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Evaluation of Natural Radioactivity and Radiation Hazard of Different Kind of Egyptian Kaolin

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Abstract: *The natural radionuclides (238U, 226Ra, 232Th and 40K) content of different kind of Egyptian kaolin has been determined by a gamma ray spectroscopy system using a high purity germanium detector. Twenty Kaoline samples were collected from four different areas (Tushka, kalabsha, El-Esila and El-Shallal). Radium equivalent, gamma radioactivity level index, radiation exposure rates and radiation doses were measured due to external exposure to the kaoline gamma ray. Excess life time cancer risk (ELCR) was calculated. Total excess life time cancer risk (ELCR) was found to be high due to high natural radioactivity concentrations in different areas which represent radiological risk for the health of the population. The activity ratios between thorium to uranium concentration for all samples were calculated (232Th/238U) clark's value.*

In this work, the activity concentration of radon 222Rn, radon emanation factor, radon mass exhalation rate and annual effective dose from radon in these locations of kaolin samples were calculated.

This study reveals in general that all samples are exceeding the world permissible safe criteria and consider a risk source for human environment.

Keywords: *Kaoline rock, Natural Radioactive, HPGe Detector, Radiological hazard, Radon Exhalation.*

1. INTRODUCTION

Kaolinite is a clay mineral with the chemical composition $Al_2Si_2O_5$ $(OH)_4$. It is a layered silicate mineral. Rocks that are rich in kaolinite are known as china clay or kaolin. It is a naturally occurring weathered product characterized by its white color that may be changed by impurities. It is formed by decomposition of alumina –silcate minerals, especially feldspars **(Adagunodo, T.A., et al., 2018)**.

Kaolin is one of the most important industrial minerals because, Kaolinite is white or near – white in color to its chemical composition. Kaolinite has theoretical chemical composition of 39.8% alumina, 46.3% silica and 3.9% water**.** Kaolinite is soft. Pure kaolin is refractory and melts at a temperature of about 185°C. These properties make kaolin a very important ceramics raw material **(Aras, A., et al., 2016)**. Kaolinly is widely used in paper industry, refractory bricks, white cement, textiles, rubber medical industries, and special types of plastics, It is also used in most paints and inks. Commercial grades of kaolin are supplied and transported as dry powder, semidry noodle or liquid slurry.

A more recent, and more limited, use is as a specially formulated spray applied to fruits, vegetables, and other vegetation to repel or deter insect damage **(Aras, A., et al., 2016).**

2. EXPERIMENTAL METHOD

2.1. Geologic Setting

Kaolin deposits in Egypt are found in southwest of Aswan at Kalabsha and Tushka, bounded by latitudes 23° 24ō N and longitudes 30 °23ō E.

Kaolin ore in Kalabsha and Tushka area are found as alternating beds (plastic and non plastic) exposed on the surface or hidden beneath small thicknesses of over burden in a wide area of the southwestern desert **(Walley, N., et al., 2004)**.

The ore is also found in other localities in Egypt in sinai, the ore is found as alternating beds with thick sand stone beds as in Abu zeneima.

In Sinai, kaolin occur interbeded with sandstones in several areas. The studied areas are located in central west Sinai to the east northeast, and southeast of Abu zeneima city, 120 Km east south of suez. The studied areas south Abu zeneima includes the following sites El Esila and El Shallal . Wadi El Shallal is located at latitude 28° 25◌ N and Longitude 33° 21◌ E, wadi El Esila lies in central Sinai, near the eastern side of the Guff of suez, about 25 Km to the north east of Abu zeneima city.

2.2. Sampling and Sample Preparation

Twenty samples of kaolin ore were collected from different area for the study. Five samples from each location. Samples (1-5) were collected from Tuska, samples (6-10) were collected from Kalabsha, samples (11-15) were collected from wadi El-Esila and samples (16-20) were collected from wadi El-Shallal.

The samples were crushed using a laboratory jaw crusher and then placed for drying at 110◦C for 20-24 hours to remove the moisture. The samples were sieved through 200 mesh size, and weighted the samples after placed in polyethylene bottles of 250cm^3volume. Each sample was sealed using adhesive in order to avoid any possibility of out gassing of radon from them.

