Content lists available at www.jacsonline.org/D176750082-LROR/ JACSONline GP, DOI:10.22341

Journal of Applied Chemical Science

Journal homepage: www.jacsonline.org/journals/jacson/

The Radioisotope Strengths of the Mineral Deposits in Lands of the West Timor Island-Indonesia

Bartholomeus Pasangka^{*1}, Kirbani Sri Brotopuspito², and Abdul Wahid¹

¹Department of Physics Faculty of Sciences and Engineering Nusa Cendana University, Kupang 85001, INDONESIA;

²Department of Physics/Geophysics Faculty of Mathematical and Natural Sciences, Gadjah Mada University, Yogyakarta, INDONESIA

Article history: Draft reached journal: 27-09-2016 Received in revised form: 28-05-2017 Accepted: 05-06-2017

Cite this article as: Pasangka B, Brotopuspito KS, and Wahid A. 2017. The Radioisotope Strengths of the Mineral Deposits in Lands of the West Timor Island-Indonesia. J Applied Chem. Sci. 4: 330-337, DOI: <http://doi.org/10.22341/jacson.00401p330>

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ABSTRACT

The objective of this work was to investigate the radioisotope distribution and centered accumulation in mineral deposits in lands of West Timor Island. The procedures consisted of observation and identification of the potential regions and planning the plot gridding, calibration of necessary equipments, measurement of counting background around the survey location and the nuclear radiation in the survey location, planning the plotting of three-dimensional curves and contours. Based on geology information (drilling data), the three depth levels (about 20 m, 40 m and 60 m) were determined. Radiation powers were calculated to estimate the accumulation centers of the radioisotopes in mineral deposits. Thereafter, the contour and three-dimensional curves of radiation powers of the radioisotopes were plotted. Based on three-dimensional curves and contour mapping of the radioisotopes, the radiation counts and radiation powers of those three land depth levels were found at a width area of $3.00 \times 10^6 \text{ m}^2$ and $1.56 \times 10^4 \text{ m}^2$, respectively. The interval of radiation counts of radioisotopes in the mineral deposit were 10 to 137 counts per min. **In conclusion:** the strengths of the radioisotope decays of the mineral deposits from the land areas of the West Timor Island of Indonesia are in range of 14,400 to 197,280 counts per day.

Keywords: Measurement, radioisotope, mineral, deposits

*Corresponding author: bpasangka15@gmail.com, Tel./fax: (0380) 881597/ 881557, HP: (+62)82237044338

1. Introduction

The decay of the radioisotope or radioactivity was an incident caused by the changing process in the unstable atomic nucleus with processing goes on spontaneous. The nucleus stabilization of an atomic was established by a combination of proton and neutron number. The stable light elements have ratio N/Z equal to 1.00, while the stable heavy elements have N/Z until 1.50 ($1.0 < N/Z \leq 1.5$). On the changing process, N/Z is change accompanied with alpha and beta emission and followed with gamma emission. The emission event of radiation accompanied with electron capture was called radioactive decay (Krane, 1988). The spontaneous change of elements can directly produce the stable daughter (single decay) and can also on a series process like as series of Uranium and Thorium decay (series decay). Both the radioactive decays process fulfills the continual equation:

$$N = N_o e^{-\lambda t} \dots\dots\dots (1)$$

$$N_n = C_1 e^{-\lambda_1 t} + C_2 e^{-\lambda_2 t} + \dots\dots + C_n e^{-\lambda_n t} \dots\dots (2)$$

$$\text{Where: } C_1 = \frac{\lambda_1 \lambda_2 \dots\dots\dots \lambda_{n-1} N_1^o}{(\lambda_2 - \lambda_1)(\lambda_3 - \lambda_1)(\dots\dots\dots)(\lambda_n - \lambda_1)},$$

$$C_2 = \frac{\lambda_1 \lambda_2 \dots\dots\dots \lambda_{n-1} N_1^o}{(\lambda_1 - \lambda_2)(\lambda_3 - \lambda_2)(\dots\dots\dots)(\lambda_n - \lambda_2)}, \text{ etc.}$$

N was the number of atomic elements after the decay during t time, N_o was the number of initial atomic elements, t was the length of decay time (in second), λ was decay constant.

