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Research Paper

Determination the Index of Radioactive Risk In The Batang Kuantan River

Rindi Genesa Hatika[1], Indang Dewata[2], Alizar[3], Purwo Subekti[4], Saiful Anwar[5]

[1]Physics Education Study Program, Universitas Pasir Pengaraian, Indonesia
[2,3]Faculty of Math and Science Universitas Negeri Padang, Indonesia
[4,5]Faculty of Engineering, Universitas Pasir Pengaraian, Indonesia
**Corresponding author E-mail: rindigenesa@gmail.com*

Abstract

NORM is a material containing radioactive elements that exist naturally. All minerals and raw materials contain radionuclides from nature, most important for radiation protection purposes are the U-238, Th-232 and K-40 decay series. This element naturally grows and is considered a major contributor to the annual individual background radiation dose. Therefore, each individual can be exposed to NORM through various activities they do, one of which is gold mining activities. Gold mining in addition to causing exposure to NORM, is believed also can cause significant environmental damage. This study aims to determine the index of radioactive risks that resulted from gold mining activities in the batang kuantan river. The sample used for this research is soil from batang kuantan river which then analyzed using gamma ray spectrometry. The results show that the index of radioactive risk value indicated by all soil samples in the batang kuantan river is still below the predetermined maximum limit value.

Keywords: *NORM, Soil, Gold Mine, Gamma Spectrometry*

1. Introduction

NORM is a material found in an environment containing radioactive elements derived from nature. All minerals and raw materials contain radionuclides from nature, most important for radiation protection purposes are U-238, Th-232 and K-40 decay series. This element grows in nature and is considered a major contributor to the annual individual background radiation dose. NORM is often found in its original state in stone or sand, but can also be found in consumer products such as building materials (stone, cement), tiles, granite, tobacco products and phosphate fertilizers [1].

Mining has been identified as one of the potential sources of NORM exposure [2]. As a result, need for basic studies prior to prior to commencement of mining activities and subsequent studies conducted to ensure level of these radio nuclides turned out as a result of mining activities in the operational phase of the mine [3].

Related research on Assessment of Public Exposure to Natural Radioactive Material (NORM) In Gold Mining Activity in Indonesia, very little done, so the information related to the existence of NORM contained due to gold mining activity is very limited. In fact, if left unchecked, it will have a negative impact on human health and nature conservation. Therefore, this study was conducted to determine the index of radioactive risk in the gold mining activity in the Batang Kuantan river. Batang Kuantan River, located in Sijunjung Regency, is believed to have a wild gold mine which is located around the waters of the river [4].

Gold mining in the Batang Kuantan River is illegal gold mining conducted by the surrounding community, so it may not know about the existence of NORM in their activity. In the absence of this knowledge, it allows the public to be exposed to NORM radiation beyond the prescribed minimum limit. Mining results can cause soil and water to become contaminated.

2. Methodology

This research was conducted along the Batang Kuantan River, West Sumatra. This river, located in the Sijunjung Regency, is believed to have a jungle gold mine located around the river waters. There are 4 specified sample locations using the Global Positioning System (GPS) tool aid. The samples used in this study are soil samples. Soil samples were then analyzed using gamma ray spectrometry.

A. Specific Activity Concentration

Gamma ray spectrometry is used to determine the type of radionuclides present in the sample. Each sample collected weighed 1000 grams and, was then dried in the oven at 110 ° C for 24 hours. The sample was then mashed and sieved using a sieve of 200 μm.

The sample used was 200 μm in size, place in bottle and weighed. The bottle was sealed for 4 weeks to achieve a secular balance, then in the sample bottle is counted for 12 hours [5].

B. *The Index of Radioactive Risk*

In determining the index of radioactive risk is done by determining the radium equivalent activity, absorbed dose, gamma radiation risk index and annual effective dose.

1. Determination of the Radium Equivalent Activity

Radium Equivalent Activity (Raeq) is the actual activity level of 238U, 232Th and 40K in soil samples. This yields the weighted

amount of radionuclide activity with an estimate that 370 Bq/kg of 226Ra, 259 Bq/kg of 232Th and 4810 Bq/kg of 40K will produce the same dose of gamma radiation level. Each of these natural radionuclides produces an effective dose of 1.5 mGy per year. This value is considered the maximum acceptable dose by society from exposure to natural radiation from the soil [6].
In determining the radium equivalent activity (Raeq) use the following equation[7]:

$$Raeq = ARa + 1.43\ ATh + 0.077\ AK \quad (1)$$

Where ARa, ATh, AK is the activity of 226Ra, 232Th and 40K (Bq kg^{-1}). The value to be found should be less than 370 Bq to be neglected by the dangers of radiation [2].

