NATURAL RADIOACTIVITY LEVEL OF PRODUCTS AND BY-PRODUCTS OF ILMENITE PROCESSING INDUSTRIES IN PERAK, MALAYSIA.

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To my beloved family (my lovely mother, father, sisters and brother) for their encouragement and love

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ABSTRACT

Natural background radiation levels in the minerals collected from two tin tailing processing factories at Kinta Valley, Perak, Malaysia were measured. Nine samples were collected analyzed for the activity concentration of the naturally occurring radionuclides and gross alpha and gross beta activities. The activity concentrations of ^{238}U, ^{232}Th and ^{40}K were analyzed by using a HPGe detector. The activity concentration of the samples were found in the range 374 - 13376 Bq $kg^{-1}$for ^{238}U, 842 - 147347 Bq kg^{-1} for ^{232}Th and 96 - 1827 Bq kg^{-1} for ^{40}K. Based on the activity concentration of ^{238}U, ^{232}Th and ^{40}K, gamma absorbed dose rates in air at 1 meter above the ground were calculated using the procedure applied by UNSCEAR 2000. The range of absorbed dose rates calculated was 720 - 95253 nGy $h^{-1}$and the range of annual effective dose rate was 883 - 116819 μSv y^{-1}. The calculated radium equivalent activities (Ra_e) were in the range 1663 – 224223 Bq kg^{-1}. The gross alpha activity of the soil samples were found in the range 5.79 - 220 Bq kg^{-1} and the range of the gross beta activity was 3.97 - 552 Bq kg^{-1}. Finally, the range of the external radiation hazard index was calculated as 4 - 605.

ABSTRAK

Aras sinaran latar belakang semulajadi dalam mineral yang diambil dari dua kilang amang di Lembah Kinta, Perak, Malaysia telah diukur. Sebanyak 9 sampel yang diambil telah dianalisis bagi kepekatan keaktifan radionuklid semulajadi dan kepekatan keaktifan gros alfa dan gros beta. Kepekatan keaktifan ^{238}U,^{232}Th dan ^{40}K telah dianalisis menggunakan pengesan HPGe. Kepekatan keaktifan dalam sampel-sampel tersebut telah ditemui berada dalam julat 374 - 13376 Bq kg^{-1} bagi ^{238}U, 842 - 147347 Bq kg^{-1} bagi ^{232}Th dan 96 - 1827 Bq kg^{-1} bagi ^{40}K. Berdasarkan kepekatan keaktifan ^{238}U, ^{232}Th dan ^{40}K, kadar dos terserap gama di udara pada ketinggian 1 m dari tanah telah dikira menggunakan prosedur yang digunakan oleh UNSCEAR 2000. Julat kadar dos terserap yang dikira adalah 720 - 95253 nGy h^{-1} dan julat kadar dos berkesan tahunan adalah 883 - 116819 µSv y^{-1}. Aktiviti setara radium yang dikira adalah dalam julat 1663 - 224223 Bq kg^{-1}. Keaktifan gros alfa yang ditemui dalam sampel adalah dalam julat 5.79 - 220 Bq kg^{-1} dan julat bagi gros beta adalah 3.97 - 552 Bq kg^{-1}. Akhir sekali,, julat indeks hazad sinaran luaran yang dikira adalah 4-605.

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A	-	activity at time t
A_0	-	initial activity
λ	-	decay constant
$t_{\frac{1}{2}}$	-	Half time
H	-	equivalent dose
D	-	absorbed dose
Wr	-	radiation weighting factor
W_t	-	the tissue weighting factor
v_i	-	Tyre ground contact point velocity at i^{th} wheel
ω_i	-	Tyre rotational speed at i^{th} wheel
F_{xi}	-	Longitudinal tyre force at i^{th} wheel
ALI	-	annual limits of intake
Dl	-	is the relevant annual effective dose limit
H	-	effective dose per unit of intake
DAC	-	Derived Air Concentrations
Xr	-	exposure rate
D	-	distance in meters from the source to the position
Γ	-	specific gamma constant for that particular radionuclide
C_{std}	-	activity concentration of the standard sample
C_{sampl}	-	activity concentration of the sample
W_{std}	-	weight of the standard sample
N_{sampl}	-	net count of the photopeak area for the sample
W_{sampl}	-	weight of the sample
N_{std}	-	net count of the photopeak area for the standard sample

