IRAQI JOURNAL OF APPLIED PHYSICS Vol. 21, No. 2, April-June 2025, pp. 205-208

Rawaa M. Obaid
Ali Al-Jawdah
Radhiyah M. Aljarrah

Department of Physics,
College of Science,
University of Babylon,
Hilla, IRAQ

Evaluation of the Capability of Utilizing the Local Soil as a Nuclear Radiation Shielding Materials

There are many events that may lead to exposure to radiation. In this work, the feasibility of using national soil types as nuclear shields was studied. Studies on evaluating the shielding capability of soils are still rare, therefore meaning more researches are necessary to check their performance and efficiency to attenuate radiation. Coefficients of mass attenuation for soil samples have been obtained at most common neutron and gamma energy. Then, the value of effective atomic number and half value layer have been by applying the μ/ρ values. Materials were sorted according to their sources and the geographical area from which it was taken into four main categories into four main categories (A, B, C, and D). C sample show high shielding capability to attenuate gamma and thermal neutron compared with others.

***Keywords*:** Radiation shielding; Radiation dose; Gamma attenuation; Soil
Received: 23 November 2024; **Revised:** 27 January 2025; **Accepted:** 03 February 2025

1. Introduction Abstract

The literature review shows there are many research converse about the possibility of using a soil as an applicable nuclear shielding material [1- 4]. One of the research suggest use heavy clay to shield neutrons and gamma-rays during shutdown one of the Nuclear Power Plant [x]. They show that the neutron beam and gamma-ray decay are directly dependent on the clay wet level. The shielding performance of different soils was estimated by analysing the most parameters of radiation shielding [5]. These studies showed that all studied soils were suitable for gamma-ray shielding, while specific types are proper to neutron absorber. Soil composition is complex and generally consists of three main components: solid (organic matter and mineral), liquids (soil solution) and gases. The solid part is mostly oxides such as Al_2O_3, SiO_2, TiO_2, and Fe_2O with others in low concentrations [6]. These oxides play a role in stability and the aggregation of the structure which effect on the response to the possible changes due to natural processes (wind, temperature, water, etc.). As the Earth's surface substantial is covered by rocks and soils, these materials considered interesting for purposes of radiation shielding because of their obtainability and availability. Therefore, the performance of soil as a nuclear shielding material varies depending on the geographic region of the soil. It is also worth to notify that soil is an abundant and cost-effective material, which encourages think to employ it in the large scale nuclear shielding.

The most important factors that evaluate the performance of a material as a nuclear shield are the coefficients of linear and mass attenuation, mean free path, half value layer. Linear attenuation is the probability of absorption of radiation per unit length of the radiation path, while the mean free path is an average of the distance between photon absorption events [7,8]. The half value thickness represent the width that reduces radiation intensity to half.

Although the soil varies in its components from one region to another, and impact that on its performance as a radiation shield, also at same region, the soil is affected by weather factors, which also includes the possibility of changing properties [9]. Therefore, studying soil as a shielding material should be done geographically and timely update. Moreover, monitoring the degree of weathering of the soil and it correlate with the properties of soil-radiation interaction is a relevant matter of research [10]. In the selected search area, radiation shielding capacity of soils have not been estimated, so far, as far as we know a standard for the construction is not determined in terms of radiation protection.

Gamma attenuation is proportional to sample density. While the attenuation of the neutron beam is dependent on water content in samples [11]. In many cases such as radiation leakage, nuclear accident, use of nuclear weapons etc., dealing with radiation using locally available soil is more applicable than other materials. Therefore, it is better to know the most efficient method to employ the available soil as a nuclear radiation shield material.

This work has conducted to evaluate and define the radiation shielding ability of the main types of Iraqi soil. These information are still scarce, so, there is a need for investigating in this subject to provide the required information. Radiation elimination process is not easy, because when the radiation interact with material consist of different components, many kind of processes can be happen, which cause scattering, absorption of the radiation or even re-emission, because interaction of radiation especially neutrons, with some nuclei may lead to the absorption of neutrons and the emission of another type of radiation, often gamma rays [12,13]. Since the process is complex, it is difficult to predict its results theoretically, so using experimental results will be more useful and beneficial.

2. Experimental conditions

In general, three main types of soil in Iraq can be distinguished; Sandy soils, clay soil and gravel mixture (They are denoted by curves A, B, and C, respectively), which are readily available and expected for use to build nuclear shelters and burying radioactive war remnants. Any nuclear activity accompanied by gamma emission, because nuclear activities leave nuclei in an excited state transition to the ground state through gamma decays. Therefore, gamma shielding is one of the most important priorities of nuclear shielding. Neutron radiation is also a major concern, stopping the neutrons may also lead to the formation of a new radioactive nuclei that would be another source of gamma rays, which would complicate the nuclear shield design. While alpha and beta are not considered in this research because no matter how much energy they have, they will not penetrate the material very much and will stop at a small distance due to their electrical charge. The setup has used to exam the radiation shielding capacity of the soil samples is shown in Fig. (1).

