is 0.25 m (Figure 3). The assumed level of: the basement floor in the assumed building is - 1.80 m below the ground surface level (sidewalk), the ground floor is + 1.45 m above the ground surface level, the first floor is + 4.70 m above the ground surface level, the





second floor is + 7.95 m above the ground surface level, and the roof is + 11.20 m above the ground surface level.

Structural Specifications Of The Assumed Building

It is assumed that the building has density of reinforced concrete = 2.5 ton/m³, density of sand = 1.6 ton/m³, and density of clay brick = 0.7 gm/cm³.

Calculations of Radiations Attenuation and dose Assessments for the Assumed Building

The assumed building, constructed from clay brick walls, reinforced concrete walls and reinforced concrete slabs can be dual used as domestic nuclear shelter to protect some people. MCNP5 computer code, which is Monte Carlo neutron, photon and electron transport code (Briesmeister, 1996) was used to account attenuation of gamma ray passing through the air, the clay brick walls (assumed thickness 0.25 m), the reinforced concrete walls (assumed thickness 0.25 m), the

reinforced concrete slabs (assumed thickness 0.15 m) and the finishing's layers (assumed thickness 0.10 m). Also, the computer code (MCNP 5) was used to account the dose inside each storey of the assumed building at different heights from the ground surface level. The total dose was estimated by $\mu\text{sv/h}$.

Source

There are two types of the investigated sources; external exposure of industrial γ -source ¹⁹²Ir and external exposure of fallout which contains radionuclides ¹³¹I, ¹³⁴Cs and ⁸⁹Sr. The source activity of ¹⁹²Ir is 20 Ci and the source activity for each investigated radionuclide (¹³¹I, ¹³⁴Cs and ⁸⁹Sr) is 0.1 Ci, 0.01 Ci and 0.001 Ci.

The Source Location

It was suggested that the source location was outside the building and has the following characteristics: on the left of the building, on the sidewalk (height = 0.00 m) and the distance between the source and the building wall was 4 m as shown in Figure 4. The location of measuring

point outside the building was noted by P_1 and for inside the building was noted by P_2, P_3, P_4 and P_5 as shown in Figures 5 and 6.

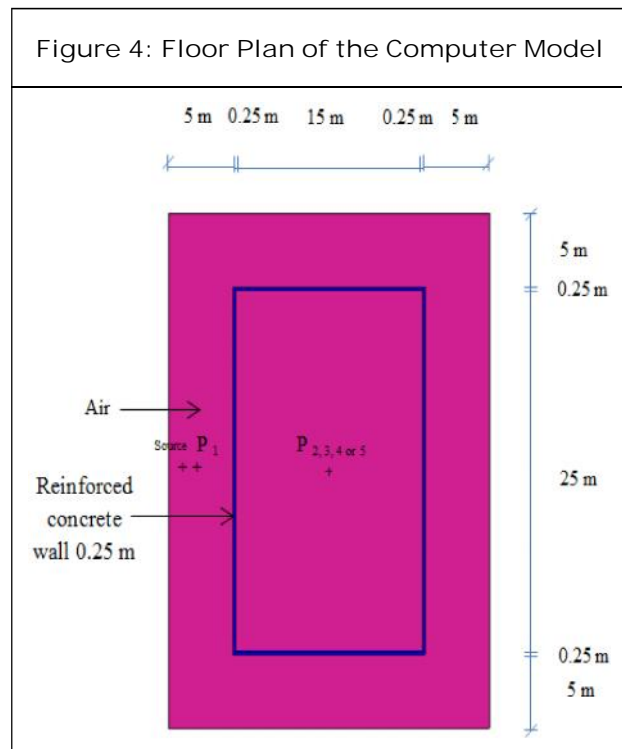
P_1 : is on the left of the building, on the sidewalk (height = 0.00 m) and the distance between it and the building wall is 3.10 m, i.e., the distance between the source and P_1 is 0.90 m.

P_2 : is in the middle of the basement storey. Its height from the sidewalk level is - 0.30 m.

P_3 : is in the middle of the ground storey. Its height from the sidewalk level is 2.95 m.

P_4 : is in the middle of the first storey. Its height from the sidewalk level is 6.20 m.

P_5 : is in the middle of the second storey. Its height from the sidewalk level is 9.45 m.

