ENVIRONMENTAL TERRESTRIAL GAMMA RADIATION DOSE-RATE AND ITS RELATIONSHIP WITH SOIL TYPE AND UNDERLYING GEOLOGICAL FORMATIONS IN KOTA TINGGI DISTRICT, MALAYSIA

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Abstract: The terrestrial gamma radiation level was determined covering the Kota Tinggi district of Peninsular Malaysia. The dose-rate was measured at 748 locations using gamma ray detector system consisting of a 2.54 cm×2.54 cm NaI (Tl) as a gamma detector. Results have allowed construction of a terrestrial gamma ray isodose contour map of Kota Tinggi district. The relationships between the gamma radiation dose level measured at various locations and the soil type and underlying geological are discussed. The highest terrestrial gamma dose-rate measured is 630 ± 63 nGy $h^{-1}$and the lowest terrestrial gamma dose-rate measured is 45 ± 5 nGy h^{-1}.

Keywords: Gamma radioactivity, Naturally occurring radionuclide, Soil, Geology, Contour lines map

INTRODUCTION

Naturally occurring radionuclide of terrestrial origin is ubiquitously present in the environment. Irradiation of the human body from external sources is mainly by gamma radiation from radionuclide in the ^{238}U and ^{232}Th series and from ^{40}K. Direct measurements of absorbed dose-rate in the air from terrestrial gamma radiation dose-rate have been carried out in many countries in the world. Average values outdoor for different countries surveyed range from 18 to 93 nGy h^{-1} and the population weighted average is 59 nGy h^{-1} (UNSCEAR, 2000) [21].

Measurement of natural radioactivity in the soil is very important to determine the amount of change of the natural background activity with time as a result of any radioactivity release. Monitoring of radioactivity release to the environment is important for radiation protection. Our present aim is to study the relationship between terrestrial gamma radiation dose-rate with soil type and underlying geological formations at Kota Tinggi district, Malaysia.

Kota Tinggi district is located between latitudes 1°20' and 2°03' North and longitudes 103°33' and 104°18' East. It has an area of approximately 3,500 km^2 and a population of about 200,000. Seventy percent of the district is covered by forest and the main the main use of the land is for agriculture. Kota Tinggi district also is a tourist spot. Several places in Kota Tinggi district have mineral resources such as tin ore and alluvial ore mineral (ilmenite, zircon, monazite, wolframite and xenotime).

Kota Tinggi district can be divided into six major geological groups of different geological age (Director General of Geological Survey, 1982) [6] as shown in figure 1. The geological formations overlaid are (a) Quaternary, (b) Tertiary, (c) Cretaceous-Jurassic, (d) Triassic, (e) Permian and (g) Acid Intrusive rock. Quaternary, Permian and Intrusive Rock are the most abundant in Kota Tinggi district.

Kota Tinggi district is overlaid by eight groups of soil types as classified by FAO/UNESCO (Director General of Agriculture Peninsular Malaysia, 1973) [5] as shown in figure 2. Most of Kota Tinggi district is steep land with forested area of above 30 m in height (Yaacob and Jusop, 1982) [22]. The soil types are:

Fluvisols; this group consists of flood plains and alluvial soil. There are two types of *Fluvisols*, namely *Dystric Fluvisols* and *Thionic Fluvisols*, and the local names are *Rusila* and *Kranji*. Most of this group are found on the coastal plain, mostly in tidal swamps covered by mangrove.

Gleysols, this is a group of mucky soil due to excess of water. It is characterised as *Dystric Gleysols* and the local name is *Lunas*. This group is deposited mostly along rivers especially the Johore River.

Nitosols is a type of soil of shiny pad surfaces. There are two types of *Nitosols*, namely *Dystric Nitosols* and *Rhodic Nitosols*, and the local names are *Renggam* and *Kulai*. *Dystric Nitosols* is the most abundant soil type in Kota Tinggi district.

Histosols, this group of soil is structured and are derived from weathering in situ and only one type is found, known as *Dystric Histosols*, and the common name is *peat*. It is deposited mostly in swampy area and not far from the coasts of the eastern and southern part of Kota Tinggi district.

Ferralsols is a type of soil with high content of sesquioxides. There are three types found in the north and in the middle part of Kota Tinggi district. These soil types are characterised as *Xanthic Ferrasols, Orthic Ferrasols* and *Plinthinc Ferrasols*. It is also called *Holyrood, Munchong* and *Malacca* locally.

