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Research on Classification and Control Indexs for Associated Radioactive Minerals and its Mineral Products

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Abstract it is to seek in the implementation details about the management of the naturally occurring radioactive materials. Especially for natural radioactivity concentration in raw materials and tailings and its mineral products are used for manufacturing refractory products.It needs to be further improved. The classification method is based on the γ radiation dose rate limit under the measured environment or material surface at different heights and the activity concentration of radionuclide.The aim of this work is to investigate the Control index problems the different influencing factors or parameters of radiation level.The results show that the limits of Radionuclide on the different of the Influence factors with the height of the raw radioactive materials and its Tailings or its product.It is mainly studied from three aspects: ①the judgment of the raw radioactive materials and its Tailings or its product.②the building materials form of the raw radioactive materials and its Tailings or its product were judged.③The absorbed dose rate(Iγ) and radium equivalent activity(Raeq)，alpha index (Iα) , et al. wered assessed.The Results show that the control index about the representative management. It will play an important role in radiation protection and measurements， and it provides technical basis for future evaluation standard of scientific and practical management.

Keywords: *naturally occurring radioactive materials, limits of control index, levels of radiation*

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1. Introduction

Naturally occurring radioactive material (NORM) is material found in the environment that contains radioactive elements of natural origin. the primarily contains uranium and thorium and potassium. These elements are naturally decaying and are considered a primary contributor to an individual's yearly background radiation dose.

The Typical of NORM has nonferrous metal, ferrous metal, rare metal and others. The natural radio nuclide will also be diffused, transferred, concentrated to the raw radioactive Tailings or its product, so it will lead to cause additional radiation pollution to human beings or the environment to a certain extent.

China is rich with resources of NORM, but the management and systems and measures are imperfect, it leads to excessive digging and blind exploitation. so that, It not only fails to fully utilize the expected benefits of resources, but also aggravates the pollution of environmental. Therefore, it is particularly important to strengthen the supervision of exploit these Material resources, especially for the model of supervision and control rules.

2. Physical Model and Theoretical Derivation

2.1. Physical Model

It gives a description of the scope of radiation protection, especially for the problem on Control and immunity In the paper [1]. In general,the annual additional effective dose limit of public exposure should be
10% - 30% of the public exposure dose limit(1msv/a). in the standard of 《Basic standards for protection against ionizing radiation and for the safety of radiation sources》[2]. the Additional absorbed gamma dose rate in air is Greater or equal to 400nGy/h at 0.1m above the ground,under the diameter is Greater or equal to 2 metres and the thickness is Greater or equal to 1 metre of metal mineral products in the standard of 《Limitation concentration of natural radioactivity in non-ferrous metal ores and concentrates products》.

There are many researches on NORM, and The scope of the study is relatively broad.eg. the article of Xinmin Wu in 2005 [3].the Additional absorbed gamma dose rate in air at 0.1m above the ground are compared and analyzed in The paper,and The specific radioactivities of Radium (226Ra), Thorium(232Th) and Potassium (40K) are considered. The article of You Hua Hu in 2013 [4]. This paper compared and analyzed that the Additional absorbed gamma dose rate in air above the ground and The specific radioactivities of Radium (226Ra), Thorium(232Th) and Potassium (40K).In 2010, the General Administration of Quality Supervision [5], Inspection and Quarantine of China issued The natural radioactive limit standard for non-ferrous metal mineral products is studied from a distance of 0.1 m on the surface of the mineral product pile to investigate the control of natural radioactive nuclides Value size.

These studies compared and analyzed that the Additional absorbed gamma dose rate in air at Different Heights above the ground and The specific radioactivities of Radium (226Ra), Thorium(232Th) and Potassium (40K) [6,7], but in fact, the difference of the test distance leads to misuse,so that The result is false.

The purpose of this paper is to make a preliminary study on the relationship between the absorbed gamma dose rate in air at 1m and 0.1m and 0.3m above the measured environment or material surface.such as in soil, sand and the radioactive materials and its tailings or its product.Through the analysis of the radioactive materials and its tailings or products.the control index was proposed. It will play an important role in radiation protection and measurements, and it provides technical basis for future evaluation standard of scientific and practical management.