All samples were stored in a sealed container for about one month to achieve radioactive secular equilibrium between ^{238}U and ^{232}Th and their corresponding daughters to be measured by gamma spectrometry. This step was necessary to ensure that radon gas is confined within the volume and the daughters will also remain in the sample **(A. Estokova and L. Palascakova, 2013)**

2.3. Instrumentation and Calibration

A high resolution gamma-ray spectrometry based on a germanium detector of vertical closed-end coaxial manufactured by ORTE of sensitive volume of 76.11 cm3. The energy resolution of HPGe detector is 1.9 KeV.at 1332.5 gamma 60Co transition. The quantitative and qualitative analysis was achieved by using a Maestro (EG&G) card which was interfaced with IBM Pc compatible to work as a multi-channel analyzer (MCA).

To reduce the gamma rays background, cylindrical lead shield with a fixed bottom and movable cover shielded the detector were used. The Lead shield contained two inner concentric cylinders of copper and cadmium to prevent interference of X-rays by lead.

All gamma measurement were determined after calibrating the MCA with 241Am, 60Co and 226 Ra standard point gamma ray sources, which emit known gamma ray energy lines (EML, 1990).

Absolute efficiency calibration curves were calculated for activity determination of the sample by using standards 232Th and 238U with activities of 1332.96 and 2120.37 Bq respectively, contained in the same cylindrical bottles as the samples (IAEA,1987).

The standards and the samples were prepared with a uniform geometry. In order to determine the background distribution in the environment around the detector, an empty bottle was counted in the same manner and geometry as the samples. The background spectra were used to correct the areas of gamma rays for measured isotopes. The quality assurance of the measurements was carried out by daily energy calibration and repeating each sample measurements, the samples were counted for a period of 70000 second and the spectra are analyzed for the photo peak of uranium and thorium daughter products and 40K.The activity concentrations were calculated as follow 226Ra concentration was determined by measuring the gamma peak of 186 (3.3%), the 238U concentration was determined by measuring the 295.1 (19.2%) and 352 (37.2%) KeV gamma rays from 214Pb and 609.3 (46.1%) and 1120.3 (15.1%) KeV gamma rays from 214 Bi. The 232Th activity was determined from the gamma peaks of 238.6 (43.6%) KeV from 212 Pb, 911.2(29.0%) and 969.0 (23.2%) KeV from 238Ac. Also 40K concentration was measured from its 1460 (10.7 %) KeV gamma line (Raghu. Y. et al, 2015).

The activities were determined from measuring their respective decay daughters. The activity concentrations were calculated from the intensity of each line taking into account the mass of the sample, the branching ratios of the γ-decay, the time of counting and the efficiencies of the detector (Papaefthymiou and Psichoudaki , 2008) .

3. RESULTS AND DISCUSSION

Activity concentrations of ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K in Egyptian kaolin samples are presented in Table (1). In Tushka area, the activity concentrations of ^{226}Ra in the range from 82.7 to115.4 Bq kg^{-1}, ^{238}U in the range from 78.4 to 109.5 Bq kg^{-1}, ^{232}Th in the range from 130.63 to 175.4 Bq $kg^{-1}$and ^{40}K in the range from 12.8 to 38.8 Bq kg^{-1}. Kaolin obtained from Kalabsha area, the activity concentrations of

^{226}Ra in the range from 45.1 to 59.5 Bq. kg^{-1}, ^{238}U in the range from 41.4 to 46.35 Bq kg^{-1}, ^{232}Th in the range from 74.96 to 91.13 Bq kg^{-1}and ^{40}K in the range from 30.1 to 38.4 Bq kg^{-1}. Kaolin obtained from EL-Esila area, the activity concentrations of ^{226}Ra in the range from 32.3 to 57.2 Bq kg-1, ^{238}U in the range from 30.35 to 54.35 Bq kg^{-1}, ^{232}Th in the range from 51.9 to 78.36 Bq kg^{-1}and ^{40}K in the range from 9.92 to 20.7 Bq kg^{-1}. Kaolin obtained from EL-Shallal area, the activity concentrations of ^{226}Ra in the range from 89.7 to 120.2 Bq kg^{-1}, ^{238}U in the range from 81.35 to 109.7 Bq kg^{-1}, ^{232}Th in the range from 42.46 to 75.1 Bq kg^{-1}and ^{40}K in the range from 7.5 to 17.4 Bq kg^{-1}.