Acrisols is an acidic soil of low base saturation. Three types are found in the northern, eastern and southern part of Kota Tinggi district. They are characterised, as *Ferric Acrisols, Orthic Acrisols* and *Plinthinc Acrisols*, and the local names are *Harimau Tampoi* or *Durian* series, *Batu Anam* and *Apek* respectively.

Podzols is a group of BRIS soils (Beach Ridge Interspersed with Swales). It is characterised as *Humic Podzols* and the local name is *Rudua.*

Miscellaneous soils. (i) Steep Land. (ii) Urban Land. These soil types are mostly found in the western and northern part of Kota Tinggi district.

MATERIALS AND METHODS

Kota Tinggi district is divided into 1020 stations by aligning the grid along the latitudinal and longitudinal lines (1'× 1'). Each station measures around 1.85 km × 1.85 km. Soil types with underlying geological formations for each station is determined (Ramli A.T. et al., 2003a) [14]. Measurements of the terrestrial gamma radiation dose-rate are conducted with gamma ray detectors manufactured by Ludlum of the U.S.A. using model 19, Micro R Meter. The equipment uses a 2.54 × 2.54 cm NaI crystal doped with thallium [NaI (Tl)], which responds to gamma radiation. The smallest scale division for the instrument is 1 $\mu R\ h^{-1}$ (~ 9 $nGy\ h^{-1}$). The instrument had almost a flat energy response to gamma radiations, which is between 40 keV to 1.2 MeV. The low response of the instrument to high energy gamma radiation implies that contributions from cosmic sources are negligible. It is suitable for environmental gamma radiation measurements (Ramli A.T. et al. 2003a [14]; Ramli A.T. et al 2003b [13]; Ramli A.T. 1997 [10]). It covers a majority of significant gamma radiations emitted from terrestrial sources. The uncertainty of reading observed on the maximum scale of the instrument is of the order of 10%.

The terrestrial gamma radiation dose-rate measurements are made from the selected location of Kota Tinggi district. The factors like local soil types with underlying geological formations and ready accessibility are taken into account while selecting the stations for measurement (Narayana, Y. et al. 2001) [8]. The terrestrial gamma dose-rate measurements are taken away from sites of developments such as road, building and foundation soils. The location for each sampling point is established by global positioning system (GPS) (Goddard, C.C. 2002 [7]; Sejkora, K.J. and Most, M. L. 1993 [17]). A total of 748 measurements is taken, which is about 73.3 % of the whole of Kota Tinggi district.

RESULTS AND DISCUSSIONS

Figure 1 and 2 shows graphically the terrestrial gamma dose-rate contour line map constructed from measurements using the main detector. The terrestrial gamma radiation dose-rate contour line map is plotted using the GIS Arc View version 3.1 program by ESRI (Adsley, I. 2004 [2]; Goddard, C.C. 2002 [7]). The figures clearly show how the terrestrial gamma dose-rate contour lines match some of the geological formation's boundaries and soil type's boundaries as shown in figure 1 and figure 2 respectively. It shows clearly a close relationship between terrestrial gamma dose-rate with the underlying of geological formations and soil types in Kota Tinggi district.