The layer composition of the earth's crust consists of the earth's outer crust, cover, and mantle which can be characterized of solid, liquid, and gas. The solid material was called rocks in the composition of minerals. Based on it's formed, the rocks consist of igneous, sedimentary, and metamorphic rocks. The composition of rocks on the earth surfaces generally was dominated by sedimentary rocks that approximately 66% on the surface, extrusion rocks 8%, intrusion rocks 9%, and metamorphic rocks 17% (Munir, 1996). The rocks composition was created simultaneously by the natural radioisotopes at the time of the earth and universe forming. The primordial radionuclides that have been present simultaneously with forming of the earth and

rocks, generally, consist of Potassium-40 and a row of nuclide as a product of radionuclide decay occurred in natural like as series of Uranium ($4n+2$), Thorium ($4n$), and Actinium ($4n+3$). The others primordial radionuclides were found in natural included Rb-87, La-136, Lu-176, Ln-115, Re-187, and C-14 (Munir, 1996). Burnett (1986) give an expression that the abundance of radioisotopes such as Potassium, Thorium, and Uranium can be found in the several kinds of rocks i.e. as meteorites, Terrestrial that consist of Olivine Hornblende, Plagioclase (Granite), and Basalt. Furthermore, Langford (1987) proposes the accumulation of the Uranium, and many other radioisotope elements were existed within several rock minerals as *Pegmatites*, *Carnotite*, *Tazin Gneiss*. The research result from Hanson et al. (1987) give the report that the anomaly of radioisotope element deposit was accumulated at the *alluvial* area which is rich of Granite, *Carnotite*, *Tyuyamunite*, Asphaltic Sandstones, Moccasin Creek Gypsum, Carbonate, and generally in sedimentary rocks. Accumulation anomaly of radioisotope deposit within the rock's mineral physically was influenced by the several factors include depth, the permeability of rocks, rainfall, flow dynamic, and association with non-radioisotope rocks (Huang, 1988). These factors are unique for the Timor Island.

The position of Timor Island is approximately located on 8° - 11° south latitude and 123° - 126° east longitude in East Nusa Tenggara Indonesia. The region of Timor Island is rich with any kinds of mining mineral like the natural gas, petroleum, geothermal, iron, coal, and tin/lead (A group minerals), aluminum, gold, silver, nickel, copper, manganese, and radioisotope (B group minerals), limestone, sulfur, barite, gypsum, marble, granite, and dolomite (C group minerals). Our pre-survey gave a result that radiation counts and specific activities of radioisotope in deposit mineral in West Timor-subdistrict of middle Kupang-respectively were 32 to 138 counts per min and $1.4 \times 10^{-5} \mu\text{Ci}$ - $6.20 \times 10^{-4} \mu\text{Ci}$ (Pasangka, 2003). Radioisotope content in mineral deposit at these regions was estimated to occur since Timor Island formed. The forming of Timor Island resulted of uplift caused by a collision between Banda Arc and Continental Australian Shelf on the processing of tectonic (Hamilton, 1981).

Numerous authors suggest that rocks association and structure in the Timor Island were originally uplift a part of Continental Australian Shelf deformation, and others masses enclosed up to cover of all rocks in Timor Island (Audley-Charles et al. 1972; Gageonnet et al. 1958; Grunau 1953, 1957; Hamilton, 1981). From this case can be proposed that radioisotope in mineral deposit in Timor Island was directly involved with earth material that came from continental Australian Shelf. The accumulation of radioisotope in rocks mineral caused by several migrations processes like as migration of radioisotope during formation of the earth's zonation, migration during tectonic activity (migration

during orogeny, migration via volcanic activity), migration via *taphrogeny*, and migration via hydrothermal solutions.

Radioisotope was an energy source on Electric Generator of Nuclear Power. Currently is considering that energy source from petroleum will more decrease on future time. The nuclear power planning has been begun on 1997 which will be developed in Indonesia located at Jepara Middle Java. Therefore, this report has a meaningful function in line with the Government planning. The research was to investigate the accumulation center and distribution of radioisotope in mineral deposits. The specific problems inspected were distribution of radioisotope in mineral deposit in the land of west Timor Island, estimates the accumulation center of radioisotope in mineral deposits, and counts the range of nuclear radiation at the center region of the radioisotope. The research procedure was conducted by mapping the distribution of radioisotope in the mineral deposit, estimating area of accumulation center of radioisotope in the mineral deposits, and establishes a range of nuclear radiation at the center region of radioisotope in mineral deposits.