The permissible levels **(UNSCEAR, 2010)** for ^{226}Ra, ^{238}U, ^{232}Th and ^{40}K are (32, 33, 45 and 412) Bq kg^{-1}**.**

The activity ratios of ^{226}Ra/^{238}U >1 (Table 1) for most samples are showed equilibrium around unity.

In this work the activity concentration of ^{238}U and ^{232}Th in kaolin samples (in ppm) and activity ratio (clark's value) ^{232}Th/^{238}U were calculated illustrated in (table 2). In Tushka area, the ^{232}Th/^{238}U ratios range between 3.66 and 5.88. In Kalabsha area, the ^{232}Th/^{238}U ratios range between 5.21 and 6.77. In El-Esila area, the ^{232}Th/^{238}U ratios range between 4.12 and 6.13. In El-Shallal area, the ^{232}Th/^{238}U ratios range between 1.49 and 2.10.

Table1. *Activity Concentrations in Bq.Kg^{-1} of ^{226}Ra ^{238}U, ^{230}Th, ^{40}K in Egyptian kaolin samples.*

Sample No.		^{226}Ra Bq. Kg^{-1}	^{238}U Bq. Kg^{-1}	^{230}Th Bq. Kg^{-1}	^{40}K Bq. Kg^{-1}	^{226}Ra/^{238}U
Tushka	1	85.3	80.25	150.26	13.2	1.062
	2	97.2	92.25	175.4	29.1	1.053
	3	115.4	109.5	130.63	29.8	1.053
	4	82.7	78.4	145.8	12.8	1.054
	5	90.1	81.95	156.93	38.8	1.099
Kalabsha	6	50.8	41.4	91.13	38.4	1.227
	7	46.2	42.05	76.83	29.2	1.098
	8	45.1	43.15	74.96	30.1	0.943
	9	59.5	46.35	78.66	35.5	1.283
	10	54.3	42.65	85.3	37.7	1.273
EL-Esila	11	42.9	39.3	78.36	9.92	1.091
	12	57.2	54.35	78.2	10.5	1.052
	13	32.3	30.35	51.9	20.7	1064
	14	43.9	39.1	52.46	15.1	1.122
	15	50.1	38.65	74.6	10.2	1.296
El-Shalal	16	91.5	90.15	44	8.9	1.014
	17	89.7	81.35	42.46	7.5	1.102
	18	120.2	109.7	75.1	17.4	1.095
	19	90.6	86.75	56.16	8.5	1.044
	20	110.5	103.8	55.13	12.1	1.064
P.L		32	33	45	412	

Table2. *Activity concentration of ^{238}U and ^{232}Th in Egyptian kaolin samples. (in ppm) and ^{232}Th/^{238}U ratio Clark's value.*

Sample No.		^{238}Uppm	^{232}Thppm	^{40}K%	^{232}Th/^{238}U
Tushka	1	6.47	37.19	0.67	5.74
	2	7.43	43.41	0.092	5.84
	3	8.83	32.33	0.095	3.66
	4	6.32	36.08	0.040	5.70
	5	6.60	38.84	0.123	5.88
Kalabsha	6	3.33	22.55	0.122	6.77
	7	3.39	19.01	0.093	5.60
	8	3.28	18.55	0.096	5.65
	9	3.73	19.47	0.096	5.21
	10	3.73	19.47	0.096	5.21
EL-Esila	11	3.16	19.39	0.0316	6.13
	12	4.383	19.356	0.0316	4.41
	13	2.447	12.846	0.0661	5.26
	14	3.153	12.985	0.048	4.12
	15	3.116	18.465	0.0325	5.93
El-Shallal	16	7.27	10.891	0.0284	1.49
	17	6.56	10.509	0.023	1.60
	18	8.846	18.589	0.055	2.10
	19	6.99	13.90	0.0271	1.98
	20	8.370	13.646	0.0386	1.62

Most of samples are higher than the Clark's value (3.5), which indicates that these areas are enriched in thorium but in El-Shallal area samples are lower than the Clark's value (3.5), which indicates that these areas are enriched in uranium.