A_{sampl} - activity concentration of the sample

A_{std} - activity concentration of the standard sample

ΔA_{std} - uncertainty of the specific activity

Ra_{eq} - Radium Equivalent

A_{RA} - average activity concentrations of ^{238}U

A_{Th} - average activity concentrations of ^{232}Th

A_K - average activity concentrations of ^{40}K

Dc - absorbed dose rate at 1 m from the ground

CHAPTER 1

1.1 Introduction

Natural substances that are radioactivity are called natural occurring radioactive materials (NORM). Atoms of the substances emit invisible radiation. Usually there are two types of radiation: ionizing radiation and non-ionizing radiation. The ionizing radiations emitted from these atoms are, gamma, alpha, and beta. These radiations can penetrate materials in different levels. The effects of these ionizing radiations can dangerous to the living cells (Lawson, 1999). Nucleus exists only in specific energy levels just like electrons. If the nucleus is not stable it will emit radiation that depends on the difference between the energy levels to reach the stability level. Alpha particles consist of two protons and two neutrons. Beta particles have the same properties of electrons. Gamma ray is electromagnetic waves with high energy. Alpha and beta particles have penetration power weaker than gamma ray. The skin of the human body can block alpha and beta particles. Gamma ray can penetrate the skin and interact with the internal cells causing harm to the tissue in the human body.

Cellular damage can be classified into two types, direct and indirect damage. The direct damage is if radiation interacts with the atoms of the DNA molecule, or some other cellular component critical to the survival of the cell, it is referred to as a direct effect. Such an interaction may affect the ability of the cell to reproduce and, thus, survive. If enough atoms are affected such that the chromosomes do not replicate properly, or if there is significant alteration in the information carried by the DNA molecule, then the cell may be destroyed by direct interference with its life sustaining system.

In Malaysia, there are a lot of mines, production ore, raw gold, iron ore, coal, bauxite, mica, silica and kaolin. Rare earth minerals such as zircon, eliminate and

Struve rite were produced as by-products of tin process (Cohen, 1993). The mining and processing of ores for the production of metals and minerals generate large quantities of residual bulk solid and liquid wastes. Because the minerals of value make up only a small fraction of the ore, most of these bulk minerals has no direct use (Hu et al, 1981). Depending on the original ores and processing methods, some of these wastes contain elevated concentration of Technologically-Enhanced, Naturally-Occurring Radioactive Materials (TENORM). It has been reported that some of uncommon metals have highly radioactive waste products (Myrick et al, 1983). Some processes associated with metal extraction appear to concentrate certain radionuclide and enhance their environmental mobility. In Malaysia, tin ore mining has left large areas of radioactively contaminated spoil heap. Amang is a general term for the byproducts obtained when tin tailings are processed into concentrated ores. It includes minerals such as monazite, zircon, eliminate, rutile, struverit and xenotime (Mireles et al, 2003).

1.2 Statement of Problem

The NORM in the tin mining is an important parameter since the radioactivity harms the human body. The occurrence of the NORM in minerals causes health hazard to a living tissue. Therefore, it is aim of this project to detect activity concentrations of natural radionuclides emitting gamma radiations and the activity of alpha and beta rays radiations. From the activity concentration of natural occurring radionuclides, the radiation hazard can be estimated.

1.3 Objectives of the Study

In this study, to accomplish the aim of determining the radiation hazard to the public leaving close to the factories, the following objectives are outlined:

1. To determine the concentration of naturally occurring radioactivity concentration of ^{238}U, ^{232}Th and ^{40}K of the samples collected from two tin mining factories at Kinta Valley, Perak Malaysia.
2. To determine the activity concentration of gross alpha and gross beta of the samples collected from two factories at Kinta Valley, Perak Malaysia.
3. To assess the radiation hazard to the publics in the area around the factories.

1.4 Scope of the Study

In this study the scopes are following according to the objectives.

1. Samples are analyzed in this study are 9 samples collected from two factories.
2. The activity concentration of ^{238}U, ^{232}Th and ^{40}K measurement by using γ-ray spectrometry using HPGe detector.
3. Gross alpha and gross beta activity concentrations measurement by using Tennelec counting systems.
4. Radiation hazard equation is used to calculate the radium equivalent, dose rate equation is used to determine the dose rate, while equation of annual effective dose rate is used to calculate the annual effective dose rate, AEDR, and to calculate the external radiation hazard equation of the external radiation hazard is used.
5. Evaluate the excremental results according to international standard of radionuclides.