There were two steps on radiometric survey i.e observation step and field survey step. Observation was to identify the regions that potentially contain the radioisotope and state the area where the most potential area as the survey location (Bell and Dlouhy, 1994, ElBaradei and Na, 2004, ElBaradei et al., 2006). Fields survey was started on local area appropriate to survey location which has been chosen and then expanded for regional mapping. Local survey was proposed to accurately identify distribution anomaly of radioisotope in mineral deposit. The region area for the local survey was only several kilometers square (Johnson, 1984., Bell and Dlouhy, 1994). Radiometric survey on local state was done on foot with using Geiger-Muller portable detector. Radiation counts in units counter per min. This equipment detects total counts (alpha, beta, and gamma radiation) from radioisotope sources. Gamma radiation was an electromagnetic wave in order that it was easy to be measured. Radioisotope radiation was detected at 100 feet distance (approximately 30 meters) above source surface with using airborne survey (Johnson, 1984). Measurement of radiation count can be done based on measure point on each line (grid) which had been planned to obtain the best mapping on survey location. Actually, measurement of radiation counted on the radiometric survey was done randomly according to the author (Johnson, 1984). The radiometric local survey was expanded for regional mapping and continuously expanded for more areas of the region. Target reconstruction of rock mineral was predicted based on the profile of content anomaly of radioisotope in the mineral deposit, in generally appropriate with magnetic anomaly profile of rock (Telford et al., 1976., Aiken et al., 1981). For dry region and relatively homogeneous rock structure, content anomaly profile of radioisotope in the

mineral deposit, in generally, appropriate with temperature anomaly profile produced by the decay of radioisotope. If radioisotope Uranium contained in the mineral deposit with a composition of U_3O_8 , standard classification characteristics for ore deposit quality (ore grade deposit) were low if $< 0.15\%$ U_3O_8 , middle: 0.15% up to 0.50% U_3O_8 , and high if $> 0.50\%$ U_3O_8 (Dahlkamp, 1989).

Based on those facts and reports, the hypothesis of the research was composition and distribution of radioisotopes in the mineral deposits, contents of radioisotope in accumulated center of the rock minerals and the range of radiations counted were higher than prospect standard.

2. Materials and Procedures

2.1. Materials

Radioisotope distributed in mineral deposits. The main instruments (Laboratory of nuclear Physics Faculty of Sciences and Technology Nusa Cendana University) used in this research consist of Portable Geiger Muller Counter, GPS, Computer with surfer 11 and MATLAB software, and others add equipment.

2.2. Experimental procedures

The methods were used in the research comprises of observation/ surveying, mapping, analysis, and interpretation. Detail procedures of research as follow: 1) prepare and calibrate Geiger-Muller counter with using Cs-137 standard on energy 662 keV. The Geiger Muller Counter was calibrated on count was 1050 counts per min, 2) observe for determining measurement points and measurement lines (gridding), 3) measure background counts around field survey to correct of field data, 4) measure count of radioisotope in mineral deposit, 5) contour and three-dimensional curves of radioisotope content in mineral deposit plot, 6) plot profile curve based on contour slice for geometry modeling to calculate radiation power, 7) calculate radiation power of radio-isotope content in mineral deposit with using MATLAB program and matrix formula, 8) plot contour and three-dimensional curves of radiation power, 9) interpret and conclusion. Distribution and accumulation of radioisotope in the mineral deposit was estimated with plotting profile curve and contour of modeling. The target modeling of radioisotope content was cleared with to paint a profile of contour slice on several directions. Target modeling was done with earlier or previous to estimate the depth of radioisotope content based on geology information. The average depth of radioisotope content in mineral deposit estimated 20 m (previously geology information). Furthermore, to calculate radiation power (P keV/s) may be in mutual accord with a profile of field data. In this case used MATLAB program and source point model. The calculation of radiation power was taken three layers of rock mineral with depth respectively 20 m, 40 m, and 60 m. The distance of measurement points in the research location was 85 m and distance of measurement lines was 400 m. The distance of

measurement points in the center region of deposit was 10 m and the distance of measurement lines was 40 m.