The radium equivalent activity (Ra_{eq}) was used to compare the radiological effects of the kaolin samples in different Egyptian areas. The index compares the activities of materials containing different amounts of radium, thorium and potassium. The index is based on the estimation that 370 Bq. Kg^{-1} of ^{226}Ra, 259 Bq. kg^{-1} of ^{232}Th and 4810 Bq. kg^{-1} of ^{40}K produce the same gamma-ray dose rates, and therefore Ra_{eq} can be written as:

$$\mathbf{Raeq = C_{Ra} + 1.43\ C_{Th} + 0.077C_K} \quad \mathbf{(1)}$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K in Bq. kg^{-1}, respectively. The maximum value of Ra_{eq} must be less than 370 Bq. kg^{-1} in order to keep the external dose to be less than 1.5 mGy. y^{-1} **(Ababneh , et al , 2010).**

Based on their Ra_{eq} values, most the kaolin samples examined produce radiation levels considered safe for dwelling and workplace. Table (3) compares the reported values of radium equivalent activities for Kaolin in different areas of the Egypt with those determined in this study.

The gamma-rays emanating from kaoline samples can pose a health hazard. This is usually given in terms of the external hazard index, H_{ex} **(Jankovic**, **et al 2008);**

$$\mathbf{H_{ex} = C_{Ra}/370 + C_{Th}/259 + C_K/4810} \quad \mathbf{(2)}$$

H_{ex} should be less than unity. The obtained for the external hazard index were found to lie in the range of 0.789 and 0.945 for the Tushka area, for the kalabsha area, the values ranged between 0.405 and 0.497. For the El-Esila area, the values ranged between 0.291 and 0.537. For the El-Shallal area, the values ranged between 0.215 and 0.538.

The activity index or gamma index I_γ of the samples is found from the following Equation **(Ademola J. A., 2009):**

$$\mathbf{I_\gamma = C_{Ra}/300 + C_{Th}/200 + C_K/3000} \quad \mathbf{(3)}$$

Where C_{Ra}, C_{Th} and C_K are the activity concentrations of ^{226}Ra, ^{232}Th and ^{40}K, respectively in Bq. kg^{-1}.

I_γ should be less than unity. The obtained for the radioactivity level index were found lie in the range of 2.01 and 2.42 for Tushka area, for kalabsha area, the values ranged between 1.04 and 1.27. For El-Esila area, the values ranged between 0.74 and 1.36. For El-Shallal area, the values ranged between 0.55 and 1.36.

The absorbed gamma dose rates in air at 1 m above the ground surface for the uniform distribution of radionuclides (^{238}U, ^{232}Th and ^{40}K) were calculated by using equation:

$$D = 0.427*C_U + 0.662*C_{Th} + 0.043*C_K \text{ (nGy/h)} \quad \mathbf{(4)}$$

Where C_U, C_{Th} and C_K are the activity concentration of ^{238}U, ^{232}Th and ^{40}K in Bq/kg, respectively. Most values of the Dose rate calculated during present study are found higher than the permissible level of 59 nGy/h **(Abd El-Halim et al ., 2017) .**

The annual outdoor effective dose (E_{out}) is estimated from the outdoor external dose rate (D_{out}), time of stay in the outdoor or occupancy factor (OF = 20 % of 8760 h in a year) and the conversion factor (CF = 0.7 $Sv.Gy^{-1}$) to convert the absorbed dose in air to effective dose. During the present study, the E_{out} was calculated using the following equations from **(UNSCEAR, 2010)**:

$$E_{out} = D_{out}\ (nGy\ h^{-1}) * 0.2 * 8760\ h * 0.7\ (Sv * Gy^{-1}) \times 10^{-6} \quad \mathbf{(5)}$$

The values of the most studied samples listed (in table 3) are found higher than the world's average 0.07 mSv/y**.**

3.1. Excess Lifetime Cancer Risk (ELCR)

The value of annual effective dose excess lifetime cancer risk (ELCR) was calculated by using the equation:

$$ELCR_{out} = E_{out} * LE * RF \quad \mathbf{(6)}$$

where E_{out} is the annual effective dose , LE life expectancy (66 years) and RF (Sv^{-1}) is risk factor per Sievert, which is 0.05 . Table (3) most values are higher than the permissible level 0.29 * 10^{-3} **(Qureshi, 2014)**

Table3. *The values of radium equivalent (Bq/kg), radioactivity level index , external hazard, the outdoor absorbed rate (nGy/h), outdoor annual effective dose (mSv/y) and outdoor Excess lifetime cancer risk in Egyptian kaolin samples.*