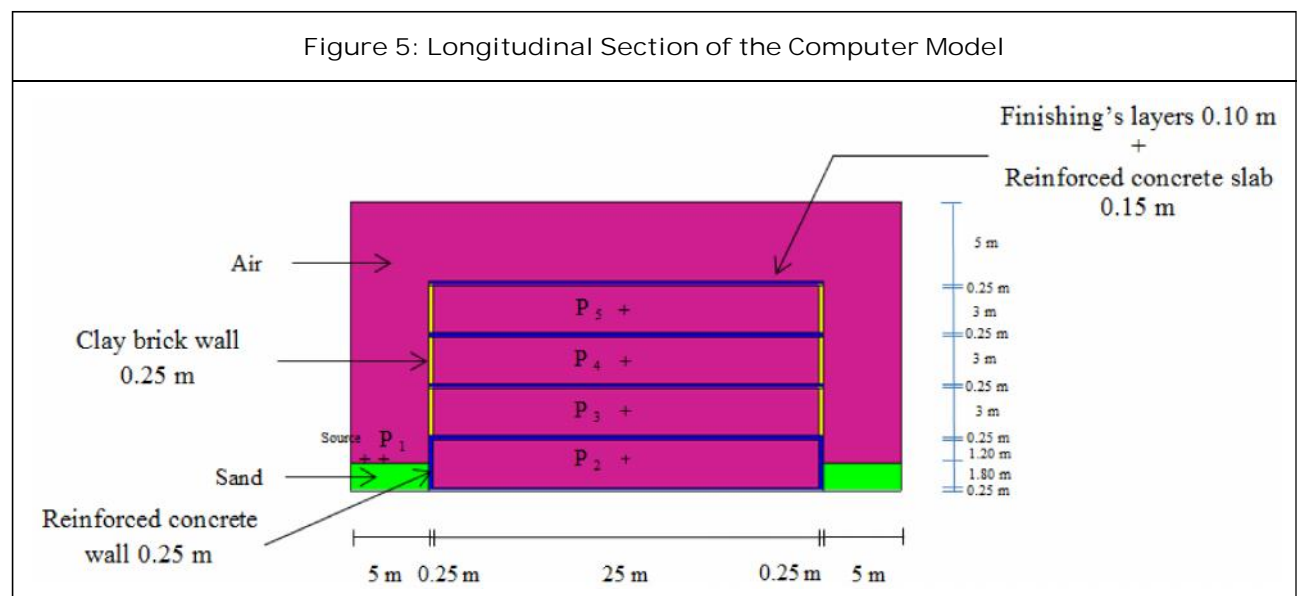


RESULTS

The computer code (MCNP 5) was used to calculate different doses for external exposure of ^{192}Ir , ^{131}I , ^{134}Cs and ^{89}Sr and the obtained data are represented in Tables 1 and 2.

Table 1: Different Gamma Doses versus the Height of Measuring Point from the Sidewalk Level for External Exposure of ^{192}Ir

| Measuring Point | Height of Measuring Point from Sidewalk Level (m) | γ - Dose ($\mu\text{sv/h}$) |
|-----------------|---|--------------------------------------|
| P_1 | 0 | 1.054 E+5 |
| P_2 | -0.3 | 1.604 E+1 |
| P_3 | 2.95 | 5.661 E+0 |
| P_4 | 6.2 | 6.689 E-1 |
| P_5 | 9.45 | 1.542 E-1 |