2. Determination of Absorbed Dose
The absorbed dose rate derived from external gamma radiation can be calculated through the concentration of activity in the soil. The dose level is absorbed outdoor in air because terrestrial gamma rays at 1 m above ground level are calculated from concentrations of 226Ra (238U), 232Th and 40K in soil [8].
The effects of gamma radiation are usually expressed in dose levels absorbed in the air. Absorbed dose (D) is a gamma radiation in the air at a height of 1 m from the surface to equalize the distribution of natural radioactive materials or commonly abbreviated as NORM ie 226Ra, 232Th and 40K [9]. The equation used to determine D are:

$$D=0.462ARa+0.604\ ATh + 0.0417\ AK \quad (2)$$

Where ARa, ATh, AK is the activity of 226Ra, 232Th dan 40K. The dose coefficient in units of nGy · h^{-1} per Bq · kg^{-1} is taken from the UNSCEAR report.

3. Determination of Risk Index Gamma Radiation and the Annual Effective Dose
In determining the gamma radiation risk index (Iγr), the equation used is:

$$I\gamma r=0.0067ARa+0.01ATh+0.00067AK \quad (3)$$

Where ARa, ATh, AK is the activity of 226Ra, 232Th and 40K.
The dose absorbed in the air does not present a direct radiological risk. Therefore, the annual effective dose is used to assess the radiological risk. So D is converted to AED by using conversion coefficient and external occupancy factor [6].
The annual effective dose (AED) received by someone calculated using variable factor of 0.7 Sv Gy-1, which is used to convert absorbed dose to effective dose [10]. The equation used to determine the AED is [11]:

$$AED=D \times 8760\ hr \times 0.2 \times 0.7SvGy^{-1} \times 10^{-6} \quad (4)$$

Where,
AED is an Annual Effective Dose (mSv)
D is the dose calculated (nGy hr^{-1})
8760 is the time in hours for one year
10^{-6} is the factor converting from nano to mili.

3. Results and Discussion

A. Specific Activity Concentration
Gamma ray spectrometry is used to determine the type of radionuclides present in soil samples. The sampling machine used is the Gamma Ray Spectrometry belonging to BATAN (National Nuclear Power Agency). The results of determining the specific activity of radioactive elements in soil samples are shown in Table 1.

Table 1: Radioactive Activity in Soil Samples

Sample Code	Radionuclide	Activity (Bq/Kg)
T1	Ra-226	109,77 ± 7,08
	K-40	713,33 ± 9,02
T2	Ra-226	106,41 ± 3,32
	K-40	690,48 ± 8,47
T3	Ra-226	35,22 ± 0,77
	K-40	883,35 ± 7,92
T4	Ra-226	88,13 ± 7,25
	K-40	714,45 ± 8,15

Table 1 shows the radioactive activity of Ra-226 and K-40 elements in soil samples in batang kuantan river. In the T1 sample the activity of the elements Ra-226 and K-40 was 109.77 ± 7.08 Bq/Kg and 713.33 ± 9.02 Bq/Kg. The activity of Ra-226 and K-40 elements in T2 sample is 106,41 ± 3,32 Bq/Kg and 690,48 ± 8,47 Bq/Kg. In T3 sample also found activity of element Ra-226 and K-40 is equal to 35,22 ± 0,77 Bq/Kg and 883,35 ± 7,92 Bq/Kg. While activity of element of Ra-226 and K-40 in sample of T4 is 88,13 ± 7,25 Bq/Kg and 714,45 ± 8,15 Bq/Kg.

Table 2.: Comparison of NORM activity concentration in soil sample in the study area with other study

Country	Sample	Specific Activity Concentration (Bq/Kg)			Reference
		238U	232Th	40K	
India	Soil	46	68	635	[12]
Turkey	Soil	35	37	430	[13]
Ghana	Soil	64,3	68,4	1243,9	[14]
Indonesia	Soil	84,9	-	750,4	This study
UNSCEAR (2000)	Soil	35	30	400	[2]

The average value of radioactive activity in soil samples in this study with other countries is shown by Table 2. The value of specific activity concentration on the sample of soil in batang kuantan river for element 238U (226Ra) and 40 K exceeds the world-defined limit in UNSCEAR is 84,9 $Bq.Kg^{-1}$ for 238U (226Ra) and 750,4 $Bq.Kg^{-1}$ 40K element. While in UNSCEAR the maximum allowable limit for the 238U element (226Ra) is 35 $Bq.Kg^{-1}$ and for the 40K element is 400 $Bq.Kg^{-1}$. Exposure pathway for public exposure in gold mining environment comes from Direct external gamma ray exposure from natural radioactivity concentrations in soil due to 238U, 232Th and 40K.

B. The Index of Radioactive Risk
In determining the radioactive risk index on the soil samples in batang kuantan river which are illegal gold mining areas is done by determining radium equivalent activity, absorbed dose, gamma radiation risk index and annual effective dose.
1. The Radium Equivalent Activity
The equivalent activity of radium in soil samples in batang kuantan river is shown in Table 3.

