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ASSESSMENT OF RADIOACTIVE ELEMENTS IN THE RAMU NICKEL AND YANDERA MINING SITES OF PAPUA NEW GUINEA RELATED TO RADIATION POLLUTION OF THE ENVIRONMENT

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ABSTRACT

Radioactive elements present in the soil emit radiation of different types that poses a threat for human life. Mining waste and residues create environmental pollution and these have to be properly monitored and managed. Measurement of ambient radiation doses and determination of radionuclides in the mining waste and soil were performed in six riverside locations of Ramu Nickel and Yandera mining sites in Usino Bundi district of Madang and in a nearby place, Lae, in Morobe Province, Papua New Guinea. The average dose rate in air in the mining sites and in Lae have been calculated and it was observed that the annual dose rate in the mining site varies from 0.9 mSv/y to 1.1 mSv/y whereas in Lae, it is only 0.78 mSv/y. The outdoor dose rate was found to vary from 126.8 mGy/y to 155.4 mGy/y and the indoor dose rate was found to vary from 507.2 mGy/y to 621.7 mGy/y in the mining sites. The soil samples were analyzed using NaI(Tl) gamma ray spectrometer. Radioactive elements Ca^{45}, I^{129},Hg^{203}, Cr^{51}, Au^{198}, Fe^{59}, Co^{60}, Ti^{201}, Cd^{109}, Bi^{214} and Sc^{47} were observed to be slightly higher in the mining area compared to that observed in nearby sites. Though radioactivity level in the mining sites is slightly higher, it is well below the global standards.

KEY WORDS : Mining waste, Radiation pollution, Radio nuclides, effective dose

INTRODUCTION

The earth is estimated to be around 4.54 billion years old. Surrounding the earth is its atmospheric layers and with solid earth made up of crust, mantle and core. The crust layer consists of over one hundred radioactive elements and stable elements. The naturally occurring radionuclides when undergoing decay process to become stable, release significant amount of radiation energy which contributed to elevation in the level of natural background radiation dose. The chief contributor to the rise in natural background around the globe are the low levels of radionuclides Potassium, Uranium and Thorium with decay products of the latter two more prominent and account for approximately 50% of natural radioactivity. The concentration varies from location to location around the world depending on the soil structure and texture.

About 82% of humans are exposed to the natural radiation internally (Shahbazi Gahrouei *et al.,* 2013) and around the globe, these naturally occurring radionuclides are found in soil, water and vegetation (National Research Council, 1999; Kandari *et al.,* 2015). The average annual effective dose globally from both natural background and man-made per person in 2000 was 2.8072 $mSvy^{-1}$, from which 2.400 $mSvy^{-1}$ is from naturally occurring radionuclides (UNSCEAR, 2000).

The independent state of Papua New Guinea is located in the south-west region in the southern hemisphere with GPS Coordinates, Latitude**:** -6° 15' 52.52" S, Longitude: 148° 57' 49.85" along the pacific ring of fire. The country of rugged mountains and complex geology is prospectivelyrich in natural resources including deposits of gold, copper, oil, gas, nickel and vast renewable sources such as hot springs and hydro. The country has mining

operations both large and small scale mines distributed all over the country with more recent discoveries of large deposits of earthen minerals all over. In the extraction process of mining, fetching of soil and materials to the surface elevate crustal radionuclides to biosphere hence elevate ionization radiation to the inhabitants. There has not been any research and publications of the natural environmental background radiation to establish a baseline data of high quality for a long-term measurements of natural environmental radioactivity for the whole country.

In this paper, we analyzed the background radiation level of the mining site of Ramu Nickel and Yandera in the Usino Bundi district of Madang Province in Papua New Guinea. We compared these results with the radiation level of a nearby place in Morobe province. We also identified radioactive elements present in these locations.

MATERIALS AND METHODS

Study Area

Fig. 1 shows the mapped out Madang province in Papua New Guinea and location of Ramu Nickel mine and Yandera Gold mine Usino Bundi District. The Fig. 2 shows the six locations of UsinoBundi District where the soil samples were collected for analysis in this work. The sampling site extends from 7°0′0" to 7°22′0" South latitude and 146°30′0" to 146°50′0" East Longitude. The study area is along six main rivers. Kwainumu, Panu and Anangari are the main tributaries that originate from dump site of Nickel mine and Imbrum is the main tributary that originate from the dump site of fully developed Gold mine.

This study area has a population of over 61,000 inhabitants (2011 national census) with total land area of 7,687 km^2 and density of 10 per km^2. The area is under the influence of a tropical climate with two seasons, rainy and sunny interchangeably, with soil Sandy loam soil type and sedimentary rocks. There have not been any past studies on natural radioactivity in this study location.