2.3. Statistical analysis

Estimation of distribution and accumulation of radioisotope in deposit mineral was based on the plotting of contour and three-dimensional curves from the calculation result of radiation power of radioisotope radiation. Radiation powers of radioisotope were calculated with previously estimating the depth of radioisotope content in mineral deposit based on geology information (drilling data). The average depth of radioisotope content in the mineral deposit was estimated 20 m (previously geology information). Furthermore, to calculate radiation power (P keV/s) used MATLAB program and taken three layers of mineral deposit with depth respectively 20 m, 40 m, and 60 m. The construction of ore deposit anomaly of radioisotope was estimated with using the principal that nuclear radiation of radioisotope source emitted to all directions. Furthermore, the construction form consists of a small ball. Accumulation of radioisotope in the mineral deposit was shown by the unions of all small balls. For calculating of radiation power of radioisotope in the mineral deposit was began with plotting profile curve from contour slice of radiation counts. The depth of ore deposit of radioisotope can be determined by using the equation:

$$d = F \left(X_{\frac{1}{2}} \right) \dots\dots\dots (3)$$

Where: d is the depth of ore deposit, $X_{1/2}$ is the half value of x maximum anomaly profile of ore deposit, F are geometry factors. $F = 1.990$ for ball, and $F = 1.000$ for infinite (Telford, 1986). Radiation power calculated with using several geometry mathematic models (Fig. 1 for one dimension, Fig. 3 for three dimensions):

$$P = I_o (4\pi r_o^2 e^{\mu r_o}) \dots\dots\dots (4)$$

$$P = I_n (4\pi r_n^2 e^{\mu r_n} = I_n [4\pi (r_o^2 + x_n^2)] e^{\mu r_n} \dots\dots\dots (5)$$

$$\text{Where: } r = \sqrt{r_o^2 + x_1^2} \text{ and } r_n = \sqrt{r_o^2 + x_n^2}$$

If a region with topography was not flat, topography correction use geometry model on Fig.2.

$$P = I_o (4\pi r^2 e^{\mu r}) \dots\dots\dots (6)$$

where: $d = r = r_o + d_1$, d_1 and i_n is measured with altimeter, $r_n = r_i + r_d$.

$$P = I_n (4\pi r_n^2 e^{\mu r_n}) \rightarrow (r_d + r_i)^2 = [(x_n + x_p)^2 + (r_o + d_n)^2]$$

$$P = I_n [4\pi (x_n + x_p)^2 + (r_o + d_n)^2] e^{\mu r_n} \dots\dots\dots (7)$$

$$P = I_o (4\pi r_o^2 e^{\mu r_o}) \dots\dots\dots (8)$$

$$P = I_n (4\pi r_n^2 e^{\mu r_n}) = 4\pi I_n (r_o^2 + x_n^2) e^{\mu r_n} \dots\dots\dots (9)$$

$$P = I_{do} (4\pi r_{do}^2 e^{\mu r_{do}}) = 4\pi I_{do} (r_o^2 + y_n^2) e^{\mu r_{do}} \dots\dots (10)$$

$$P = I_{dn} (4 \pi r_{dn}^2 e^{\mu r_{dn}}) = 4 \pi I_{dn} (r_o^2 + D_n^2) e^{\mu r_{dn}} = 4 \pi I_{dn} [r_o^2 + (y_n^2 + x_n^2) e^{\mu r_{dn}}] \dots\dots\dots (11)$$

Where: $r_{do}^2 = r_o^2 + y_n^2$, $r_n^2 = r_o^2 + x_n^2$, $D_n^2 = y_n^2 + x_n^2$, $r_{dn}^2 = r_o^2 + D_n^2$, $r_n^2 = d^2 + x_n^2$

For determining of radiation power decided several points (for example 10 points) on the profile of field data with certain counts. *P* was calculated by using matrix MATLAB program. *P* can be calculated by matrix formula:

$$\begin{pmatrix} P_1 \\ P_2 \\ \vdots \\ P_n \end{pmatrix} = \begin{pmatrix} G_{11} & G_{21} \dots G_{m1} \\ G_{12} & G_{22} \dots G_{m2} \\ \dots & \dots \dots \dots \\ G_{1n} & G_{2n} \dots G_{mn} \end{pmatrix}^{-1} \begin{pmatrix} C_1 \\ \dots \\ C_n \end{pmatrix} \dots\dots\dots (12)$$

Where: *G* was a variable defined by:

$$(G) = \frac{1}{4 \pi r_{mn}^2 e^{\mu r_{mn}}} \dots\dots\dots (13)$$

Where: μ is absorption coefficient of matter or medium. In this case was taken the average of the absorption coefficient of the medium was 0.5 (approach).