1. 5 Organization of the Dissertation

This thesis consists of five chapters. The first chapter consists of introduction, statement of problem, objectives of the study and scope of the study. Chapter two is the literature review. It covers the work of relevant studies carried out. Chapter three explain the methods and equipment used in the experimental work. Chapter four shows the data obtained from the measurements and graphs. Finally chapter five presents the conclusions of the results and discussion, recommendation and suggestion about the future works are also provided.

REFERENCES

Aigbedion, I., and Iyayi, S. E. (2007). Environmental effect of mineral exploitation in Nigeria. *International Journal of Physical Sciences*, *2*(2), 33-38.

Al-Geed, A. M. M. A., and Sam, A. K. (2000).Radiological evaluation of gold mining activities in Ariab (Eastern Sudan). *Radiation protection dosimetry*, *88*(4), 335-340.

Anagnostakis, M. J., Hinis, E. P., Karangelos, D. J., Petropoulos, N. P., Rouni, P. K., Simopoulos, S. E., and Žunić, Z. S. (2001). Determination of depleted uranium in environmental samples by gammaspectroscopic techniques. *Archive of Oncology*, *9*(4), 231-236.

Anoka, O.C. (1995). *Radioactivity Due to Low Energy Gamma Ray in Jos Tin Mine Tailings*. Bachelor, ObafemiAwolowo University, Ile Ife.

Azlina, M. J., Ismail, B., SamudiYasir, M., and Taiman, K. (2001). Work activity, radiation dosimeters and external dose measurement in amang processing plant. *J. Sains Nuklear Malaysia*, *19*(2), 31-39.

Cameron ,J.R. and Skofronick, J.G. (1978).Medical physics. John Wiley and Sons, New York.

Canberra Industries, Inc. (2001a).*Model LB5500 Low Background Counting System.*Meriden, USA: Eclipse LB User's Manual.

Chiras, D. D. (2001). *Instructor's Toolkit to Accompany Environmental Science: Creating a Sustainable Future*. Jones and Bartlett.

Cohen, S. (1993). Diffuse NORM Wastes-Waste Characterization and Preliminary Risk Assessment, US Environmental Protection Agency Office of Radiation and Indoor Air, Washington, DC.

Enghag, P. (2004). Encyclopedia of the Elements: Technical Data. *History, Processing, Applications, Wiley-VCH, Weinheim.*

Faiz, M. K. (1994). The physics of radiation therapy. Williams and Wilkins, Oxford University Press.

Gentry, R. V. (1973). Radioactive halos. *Annual Review of Nuclear Science*,*23*(1), 347-362.

Gilmore, G. R., and Hemingway, J. D. (2008).Practical gamma-ray spectrometry, John Willey and Sons. *Inc., Chichester, West Sussex, UK*.

Hamby, D. M., and Tynybekov, A. K. (2002). Uranium, thorium, and potassium in soils along the shore of Lake Issyk-Kyol in the Kyrghyz Republic. *Environmental Monitoring and Assessment*, *73*(2), 101-108.

Hasebe, N., Barbarand, J., Jarvis, K., Carter, A., and Hurford, A. J. (2004). Apatite fission-track chronometry using laser ablation ICP-MS. *Chemical Geology*,*207*(3), 135-145.

Heather, A. (2010). *Radioactivity-Nuclear Bombardment Reactions.* Retrieved on March 18, 2014, from http://chem1180.blogspot.com.

HONG, Y. C. 2005. Determination of Radioactivity Levels of Norm in Marine Sand Using Gamma Spectrometer (A Case for Malacca's Coastline).Master, UTM.

Hu S.J, Chong C.S. and Subra S. (198). U and Th in Cassitertes Sample and Amang by-Products, Health Physics, 40,248-250.

IAEA, (1989).*Construction and Use of Calibration Facilities for Radiometric Field Equipment*, Technical reports series No 309. Vienna, Austria.

IAEA. (1989). Measurement of radionuclides in food and environmental samples. *IAEA Technical Report Series 295*. International Atomic Energy Agency, Vienna, Austria.

Ismail, B., Yasir, M. S., Redzuwan, Y., and Amran, A. M. (2003). Radiological environmental risk associated with different water management systems in amang processing in Malaysia. *Pakistan Journal of Biological Sciences*, *6*(17), 1544-1547.

Lawson, R. S. (1999). An Introduction to Radioactivity. *Shieh Physicist, Nuclear Medecine Department, Manchester Royal Infirmary*.

Lee, S. K. (2007). *Natural background radiation in the Kinta District, Perak Malaysia* (master dissertation, Universiti Teknologi Malaysia, Faculty of Science).