2.2. Theoretical Derivation

2.2.1. Absorbed Dose Rate and Material Surface

2.2.1.1. Absorbed Dose Rate and at 1m Above Material Surface(D_{r-1})

The measured activity of ^{226}Ra, ^{232}Th and ^{40}K were converted into doses by applying the factors 4.29, 6.66 and 0.42(Bq/kg) for radium, thorium and potassium, respectively. These factors were used to calculate the total absorbed gamma dose rate in air upon a height of 1.0 m above the ground , were calculated using the following equation. [8,9,10,11,12]

$$D_{r-1} = (4.29C_{Ra} + 6.66C_{Th} + 0.42C_K) \times 10^{-4} \quad (1)$$

where: D_r are the absorbed gamma dose rate,μGy/h.C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.

2.2.1.2. Absorbed Dose Rate and Close to Material Surface(D_{r-0})

The measured activity of ^{226}Ra, ^{232}Th and ^{40}K were converted into doses by applying the factors 4.667, 6.717and 0.415(Bq/kg) for radium, thorium and potassium, respectively. These factors were used to calculate the total absorbed gamma dose rate in air upon a height of 0 m above the ground, were calculated using the following equation [10,11,13,14,15,16]

$$D_{r-0} = (4.677C_{Ra} + 6.717C_{Th} + 0.415C_K) \times 10^{-4} \quad (2)$$

where: D_r are the absorbed gamma dose rate,μGy/h.C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.

2.2.1.3. Absorbed Dose Rate and at 0.1m Above Material Surface($D_{r-0.1}$)

The measured activity of ^{226}Ra, ^{232}Th and ^{40}K were converted into doses by applying the factors 4.638, 6.711and 0.414(Bq/kg) for radium, thorium and potassium, respectively. These factors were used to calculate the total absorbed gamma dose rate in air upon a height of 0.1 m above the ground,were calculated using the following equation.

$$D_{r-0.1} = (4.638C_{Ra} + 6.711C_{Th} + 0.414C_K) \times 10^{-4} \quad (3)$$

where: D_r are the absorbed gamma dose rate,μGy/h. C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.

2.2.1.4. Absorbed Dose Rate and at 0.3m Above Material Surface($D_{r-0.3}$)

The measured activity of ^{226}Ra, ^{232}Th and ^{40}K were converted into doses by applying the factors 4.56, 5.299and 0.417(Bq/kg) for radium, thorium and potassium, respectively. These factors were used to calculate the total absorbed gamma dose rate in air upon a height of 0.3 m above the ground,were calculated using the following equation.

$$D_{r-0.3} = (4.56C_{Ra} + 5.299C_{Th} + 0.417C_K) \times 10^{-4} \quad (4)$$

where: D_r are the absorbed gamma dose rate,μGy/h. C_{Ra}, C_{Th} and C_K are the activity concentration of ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.

2.2.2. Annual Effective/Equivalent Dose (D_e)

The annual effective dose received by the population was calculated using the following equation(UNSCEAR, 2000) with a conversion factor of 0.7Sv/Gy (ICRP, 1988).

$$D_e = (D_r - D_{r_0}) \times T \times K \times R \times 10^{-3} \quad (5)$$

where: D_e are The annual effective dose rates, mSv/a.

D_r are the absorbed total gamma dose rate,μGy/h.

D_0 are the absorbed Natural gamma dose rate,μGy/h.

T are the time of Contact.

K are the conversion factor of 0.7Sv/Gy.

R are the average, spent their time outdoors and indoors.

2.2.3. Data Analysis

The annual activity time of the residents is 365 days, 24 hours a day. In general, the percentage of indoor and outdoor in urban areas is 82% and 18% , while in rural areas is 77% and 23% [12]. The percentage of indoor and outdoor is 80% and 20% on average in the Articles

3. Measurements of the Radiological Parameters

3.1. Hazard Indices (H_{eX})

To limit the external γ-radiation dose from materials to 1mSv/yr, the external hazard index (H_{ex}) is defined by workers,The External Radiation Dose control value is 0.6mSv/yr, which is produced by the additional radioactivity of the sample material [12,13,17,18,19,20].