Sample No.		Raeq	Igamma	Hex	D(out)	E(out)	ELCR (out)* 10^{-3}
Tushka	1	301.18	2.08	0.813	134.30	0.164	0.543
	2	350.26	2.42	0.945	156.75	0.192	0.634
	3	304.49	2.09	0.822	134.51	0.164	0.544
	4	292.17	2.01	0.789	130.54	0.160	0.528
	5	317.49	2.19	0.857	140.54	0.172	0.568
Kalabsha	6	184.07	1.27	0.497	79.657	0.097	0.322
	7	158.31	1.09	0.427	70.072	0.085	0.283
	8	154.61	1.07	0.417	69.34	0.085	0.280
	9	174.71	1.20	0.471	73.39	0.089	0.296
	10	179.18	1.24	0.483	76.30	0.093	0.308
EL-Esila	11	155.71	1.07	0.420	69.08	0.084	0.279
	12	169.83	1.17	0.458	75.42	0.092	0.305
	13	108.11	0.74	0.291	48.20	0.059	0.195
	14	120.08	0.82	0.324	52.07	0.063	0.210
	15	198.96	1.36	0.537	66.32	0.081	0.268
El-Shalal	16	153.30	1.04	0.414	68.00	0.083	0.275
	17	181.49	1.23	0.490	63.16	0.077	0.255
	18	199.33	1.36	0.538	97.30	0.119	0.393
	19	191.46	1.30	0.517	74.58	0.091	0.301
	20	79.76	0.55	0.215	81.33	0.099	0.329

3.2. Radon Exhalation Rates

The Radon mass exhalation rates the emanation rate coefficient and the fraction of ^{222}Rn that can diffuse through the raw and building materials is known as the emanation coefficient. The emanation coefficient (C_{Rn}) is a very important radiological index that can be used to evaluate the amount of the ^{222}Rn emanated fraction released from the building raw materials and products containing, naturally occurring radionuclides such as ^{226}Ra in radioactivity equilibrium with its parents. The emanation rate is estimated by measuring gamma rays from the radon decay daughter products, ^{214}Pb and ^{214}Bi. Assuming an equilibrium state:

$$C_{Ra} = C_D + C_{Rn} \quad \textbf{(7)}$$

Where C_{Ra} is the measured activity of ^{226}Ra, C_D is the measured activity of the daughter elements ^{214}Pb (or ^{214}Bi) and C_{Rn} is the estimated activity of ^{222}Rn, which escapes into the surrounding environment. C_{Rn} Can be expressed through the introduction of the radon emanation factor F, which is defined as

$$C_{Rn} = (C_{Ra} - C_D) \times \rho \quad \textbf{(8)}$$

Where ρ is the density of radon (9.73 $kg.m^{-3}$), The introduction of the radon factor F, which is defined as :

$$F = \frac{C_\varepsilon}{C_{Ra}} = \frac{C_{Ra} - C_D}{C_{Ra}} \quad (9)$$

The mass exhalation rate or radon mass exhalation rate is the product of the emanation factor and ^{222}Rn production rate **(Seref and Lüfullah., 2008)** the mass exhalation rate (E_{Rn} in Bq/Kg.S) was determined by the following equation:

$$E_{Rn} = F_{Rn} . A_{Ra} . \lambda_{Rn} \quad (10)$$

Where: A_{Ra} is the specific activity of ^{226}Ra (Bq/Kg) and λ_{Ra} is the decay constant of ^{222}Rn (2.1×10^{-6} S^{-1}).Radon concentration was converted in to an effective dose, because the long standing exposure to high concentration of radon and its progenies may lead to pathological effects like lung cancer. The

effective dose received by workers due to inhalation of radon gas and its decay products, where calculated by relation **[ICRP, 1993]**:

$$AED_{Rn} = \frac{C_{Rn} \times 0.4 \times K \times H}{3700\ Bq.m^{-3} \times 170h} \quad \textbf{(11)}$$

Where AED_{Rn} is the annual effective dose ($mSv.y^{-1}$), C_{Rn} is the emanation coefficient of radon ($Bq.m^{-3}$), K is the ICRP dose conversion factor (5 mSv $WL.M^{-1}$ for occupational worker and 3.88 mSv WLM^{-1} for general public), H is the annual occupancy at the location 2160 h for workers and 7000 h for residents (80 % of total time) and 170 is exposure hours taken for WLM^{-1} (Work Limit in Month) **(Nikl and vegvari,1992).**