Instruments and Measurement Technique.

The LB 2045 NaI(Tl) Gamma Spectrometer is a modular design half 19 inch system that can detect a very low gamma activityof 10keV is used for counting gamma rays in processed soil,food and

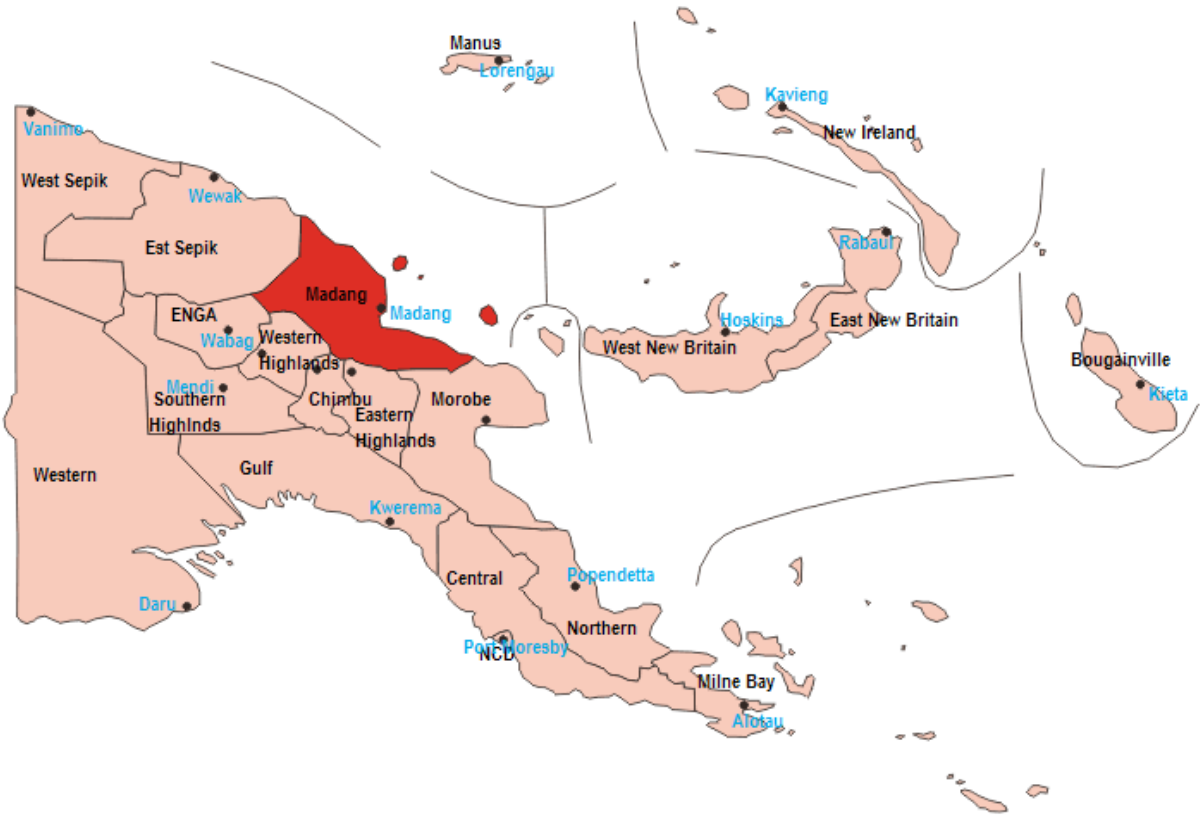

Fig. 1. Map of Madang Province of Papua New Guinea where observation has been done.

water samples. The basic version is comprised of computer unit, graphical display with touch panel and a power supply unit. The data acquisition is done via the measurement electronics with additional two plug-in cards, a high voltage unit with preamplifier (BE 0002) and an ADC for spectrum recording (BE0104). The measurement of radiation dose in air was at a distance of 1.0 m above the surface of the soil where the samples are collected using SOEKS Quantum Professional GM pocket survey meter. The locations of sample collection was done using Garmin eTrex® 30x GPS with Digital Compass. The coordinates were later plotted into the map of the sampling area using aGIS Plotter system and shown in Fig. 2.