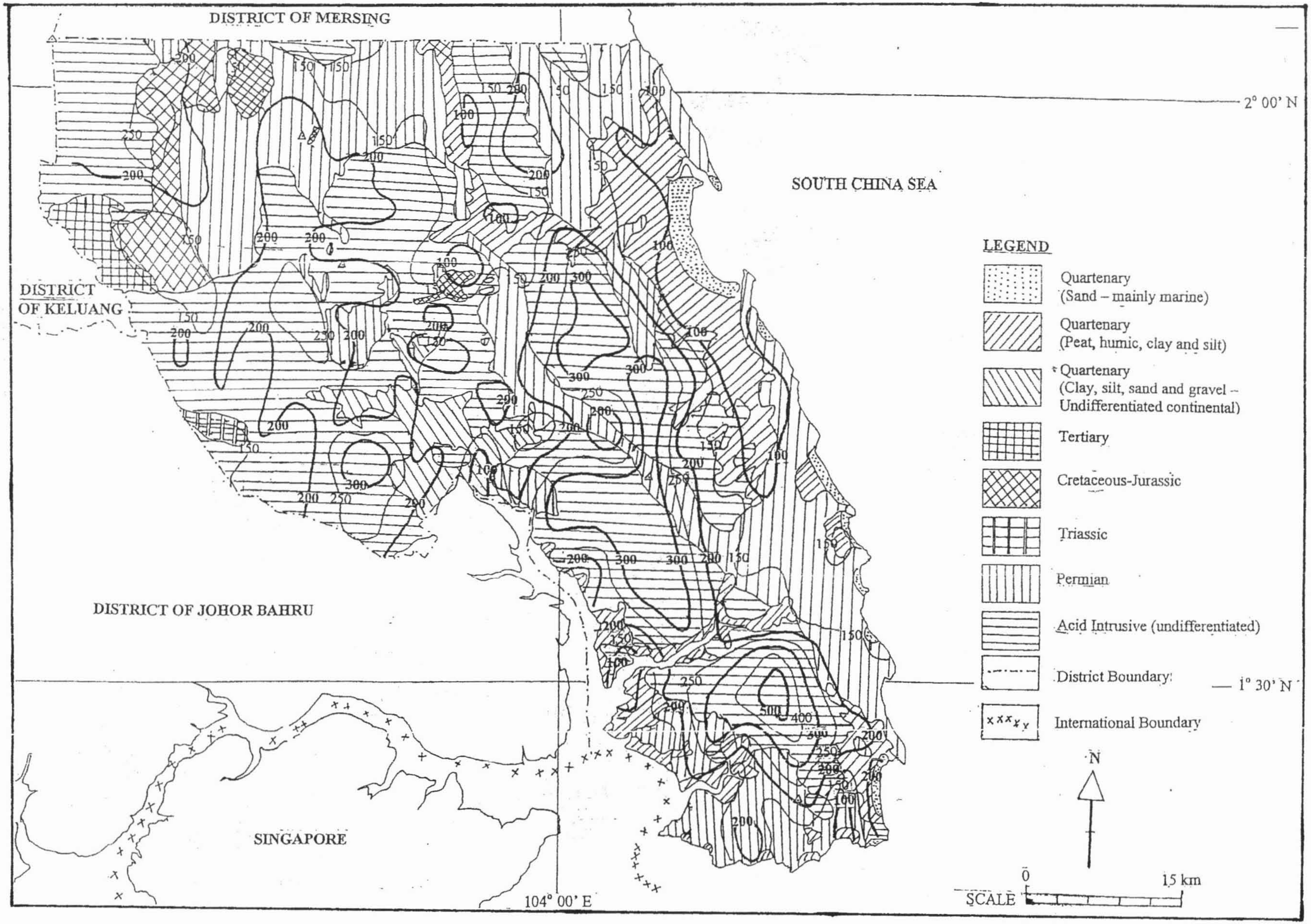

Figure 1: Isodose map of the terrestrial gamma radiation dose-rate and underlying geological formations of the Kota Tinggi district, Malaysia.