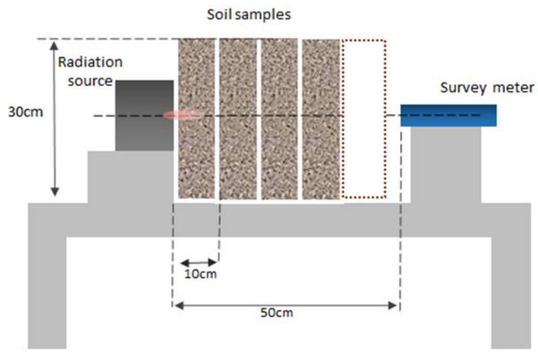

Fig. (1) Experiment setup

The setup contain 1-5 vessels to contain the soil samples materials. A radiation dose was measured across the material sample for five thickness (10 cm, 20 cm, 30 cm, 40 cm and 50cm). To avoid the effect of reflected rays, the system was placed on a base 1 m above the ground and isolated from any nearby objects. A survey meter has been used to estimate the radiation dose, fixed 60cm from the source of radiation and close to the samples vessel.

3. Radiation shielding test results

The results of five samples increasing ten centimetres with each measure step are shown in figures (2) and (3). These outcomes can be used to infer soil parameters that contribute to the radiation (neutron beam or gamma ray) shielding. Radiation strength reduction implies that the percentage of loss of radiation intensity during the passage through the shielding material sample. The radiation dose measured when samples vessels empty, the dose considered 100% and the reduction 0%, while the dose 0% when the reduction 100%. The results in Fig. (4) indicate that with the increase in soil density, the intensity of gamma rays decreases. This is consistent with the fact that gamma rays are intercepted by orbital electrons which lead to lose their energy and intensity decreases accordingly.

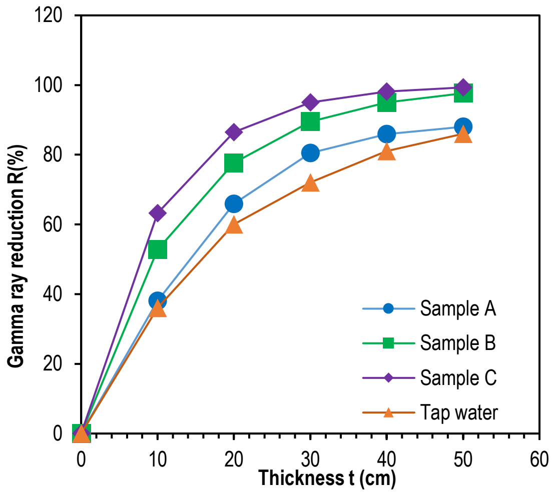

Fig. (2) Relation between gamma reduction and the soil thickness

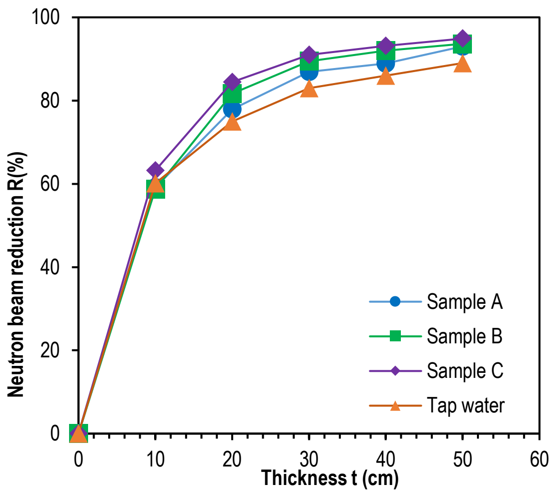

Fig. (3) Relation between neutron beam reduction and the soil thickness

Therefore, the existence of high electron density service a gamma shielding. So, the dense material is the best for gamma ray shield. On other hand, because the neutrons are particle with no electric charge, they loss their energy via react (absorption or scattering) with atomic nuclei. According to collision mechanics, the transfer of energy it will be maximum, when the colliding particles are close in mass, so logically, the small nucleus is the best for curbing neutron energy. This was clearly demonstrated in the results shown in Fig. (5), where the increase in the percentage of water presence has been led to a near-total loss of the intensity of the neutron beam. Practically, the results confirm that the reduction of the neutron beam relied heavily on the volume of water in soil. The variation in the measured values were due to variability of the samples or the neutrons of the beam not all have a same velocity exactly.