Table 3.: The Radium Equivalent Activity in Soil Sample

No	Sample	Raeq($Bq.Kg^{-1}$)
1	T1	164,70
2	T2	159,58
3	T3	103,24
4	T4	143,14
	Mean	142,67

In Table 3, it can be seen that the Raeq value on soil samples in batang kuantan river is in the range of 103.24 to 164.70 $Bq.Kg^{-1}$ with an average value of 142.67 $Bq.Kg^{-1}$. The highest Raeq value is found in T1 sample with value 164,70 $Bq.Kg^{-1}$, then T2 sample with value 159,58 $Bq.Kg^{-1}$, T4 sample with value 143,14$Bq.Kg^{-1}$ and sample T3 with value 103,24 Bq.Kg-1.

Table 4. Comparison of Raeq in Indonesia sample and other countries

Country	Sample	Raeq($Bq.Kg^{-1}$)	Reference
South Africa	Soil	880,9	[15]
Nigeria	Soil	230,72	[16]
Ghana	Soil	69,09	[17]

Indonesia	Soil	142,67	This study
UNSCEAR (2000)	Soil	<370	[2]

The radium equivalent activity (Raeq) in soil in the batang kuantan river does not exceed 370 $Bq.kg^{-1}$, which is the maximum allowable limit for radiation dose [2]. It can be concluded that land in this area may not pose a radiological health risk to the community. The comparison of Raeq in soil sampel from this research with other country is shown in Table 4.

2. Absorbed Dose (D)

The absorbed dose (D) represents gamma-ray radiation in the air at a height of 1 m from the surface to equalize the distribution of natural or normally abbreviated NORM materials ie 226Ra, 232Th dan 40K [9]. The absorbed dose for soil samples in the batang kuantan river is shown by Table 5.

Table 5. Absorbed Dose in Soil Sample

No	Sample	Absorbed Dose ($nGy.h^{-1}$)
1	T1	80,46
2	T2	77,95
3	T3	53,11
4	T4	70,51
Mean		70,51

Table 5 shows that the dose absorbed in soil samples in batang kuantan river ranged from 53.11 to 80.46 $nGy.h^{-1}$ with an average of 70.51 $nGy.h^{-1}$. The highest absorbed dose value was generated by T1 sample with value 80,46 $nGy.h^{-1}$, then T2 sample with value 77,95 $nGy.h^{-1}$, T4 sample with value of 70,51 $nGy.h^{-1}$ and T3 sample with value 53.11 $nGy.h^{-1}$.

The comparison between absorbed dose in this research with the maximum limit from UNSCEAR is shows that the absorbed dose in the three soil samples are higher than the worldwide avarege of 60 $nGy.h^{-1}$[2]. In addition, the average absorbed dose in soil samples is also higher than that defined by UNSCEAR.

3. Risk Index Gamma Radiation (Iγr) and Annual Effective Dose (AED)

The risk index gamma radiation was used to estimate the gamma radiation hazard associated with natural radionuclides in the sample [16]. Annual effective dose(AED) received by a person is calculated using a factor variable 0.7 Sv Gy^{-1}, which is used to convert the absorbed dose to the effective dose [10]. The risk index gamma radiation and Annual effective dose (AED) in soil sample in the batang kuantan river is shown by Table 6.

Table 6. Risk Index Gamma Radiation in Soil Sample

No	Sample	Iγr	AED (mSv)
1	T1	1,21	0,099
2	T2	1,18	0,096
3	T3	0,83	0,065
4	T4	1,07	0,087
Mean		1,07	0,087

Table 6 shows that the risk index gamma radiation (Iγr) in soil sample in the batang kuantan river is in the range of 0.83 to 1,21 with an avarage 1,07. An increasing the risk index gamma radiationthat is large than the world standard causes the risk of radiation that can cause cancer [18].

The annual effective dose (AED) in soil samples in batang kuantan river in table 6 shows that AED in soil ranged from 0.065 to 0.099 mSv with an average of 0.087 mSv. The highest AED value is shown by T1 sample with value 0,099 mSv, T2 sample with value 0,096 mSv, T4 sample with value 0,087 mSv and the lowest is on T3 sample with value 0,065 mSv.

The comparison of the annual effective dose value with the maximum value limit set by the ICRP is shown that the average of annual effective dose value in soil samples in the batang kuantan river is still below the justified maximum value of 1 mSv [19].

Therefore, all samples meet safety criteria for ordinary people and do not pose many health hazards. This dose limits have stated that even below the dose limit, it will still have a slight effect. Which means that any addition of dosage, it will increase the increase of possible effects on health.

4. Conclusion

The results show that the index of radioactive risk value indicated by all soil samples in the batang kuantan river is still below the predetermined maximum limit value

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