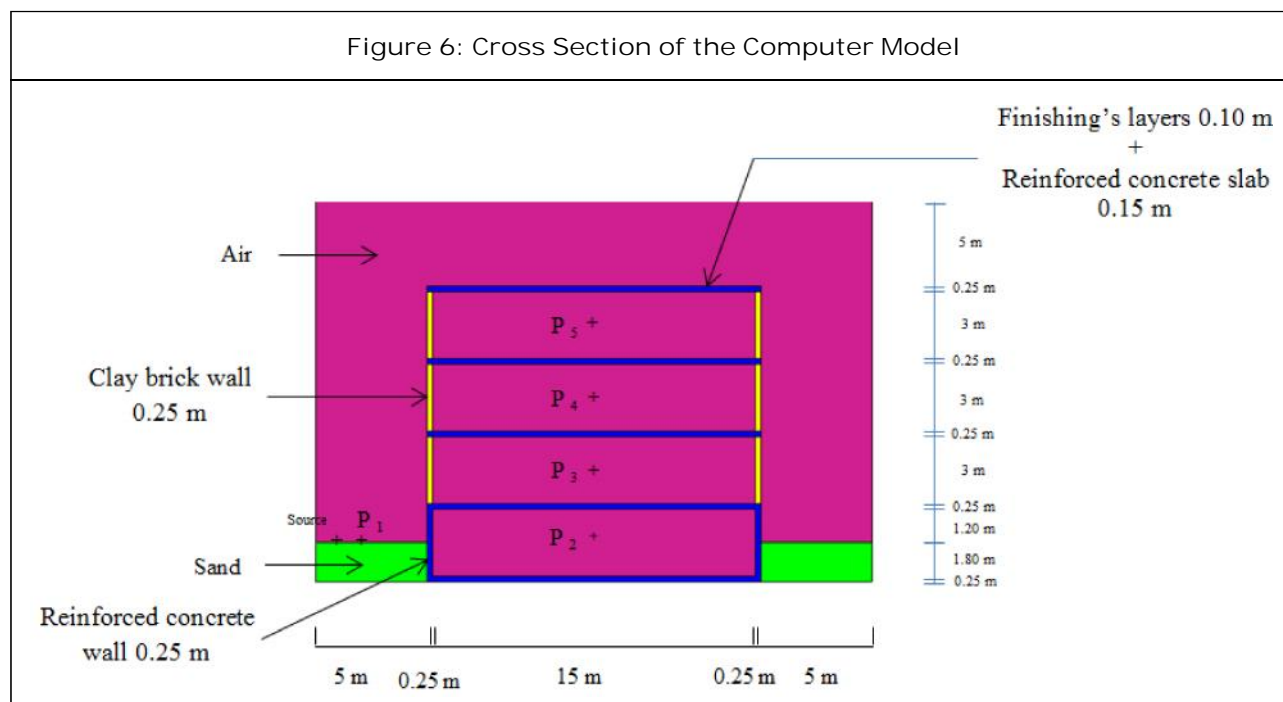


Table 2: Different Gamma Doses versus the Height of Measuring Point from the Sidewalk Level for External Exposure of Different Combined ¹³¹I, ¹³⁴Cs and ⁸⁹Sr Activities

| Measuring Point | Height of Measuring Point from Sidewalk Level (m) | Gamma Dose (µSv/h) (for Combined ¹³¹ I, ¹³⁴ Cs and ⁸⁹ Sr is 0.1 Ci) | Gamma Dose (µSv/h) (for Combined ¹³¹ I, ¹³⁴ Cs and ⁸⁹ Sr is 0.01 Ci) | Gamma Dose (µSv/h) (for Combined ¹³¹ I, ¹³⁴ Cs and ⁸⁹ Sr is 0.001 Ci) |
|-----------------|---|--|---|--|
| P ₁ | 0 | 1.169 E+3 | 1.169 E+2 | 1.169 E+1 |
| P ₂ | -0.3 | 4.673 E-1 | 4.673 E-2 | 4.673 E-3 |
| P ₃ | 2.95 | 1.349 E-1 | 1.349 E-2 | 1.349 E-3 |
| P ₄ | 6.2 | 1.528 E-2 | 1.528 E-3 | 1.528 E-4 |
| P ₅ | 9.45 | 4.381 E-3 | 4.381 E-4 | 4.381 E-5 |

The results indicate that all Gamma doses decrease with increasing the height of measuring point from the source (sidewalk).

MANUAL CALCULATION FORMULA

The manual calculation formula was used for dose rate calculations.

$$\text{Dose Rate (mSv/h)} = \text{Gamma Factor} \times \text{Source Activity} / (\text{Distance})^2 \text{ (Massoud, 2014)}$$

Where:

The dose rate: is the gamma dose rate in mSv/h.

Gamma factor: is the correlation factor depends on type of isotope.

Source Activity: Activity of radioactive isotopes in GBq.

Distance: is the distance from the source in m.

The dose rate for ¹⁹²Ir at P₁

$$\begin{aligned} \text{Source Activity} &= 20 \text{ Curies} \\ &= 20 \times 3.7 \times 10^{10} \times 1000 / 10^9 \text{ Bq} \end{aligned}$$

$$\begin{aligned}
 & \text{Dose rate at } P_1 \text{ (}\mu\text{sv/h)} \\
 & = [0.13 \times 20 \times 3.7 \times 10^{10} \times 1000/10^9]/(0.9)^2 \\
 & = 0.13 \times 200 \times 3.7 \times 1000/0.81 \\
 & = 0.13 \times 740 \times 1000/0.81 \\
 & = 96.2 \times 1000/0.81 \\
 & = 96200/0.81 \\
 & = 0.962 \times 10^5/0.81 \\
 & = 1.18765 \times 10^5 \mu\text{sv/h}
 \end{aligned}$$

The obtained result from the calculations using this formula is closed to the obtained result from the MCNP 5 code. This indicates that this code is suitable for accurate calculations of gamma dose rate outside the building.

The results indicate that all Gamma Doses decrease with increasing the height of measuring point from the source (sidewalk) at the same source activity.

CONCLUSION

Based on the obtained results in this study, it could be concluded that:

- The hidden people in studied building or any building has a height ≥ 2.95 m will not have any dangerous effects from the gamma ray, emitted by such investigated sources.
- The clay brick walls, the reinforced concrete walls and the reinforced concrete slabs well attenuate gamma ray, and the dose inside the highest floors of the building becomes approximately zero.
- The safe height of the domestic nuclear shelter space (safe stories) which can protect the hidden people from the dangerous effects of gamma ray emitted from the investigated sources is ≥ 2.95 m above the sidewalk level.

- Reinforced concrete buildings are suitable for the dual-use as nuclear shelters.
- There is a directly relationship between the height of the domestic nuclear shelter floor above land surface and the protection factor inside the shelter.

RECOMMENDATIONS

The authors recommend civil defense authority to conduct a field survey of all buildings to determine the buildings, which can be dual-used as nuclear shelters to protect citizens, calculate the protection factor, radiations attenuation and dose assessment in each one of them and determine the number of people who can be protected by these nuclear shelters.

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Hyderabad, INDIA. Ph: +91-09441351700, 09059645577

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