3. Results and Discussion

3.1. Measurement result

The radiation power calculated using geometry mathematic models according to Eq. 4 and 5 reported continually at Fig. 1 and Fig. 3 (Fig. 1 for one dimension, while Fig. 3 for the three dimensions).

Fig. 1. The continual geometry model calculated from radiation power on elevation or altitude correction

Fig. 2 Geometry model calculates radiation power on topography correction

Table 1 shows measurement results of nuclear radiation counts of radioisotope in mineral deposit at sub-district of middle Kupang West Timor Island, which appropriated with a total area of survey location. Radiation counts of radioisotope in mineral deposit ranged between 10 counts per minute up to 137 counts per minute. There was 43 (18.86%) data of radiation counts was lower than standard counts (33 cpm) and 185 (81,14%) data of radiation counts was larger than standard counts.

Fig. 3 Geometry model in three dimensions calculates radiation power on elevated correction

Fig. 4 Geometry model calculates radiation power based on profile curve

3.2. Curves and profile plotting

Based on data in Table 1, contour and three-dimensional curves of radiation counts were plotted like as shown in Fig. 5 and Fig. 6. Fig. 7 show profile curve of radiation counts of radioisotope in mineral deposit with plotting from AB and CD contour slices on Fig. 5. High radiation counts were distributed to north direction of survey location dominated by sedimentary rocks (*alluvial*) and the low radiation counts were distributed to south direction of survey location dominated by sandstone and *metamorphic* rocks. This case appropriates with the theory of composition of radioisotope in rocks mineral.

Fig. 5 Contour map of radiation counts of radioisotope in mineral deposit

Fig. 6 Three-dimensional curves of radiation counts of radioisotope in mineral deposit

Fig. 7 Profile curves of radiation counts of radioisotope in mineral deposit based on AB and CD contour slice

3.3. Determination of radiation intensities

From the profile, the curve was determined radiation intensities which appropriated with radiation counts of radioisotope in mineral deposit and included in Table 2. Based on geology data (previously research of drilling), the composition of radioisotope in deposit mineral was located on depth 20 meters from land surface.

3.4. Calculation and plotting of contour and three dimension curves of radiation power

Table 3 shows calculation results of radiation power for 60 points according to equation (12) on three layers (20 m, 40 m, and 60 m) and use MATLAB program. For estimating of accumulation center of radioisotope in mineral deposit has been plotted contour and three-dimensional curves of radiation power and shown in Fig. 8

Table 1. Measurement results of radiation counts in the region of radioisotope source at Sub-district of Middle Kupang West Timor Island

No	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19
	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm
L ₁	55	47	27	42	41	47	44	62	60	61	59	47	56	61	41	40	68	49	41
L ₂	37	38	39	30	56	44	53	55	61	56	69	63	40	47	60	71	49	63	55
L ₃	26	33	15	21	34	59	42	93	74	68	69	81	95	81	114	98	78	107	98
L ₄	23	15	31	16	27	48	42	25	29	35	49	48	46	59	71	52	66	45	49
L ₅	26	19	53	42	41	53	51	47	65	48	41	42	38	61	67	63	57	67	45
L ₆	28	36	47	39	18	21	33	48	23	32	45	47	51	48	52	59	64	66	61

Continue Table

No	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36	37	38
	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm	cpm
L ₁	41	22	53	48	47	58	37	56	47	35	37	36	41	19	34	21	15	17	19
L ₂	67	42	75	55	47	63	77	39	33	26	19	29	25	18	32	26	33	23	28
L ₃	77	89	79	109	117	137	105	126	86	58	45	48	46	37	37	37	43	39	26
L ₄	82	55	68	52	53	46	43	45	33	38	32	34	41	38	28	29	25	17	21
L ₅	41	44	36	49	47	42	55	27	18	58	37	24	33	38	17	24	17	28	15
L ₆	63	47	50	69	57	48	43	65	49	40	55	31	42	47	10	13	19	15	21