Sample Preparations

A total of 18 soil samples were collected from 6 locations using the American Society for Testing and Materials (ASTM C998-17) Standard Practice for Sampling Surface Soil for Radionuclides. (IAEA Report 486-2001). Three samples per location on average distance of 15 metres apart, from which two of the locations are non-mining sites. The samples were packed in 200 ml plastics bags and taken to laboratory in the Applied Physics Department for processing and analysis. The soil samples were dried over a period of 5 to 7 days to remove all moisture content using normal fluorescent bulb and filtered with a mesh of dimensions 1mm x 0.5 mm. The fine particles are then filled into a 20 ml marenelli beaker,weighed, labeled and then kept for a minimum period of 30 days for the radio nuclides progeny to reach equilibrium. After the minimum period of 30 days, the processed samples in containers were slotted into a shielded well chamber of the NaI(Tl) scintillator for counting of gamma rays of radionuclides in the samples. The period of counting was set at 12 hours and counting period was automated by the detector. If the statistical error is less than 1%, the counting stops automatically. Two windows were used at a time for two different radionuclides whose energy range do not overlap. The counts are integrated over the energy range and compare with the authentic in the detector library which has 25 samples and ROI Values are displayed on the read out.

Dose Rate Calculations and Activity Concentrations

The average yearly effective dose rate was estimated from absorbed dose rate by applying the conversion factor of 0.70 $SvGy^{-1}$ and outdoor occupancy factor of 0.2 and indoor occupancy factor of 0.80.

Yearly outdoor exposure formula

$$E_{.} = D_R . T. K_1 .G_1 \quad .. (1)$$

where DR- Dose rate in micro Sievert per hour in air at 1.0 m, T = time in hours in one year (8,766), K_1 = dose conversion factor(0.70) and G_1 = outdoor occupancy factor (0.20).

Yearly indoor exposure formulae:

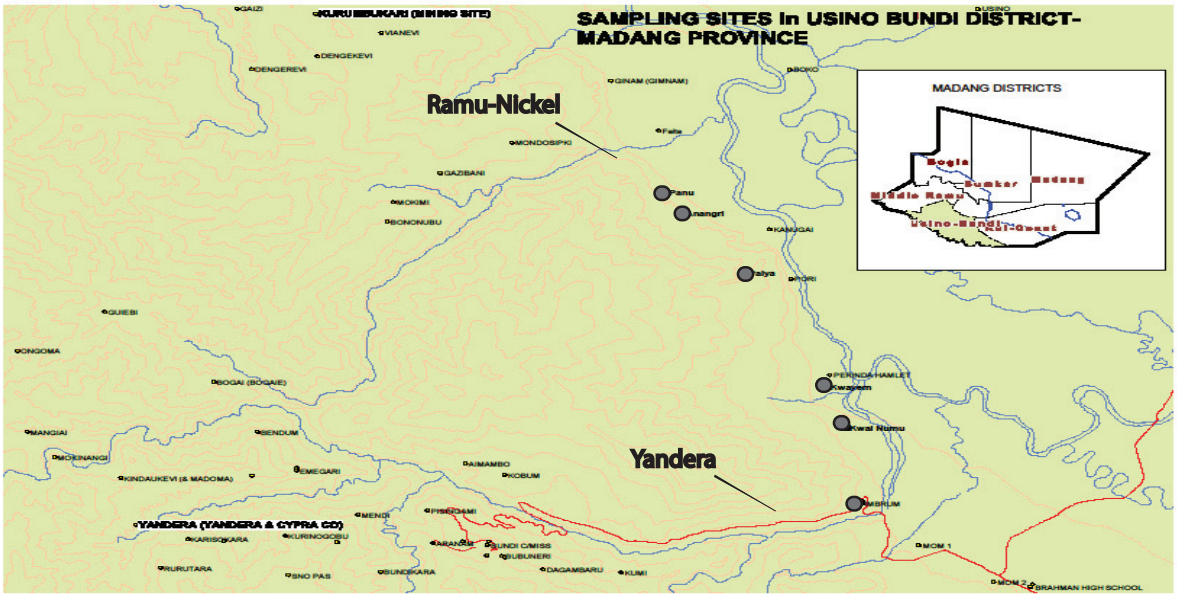

Fig. 2. Locations of sample observations in UsionoBundi marked in red colour. Mining waste dumping sites are also shown.

$E' = D_R . T. K_2 .G_2$ .. (2)

where D_R- Dose rate in micro Sievert per hour in air at 1.0 m, T = time in hours in one year (8766), K_2 = dose conversion factor (0.70) and G_2 = indoor occupancy factor (0.80).

RESULTS AND DISCUSSION

The results in Table 1 shows ambient dose rate in counts per minute (cpm) and microsievert per hour (μSv/hr) measured at a distance of 1 m directly above the surface which soil sample were collected, latitude and longitude.

The average dose rate in air in Ramu-Nickel mining site is 0.902 mSv/y and in Yandera Gold mine site, the average dose rate in air is 1.103 mSv/y (Table 2). These results are then used to estimate the yearly outdoor and indoor rates from environment sources of ionization radiation from radioactive elements mainly in the soil collected from the area using equations (1) and (2). The estimated values give the average effective outdoor dose rate and indoor dose rate as 126.81 μGy/y and 507.25 μGy/y respectively in Ramu-Nickel mining site and 155.44 and 621.79 μGy/y respectively in Yandera mining site.