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4200 < 1 \quad (6)$$

$$H_{ex} = C_{Ra}/370 + C_{Th}/242 + C_K/3800 < 1 \quad (7)$$

where: Req-This indexis related to both internal dose due to radon and external gamma dose. ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.

3.2. Radium Equivalent (R_{aeq})

To represent the level of activity of ^{226}Ra, ^{232}Th and ^{40}K by a single quantity, a common radiological index was introduced. This index is known as the equivalent radium activity symbolized by Raeq and calculated using the following expression [11,14,21,22,23,24]:

$$Ra_{eq} = C_{Ra} + 1.43C_{Th} + 0.0974C_K \quad (8)$$

where: Req-This indexis related to both internal dose due to radon and external gamma dose. ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.

3.3. Gamma Index (I_γ)

Radon and its daughters will have an internal radiation effect on the human body. Therefore, the influence factor of the internal radiation can be used to describe,These factors were used to calculate the total absorbed gamma dose rate in air at 0 m and at 1m above the ground level using the following equation [15,25,26,27,28,29]

$$H_{in} = C_u/185 + C_{Th}/259 + C_K/4200 < 1 \quad (9)$$

$$H_{in} = C_u/185 + C_{Th}/242 + C_K/3800 < 1 \quad (10)$$

where: H_{in} -This indexis related to both internal dose due to radon and internal gamma dose. ^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.

3.4. Alpha Indices (I_α)

The alpha indices have been proposed to assess the exposure level due to radon and thorium, These factors were used to calculate The alpha index in air at 0 m and at 1m above the ground level using the following equation [30].

$$I_\alpha = C_{Ra}/200 + C_{Th}/138 \quad (11)$$

$$I_\alpha = C_{Ra}/200 + C_{Th}/129 \quad (12)$$

where: I_a- The alpha index related to radon and thorium. ^{226}Ra, ^{232}Th in (Bq/kg), respectively.

4. Classification and Discussions

4.1. Discussion on the Control Value

4.1.1. Definition of the Radioactive Materials and Its Product

To limit the external γ-radiation dose from materials to 1mSv/yr, The External Radiation Dose control value is 0.6mSv/yr, which is produced by the additional radioactivity of the sample material,so the γ-radiation dose is 0.16μGy/h by calculation. the following equation was used of the absorbed gamma dose rate at 1m above the ground level and the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

$$H_{ex} = C_{Ra}/370 + C_{Th}/242 + C_K/3800 \geq 1 \quad (13)$$

$$I_\alpha = C_{Ra}/200 + C_{Th}/129 \geq 1 \quad (14)$$

where: I_a- The alpha index related to radon and thorium

Hex-This indexis related to both internal dose due to radon and external gamma dose,^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.the radioactive materials and its Tailings can be judged by The alpha index related to radon and thorium or This indexis related to both internal dose.

4.1.2. Definition About the Product of the Radioactive Materials

To limit the external γ-radiation dose from materials to 1mSv/yr, The External Radiation Dose control value is 0.6mSv/yr, which is produced by the additional radioactivity of the sample material,so the γ-radiation dose is 0.16μGy/h by calculation. The following equation was used of the absorbed gamma dose rate at 0.1m above the ground level and the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

$$H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4200 \geq 1 \quad (15)$$

$$I_\alpha = C_{Ra}/200 + C_{Th}/138 \geq 1 \quad (16)$$

where: I_a- The alpha index related to radon and thorium

Hex-This indexis related to both internal dose due to radon and external gamma dose,^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively. The radioactive materials and its Tailings can be judged by The alpha index related to radon and thorium or This indexis related to both internal dose.the analysis results at 0.1m above the ground level agree with the standard of the《Limitation concentration of natural radioactivity in non-ferrous metal ores and concentrates products》.