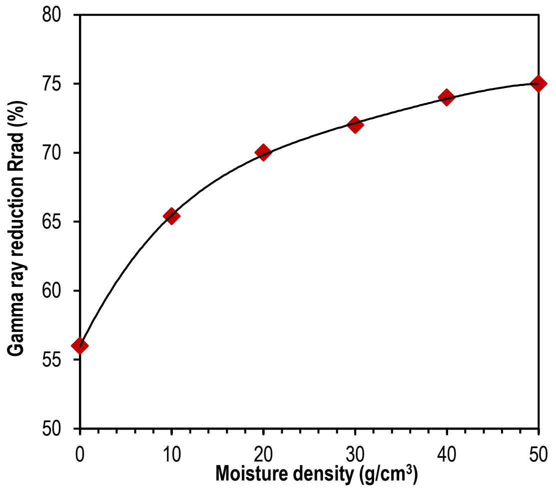

Fig. (4) The effect of wet density on the gamma ray attenuation capacity of the soil sample

Gamma ray reduction associated with soils thickness is shown in the Fig. (2). It shows that the slurry has worthy gamma ray shielding performance more than water. In addition, high density slurry has approximately same water shielding ability against neutron beam. The difference in reduction between the three models of slurries decreases with increasing thickness.

4. Application to design soil construction

These results are associate with certain state of soils in a specific geographical location to establish an arrangement plan to soil structure for nuclear radiation shielding. Therefore, it is better to pointed to some quantities that show obviously relation with the reduction of radiation. This study adopts a parameter: the values that obtained by controlling and multiplying the wet existence and the thickness of the materials that the radiation passes through it. This parameter is called (total density of transit path). As well, the probability of neutrons collision with hydrogen nuclei will called (total moisture density of transit path) which obtained by multiplying wet density and thickness (= water density x volume water content/100). The results that presented in figures (2) and (3) show that the behaver of both neutron beam and gamma ray controlled by the collision probability. The relation between transit path and reduction of gamma ray can be can be modelled by a polynomial equation (correlation factor R=0.995), and represented by the following equation [14]:

$$y = 0.0001x^3 - 0.033x + 30.062 \qquad (1)$$

The information present in this paper is application suggestion of a geotechnical field. Soil materials are available everywhere could be effortless shield to suppress radiations. Nuclear radiation safety with considering the cost require these information to design the construction properly. It is beneficial in terms of nuclear safety and cost of construction to take into account consideration of nuclear radiation shielding to the civil engineering building structures. Practical and design calculations depend on the radiation source. Then the nuclear measurement information is based on according to suggested flow chart Fig. (6).

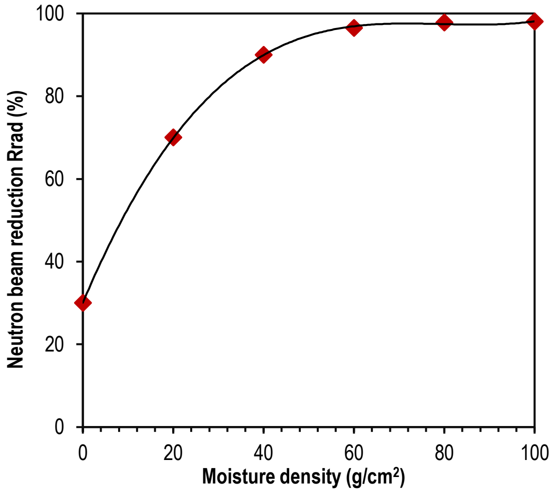

Fig. (5) The effect of water percentage in the soil sample on the neutron reduction capacity of the soil sample

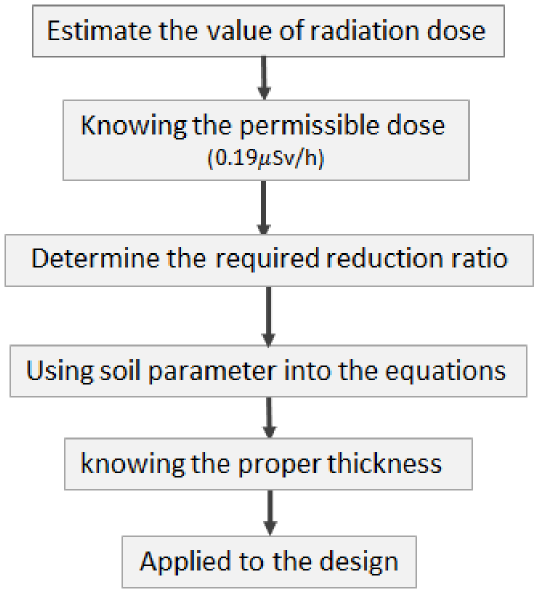

Fig. (6) Flowchart of soil construction design for radiation shielding

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ISSN (print) 1813-2065, (online) 2309-1673