Soil samples were collected from Lae in a nearby province called Morobe, at a distance of about 200 km from the mining site and the dose rate is estimated. The average dose rate in Lae is observed to be 0.788 mSv/y and the outdoor and indoor effective dose rates are calculated as 110.45 and 441.8 μGy/y respectively. Therefore this study established that the average effective dose rate is 1mSv/y external exposure which is less than 2.4 mSv/y global average for rocks and soil samples. Therefore, there is no risk at this point in time of any biological effect due to whole body exposure from natural background radiation.

The major radionuclide composition of the soil samples was analyzed. Table 3 indicates the activities of eleven radio isotopes, their energy ranges and their specific activity present in the soil samples.

The sample results show radionuclide composition of soil as given in Table 3. The samples indicate activities of eleven radioisotopes, their energy range and their Specific Activity (Bq/kg) for the study area. The specific activities of the radionuclides range from 0.05(Bq/kg) for ^{60}Co, to 1.16550 (Bq/kg) for ^{45}Ca.

Therefore this study established that average annual effective dose rate of1.0 ± 0.13mSv/y external exposure is much less than 2.4 mSv/y global average for rocks and soil samples. In this area of Ramu-Yandera area the individual dose limit is below 2.4mSv/yr for which members of the public should not be exposed to ICRP-60(1990). Therefore there is negligible or no risk at this point in time of any biological effect due to whole body

Table 1. Gamma measurements in air and estimated yearly Outdoor and Indoor Exposure in Ramu Nickel,Yandera Mining sites and in Lae

Location	Latitude	Longitude	cpm	μSv/h	Outdoor Annual Eff. Dose(μGy/y)	Indoor Annual Eff. Dose(μGy/y)
Ramu-Nickel	5.73335	145.31683	20.9	0.11	134.9	539.9
	5.68342	145.31671	20.9	0.10	122.7	490.9
	5.66672	145.30021	17.4	0.10	122.7	490.9
Yandera	5.60010	145.26688	17.4	0.12	147.3	589.1
	5.56676	145.25006	19.2	0.13	159.5	638.2
	5.55018	145.23356	18.4	0.13	159.5	638.2
Lae	6.7155	146.9999	20.9	0.09	110.5	441.8

Table 2. Average Dose Rate in air and estimated yearly Outdoor and Indoor Exposure in Ramu Nickel and Yandera Mining sites and in Lae.

Location	Latitude	Longitude	cpm	Average Dose Rate (mSv/y)	Outdoor Annual Eff. Dose(μGy/y)	Indoor Annual Eff. Dose(μGy/y)
Ramu	5.69	145.31	19.7	0.90	126.8	507.2
Yandera	5.57	145.25	18.3	1.10	155.4	621.8
Lae	6.71	147	20.9	0.79	110.5	441.8

Table 3. Radionuclides with their specific activities in locations separated by a distance of 15 m from each other.

Radionuclides	Energy range(keV)	Activity (Bq/kg)
Calcium 45	10-20	1.16
Iodine 129	20-70	0.13
Titanium 201	130-210	0.12
Mercury 203	200-350	0.18
Cromium 51	220-400	0.18
Gold 198	310-510	0.07
Iron 59	950-1500	0.07
Cobalt 60	1070-1440	0.05
Scandium 47	120-200	0.15
Cadmium 109	60-90	0.30
Bismuth214	500-700	0.29

exposure from natural background radiation.

CONCLUSION

Natural radioactivity is an integral part of the physical world and all living beings are exposed to natural radiations. If the radiation level is greater than the value recommended by the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), it is considered as radiation pollution. There has not been any research and publications carried out to date on natural environmental radioactivity in this part of the Madang Province and Papua New Guinea as a whole. This research work begins with the investigation of the natural background radiation level of Ramu Nickel and Yandera mines in Usion Bundi District. This study established that the average annual effective dose rate in Yandera is 1.1 mSv/y which is slightly higher than that in Ramu-Nickel site where the annual effective dose rate is 0.9mSv/y. The annual effective dose rate in the mining sites is less than 2.4 mSv/y, the global average for rocks and soil samples. These values measured are below the recommended limit by UNSCEAR. There is no harm to the general public as the individual dose limit is below 2.4mSv/yr for which members of the public should not be exposed to ICRP-60(1990). Though there is radiation pollution in the mining sites which is slightly higher than the surrounding regions, there is no risk at this point in time of any biological effect due to the whole body exposure from natural background radiation in this area of study.

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