Where: (L₁, L₂, L₃.....L₆ were measurement lines, cpm was count per minute)

Table 2. Radiation intensities (C keV/m²s) were determined from the profile curves which appropriated with radiation counts of radioisotope in mineral deposit on three layers (20 m, 40 m, 60 m)

C	1	2	3	4
1	37	77	46	107
2	55	99	43	94
3	69	83	78	98
4	27	41	148	49
5	69	58	99	48

C	1	2	3	4
1	158	105	84	171
2	55	109	65	182
3	218	115	123	165
4	167	81	189	85
5	112	63	213	56

Continue

C	1	2	3	4
1	57	145	51	57
2	49	205	56	61
3	112	155	58	82
4	83	121	24	72
5	167	79	43	56

Table 3. Calculation results of radiation power (P keV/s) for 60 points according to equation (10) on three layers and MATLAB program

P	1	2	3	4
1	0.52	0.52	0.72	1.15
2	0.31	0.54	0.58	1.48
3	0.31	0.28	2.23	1.07
4	0.26	0.87	0.84	0.78
5	1.33	0.46	1.58	0.57

P	1	2	3	4
1	0.88	0.83	0.94	1.67
2	0.67	0.86	0.87	2.34
3	0.68	0.51	2.56	1.23
4	0.29	1.14	0.96	0.93
5	2.24	0.76	2.36	0.94

Continue

P	1	2	3	4
1	0.91	0.87	1.35	2.49
2	0.65	1.14	1.19	2.67
3	0.76	0.58	2.96	2.38
4	0.34	1.68	1.52	1.28
5	2.55	0.66	2.87	1.24

Fig. 8 Contours of radiation power for Estimating of accumulation center of radioisotope in mineral deposit

Fig. 9 Three-dimensional curves of radiation power for estimating of accumulation center of radioisotope in mineral deposit

and Fig. 9. Distribution and accumulation center of radioisotope content in the mineral deposit was estimated from this profile curve and contour of radiation power. The measured data of the radiations counted in the region of radioisotope source are stated in Table 1.

The measurement results of radiation counts in the region of radioisotope source at Sub district of Middle Kupang West Timor Island radioisotope in mineral deposit was estimated $4.5 \times 10^6 \text{ m}^2$ (1,500 m x 3,000 m) and accumulation center of radioisotope content in mineral deposit estimated to be distributed on area $6 \times 10^4 \text{ m}^2$ (200 m x 300 m) with depth range 20 m up to 60 m which detected. Accumulation of radioisotope in mineral deposit initially follows of basic rocks layer dominated by *Tersier* sediment rocks from Permian to Jurassic which forms of Timor Island. The new accumulation of radioisotope in the mineral deposit

was formed by tectonic processing that causes faulting, folding, and dynamic motion of rocks. The content of radioisotope detected in the mineral deposit was very small, if it observed on the surface, except there was a large accumulation on the layer in more depth. The prospecting of radioisotope content in mineral deposit for exploration was necessary espoused by others data like as drilling data, gamma logging, magnetic, and seismic data which can give information on layer thickness, the depth of rocks mineralization, and the total form of content accumulation of rocks mineralization.

4. Conclusion

The distribution of radioisotope content in mineral deposit based on contour map, three-dimensional curves of field data of radiation counts, and contour map, three-dimensional curves of radiation power of radioisotope

estimated on area $4.5 \times 10^6 \text{ m}^2$ (1,500 m x 3,000 m) and accumulation center of radioisotope content in mineral deposit estimated $6 \times 10^4 \text{ m}^2$ (200 m x 300 m) with depth range 20 m - 60 m. The range of radiation counted in the center region of radioisotope content in mineral deposit 10 to 137 counts per min.

Acknowledgements

This research was supported and funded by Department of Mining East Nusa Tenggara Indonesia. Special thanks to all colleagues in English Training Centre who have helped to authors in technical writing of this manuscript.

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Conflict of interest: Non declare