Table4 represents the activity concentration of ^{222}Rn, radon emanation factor F, Radon mass exhalation rate and the annual effective dose from radon (AED_{Rn}). The activity concentrations of ^{222}Rn were varied between (28.21 – 68.11) $Bq/m^3$for Tushka area, (42.81 – 119.67) Bq/m^3 for kalabsha area, (14.59 – 126.49) Bq/m^3 for El-Esila area and (13.62 – 108.00) $Bq/m^3$for El-Shallal area (1850.21–10776.65) Bq/m^3. The results indicate low levels of annual effective dose from radon in this location. All the samples in this locality were lower than the maximum permissible dose limits (10 mSv) recommended by **(ICRP, 1993) .**

Table4. *The values of the activity concentration of radon ^{222}Rn (Bq/m^3), radon emanation factor, radon mass exhalation rate and the annual effective dose from radon (AED_{Rn}) in Egyptian kaolin samples.*

Sample No		Ra-226 Bq/kg	Pb-214 Bq/kg	F_{Rn}	^{222}Rn (Bq/m^3)	E_{Rn} (mBq/kg. s)	AED_{Rn} (msv/y)
Tushka	1	85.3	79.9	0.011	52.542	0.19	0.360
	2	97.2	94.3	0.005	28.21	0.18	0.193
	3	115.4	108.7	0.014	65.19	0.2	0.447
	4	82.7	76.3	0.013	62.27	0.27	0.427
	5	90.1	83.1	0.014	68.11	0.49	0.467
Kalabsha	6	50.8	39.8	0.023	107.03	0.32	0.735
	7	46.2	40.5	0.011	55.46	0.18	0.380
	8	45.1	40.7	0.010	42.81	0.04	0.294
	9	59.5	47.2	0.025	119.67	0.03	0.821
	10	54.3	45.1	0.019	89.51	0.06	0.614
El-Esila	11	42.9	39.9	0.006	29.19	0.4	0.2004
	12	57.2	53.8	0.007	33.02	0.12	0.227
	13	32.3	30.8	0.003	14.59	0.19	0.1002
	14	43.9	40.1	0.007	36.97	0.18	0.253
	15	50.1	37.1	0.027	126.49	0.2	0.868
El-Shalal	16	91.5	90.1	0.002	13.62	0.27	0.093
	17	89.7	80.2	0.019	92.435	0.49	0.634
	18	120.2	109.1	0.023	108.00	0.32	0.741
	19	90.6	85.2	0.011	52.54	0.18	0.360
	20	110.5	105.1	0.011	52.54	0.04	0.360

4. CONCLUSION

The study measured the activity concentrations of natural radionuclides ^{238}U, ^{226}Ra, ^{232}Th and ^{40}K by means of gamma ray spectrometry in twenty samples of kaolin are collected from different area. The activity concentration of ^{238}U, ^{226}Ra, ^{232}Th is higher than the world's average, while the activity concentration of ^{40}K is low. All the kaolin samples have the $^{232}Th/^{238}U$ ratio high than clark's value (3.5) which indicates that these area Tushka, Kalabsha and El-Esila are enriched in thorium but in El-Shallal area samples are lower than clark's value which indicates that these area are enriched in uranium. The annual effective dose in outdoor dose (E_{out}) for kaolin sample in different Egyptian area is higher than the world value 0.07 mSV/y. The area under investigation in classified as having a high level of natural radioactivity concentration and can be considered as unsafe area and therefore we can conclude that it is dangerous to use kaolin rocks in this area as a raw material in different industrial work due to their radiation hazard effect. So proper precautions needed to be taken for any measurements. It was found necessary to reduce the radiation risk due to direct gamma- radiation in kaolin to protect the worker from use kaolin in industry and to decrease the environmental impact.

Long-term occupational exposures to kaolinite dust may cause structural and functional damage to the lungs. Due to the obtained results precautions must be taken for people use kaolin in industry to protect against high radioactivity. The annual effective dose from radon (AED_{Rn}) of all samples in this locality were lower than the maximum permissible dose limits (10 mSv), because this areas are enriched in thorium.

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