Lee, S. K., Wagiran, H., Termizi, A., Heru, N., and Khalik, A. (2009). Radiological monitoring: terrestrial natural radionuclides in Kinta District, Perak, Malaysia. *Journal of Environmental Radioactivity*, *100*(5), 368-374.

Mireles, F., Davila, J. I., Quirino, L. L., Lugo, J. F., Pinedo, J. L., and Rios, C. (2003). Natural soil gamma radioactivity levels and resultant population dose in the cities of Zacatecas and Guadalupe, Zacatecas, Mexico. *Health physics*, *84*(3), 368-372.

Mould, R. F. (1985). *Radiation protection in hospitals*. Taylor & Francis.

Myrick, T. E., Berven, B. A., and Haywood, F. F. (1983). Determination of concentrations of selected radionuclides in surface soil in the US.*Health Physics*, *45*(3), 631-642.

Nasirian, M., Bahari, I., and Abdullah, P. (2008).Assessment of natural radioactivity in water and sediment from Amang (tin tailing) processing ponds.*Malay. J. Analyt. Sci*, *12*(1), 150-159.

Noz, M. E., and Maguire Jr, G. Q. (1985).Radiation protection in the radiologic and health sciences.Philadelphia.

ORTEC.(2001). *MAESTRO®-32 A65-B32 Software User's Manual.*Perkin Elmer Instruments.

Ramli, A .A. M., Besar, I., Khalid, M. A. and Hassan, S. (2000). Radiation safety.Malaysian Institute for Nuclear Technology and Research, Bangi Malaysia.

Redzuwan, Y., Ismail, B., Amran, A. M., SamudiYasir, M. Y., and Lin, C. L. (2002).The impact of amang processing activity on the water quality and sediment of open water system. In *15th Analytical Chemistry Symposium*.

Shamsuddin, J. (1990). Sifat dan Pengurusan Tanih di Malaysia, Dewan Bahasa & Pustaka, Kuala Lumpur.

Sharama, N. (2011). Sharama, R and Virk HS. *Advanced in Applied Science Research*, *2*(3), 186-190.

Sohrabi, M. (1990). Recent radiological studies of high level natural radiation areas of Ramsar: in Proceedings of the International Conference on High Levels of Natural Radiation Areas, Rasmar, IAEA, Vienna.

Sprawls, P. (1995). *Physical principles of medical imaging*. Medical Physics Publishing Madison.Wisconsin.

Thornburn, C. C. (1972). Isotopes and radiation in biology. Butterworths, London.

Tsoulfanidis, N. (1995, July). Measurement and detection of radiation. In *Fuel and Energy Abstracts* (Vol. 36, No. 4, pp. 303-303). Elsevier.

Tufail, M., Akhtar, N., and Waqas, M. (2006).Measurement of terrestrial radiation for assessment of gamma dose from cultivated and barren saline soils of Faisalabad in Pakistan. *Radiation Measurements*, *41*(4), 443-451.

Tynybekov, A. (2001). Radiological researches in a southeast part of Lake Issyk-Kul. In *International Conference Human Health and Environment. Strategies and Programs in New Millenium*.

UNSCEAR, (2000). Effects of Ionizing Radiation: 2000 Report to the General Assembly, with Scientific Annexes, Vol. II: Effects. *United Nations, New York.*

Viruthagiri, G., and Ponnarasi, K. (2011).Measurement of natural radio activity in brick samples. *Advances in Applied Science Research*, *2*(2).

World Nuclear Association. (2014). *Naturally-Occurring Radioactive Materials (NORM)*. Retrieved on March 18. http://www.world-nuclear.org.

Yeong, C. H. (2005). *Detrmintion of Radioactivity Levels of NORM in Marine Sand Using Gamma spectrometer*. Bachelor, Universiti Teknologi Malaysia, Skudia.

Yip, Y. H. (1969). *The development of the tin mining industry of Malaya*. University of Malaya Press, Kuala Lumpur.

Zhu, H., Huang, H., Song, J., Li, J., Zhang, J., Huang, J., and Guo, Y. (1993). Gamma radiation levels around the highest background area in Poland. In *Proceeding of the International Conference on High Levels of Natural Radiation*, Rasmar, IAEA, Vienna.

Zou, H., and Zindler, A. (2000). Theoretical studies of ^{238}U, ^{230}Th, ^{226}Ra, ^{235}U and ^{231}Pa disequilibria in young lavas produced by mantle melting. *Geochimica et Cosmochimica Acta*, *64*(10), 1809-1817.