4.1.3. Definition of the Radioactive Materials and Its Product

To limit the external γ-radiation dose from materials to 1mSv/yr, The External Radiation Dose control value is 0.6mSv/yr, which is produced by the additional radioactivity of the sample material,so the γ-radiation dose is 0.16μGy/h by calculation. the following equation was used of the absorbed gamma dose rate at 0.3m above the ground level and the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K.

$$H_{ex} = C_{Ra}/370 + C_{Th}/254 + C_K/4080 \geq 1 \quad (17)$$

$$I_\alpha = C_{Ra}/200 + C_{Th}/135 \geq 1 \quad (18)$$

where: I_a- The alpha index related to radon and thorium

Hex-This indexis related to both internal dose due to radon and external gamma dose,^{226}Ra, ^{232}Th and ^{40}K in (Bq/kg), respectively.the radioactive materials and its Tailings can be judged by The alpha index related to radon and thorium or This indexis related to both internal dose.

4.2. Discuss About the Product of the Radioactive Materials

4.2.1. The Radioactive Materials

The condition of the absorbed gamma dose rate at 1m above the ground level and the Radionuclide in soil, NORM was Determined,and it shall be meet the following requirements. (I) the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K is not more then 0.24Bq/g. (II) the absorbed gamma dose rate is not more then 0.16μGy/h.

4.2.2. The Radioactive Tailings or Residue Deposit

When the activity concentrations is greater than 7.4×10^4Bq/kg ,the Natural materials was treated as radioactive waste have been proposed by several investigators. on the contrary, the Natural materials was not treated as radioactive waste. For security reasons, after the NORM was exploited, radioactive waste was enriched,the coefficient of enrichment is ten times, then the activity concentrations is greater than 7.4×10^3Bq/kg, Uranium and radium are in equilibrium, so

(I) the activity concentrations is greater than 1.232Bq/g.

(II) the Additional absorbed gamma dose rate is not more then 0.5μGy/h at 0.1m above the ground level.

(III) the Additional absorbed gamma dose rate is not more then 0.3μGy/h at 0.3m above the ground level.

4.2.3. The Products of NORM

The relationship between the radiation dose rate 0.1m above the ground level and

The activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, then Number of indices dealing with the assessment of the excess gamma radiation arising from building materials.

(I) the activity concentrations is greater than 0.24Bq/g.

(II) the Additional absorbed gamma dose rate is not more then 0.17μGy/h at 0.1m above the surface level.

(□) the Additional absorbed gamma dose rate is not more then 0.15μGy/h at 0.3m above the surface level.

4.2.4. Requirements for Exemption of the Radioactive Materials or Its Product

When Requirements for exemption were fulfilled. the radioactive materials or its product will be processed into building materials or other is totally unrestricted.

When Requirements of the radioactive materials or its product for exemption were fulfilled. the radioactive Tailings or residue deposit will be processed into other products is totally unrestricted.

5. Results

The essay is based on the γ radiation dose rate under the measured environment or material surface at different heights, Requirements for control of the radioactive materials and the radioactive Tailings or residue deposit or its product,which shall be meet the following requirements.

①Definition of the NORM: if the external hazard index ($H_{ex}\geq1$) or The alpha index(I_a) ≥1,then It needs to be managed according to the corresponding requirements.

② Definition of the radioactive Tailings or residue deposit or its product: if the external hazard index ($H_{ex}\geq1$) or The alpha index(I_a) ≥1,then It needs to be managed according to the corresponding requirements.the influence factors or parameters of radiation level was understanded, so that Definition about the NORM and the radioactive Tailings or residue deposit, then whether it can be directly processed into building materials.On the classification of the management and control index classification,building materials come form the NORM and the radioactive Tailings or residue deposit was only Researched.but it is no consider that the management and control of operation, accident and retirement,it is will be in the future Work in progress.

The author declares that there are no actual or potential conflicts of interest in this article,

Human Ethics and Consent to Participate declarations: not applicable.

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