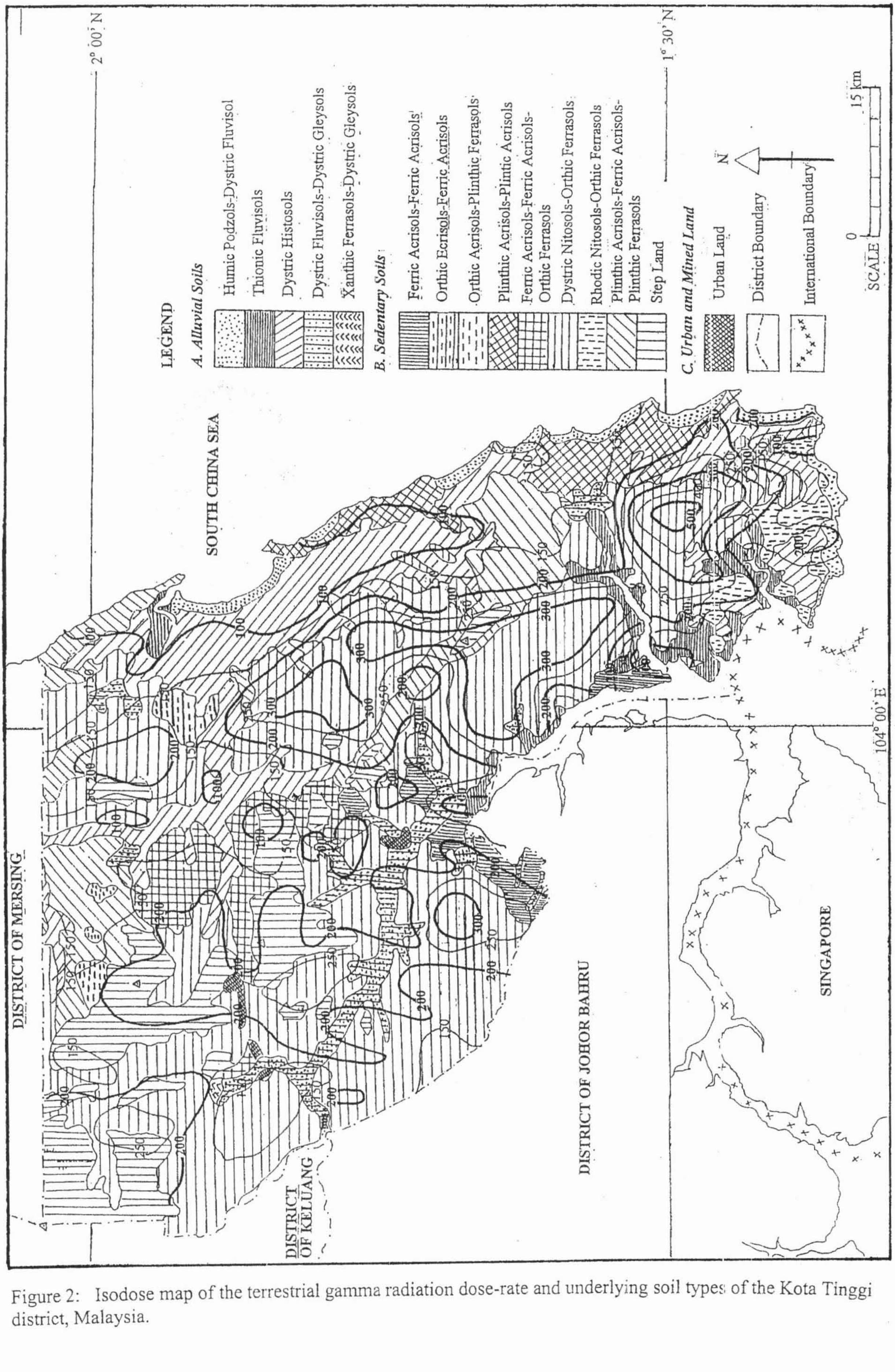

Figure 2: Isodose map of the terrestrial gamma radiation dose-rate and underlying soil types of the Kota Tinggi district, Malaysia.

This results is similar to other studies carried out in many countries in the world such as Brazil (Carlos, D.U. et al. 2004) [4], Egypt (Abd El-Naby, H.H. and Saleh G.M. 2003) [1], Italy (Brai, M. et al. 2002) [3], Spain (Tome, F. V. et al. 2002) [20], Kuwait (Saad, H.R. et al. 2002) [16], India (Selvasekarapandian, S. et al. 2000) [18] and Pontian, Malaysia (Ramli, A.T. 1997) [10]. As such it might be possible to predict the terrestrial gamma radiation dose-rate for other areas based upon the information on the geological and soil type.

From figure 1 and figure 2, it can be observed that terrestrial gamma dose-rates are lower in areas covered by soil types *Dystric Histosols* and *Humic Podzols-Dystric Fluvisols.*, and in *Quarternary* areas than in other geological formations that are as low to 45 nGy h^{-1}. The terrestrial gamma dose-rate are lowest in Quarternary areas formed from peat, humic clay and silt and could be clearly seen along river areas and near the coastal areas at the eastern part of Kota Tinggi district. Lower dose-rates are registered on alluvial sands in certain location along the coast and the river. Natural terrestrial gamma dose-rate in Dystric Histosols (Peat areas) is very low. Thus they are dependent on the thickness and purity of the peat (Rahman, A.T.A. et al. 2004 [9]; Ramli, A.T. et al. 1998 [11]; Ramli, A.T. 1997 [10]).

The highest terrestrial gamma dose-rate measured that is up to 630 nGy h^{-1} which is founded in areas covered by *Dystric Nitosols-Orthic Ferrasols* and *Steep Land* soil types. These soil types of high environmental terrestrial gamma dose-rate level are underlay by *Acid Intrusive* (igneous rock) and *Permian* geological formations as shown in figure 2. Both of these geological formations are abundant in granites and extensively intruded by schist, shale, quartzite and siltstone. Such of rock contains higher concentrations of naturally occurring radionuclide such as uranium, thorium and potassium (Ramli, A.T. et al. 2003a [14]; Ramli, A.T. et al. 2003b [13]; Ramli, A.T. et al. 2000 [12]). Most of radioactive occurrences in the basement rocks of Kota Tinggi district are in the granites. The high level of radioactivity of this rock is attributed to the presence of accessory mineral like zircon, monazite, thorite, uranothorite and allanite (Shurmann, 1966) [19]. Uranium and thorium are generally enriched in the youngest, most felsic and most potassic members of comagmatic suites of igneous rocks (Rogers and Adams, 1969) [15].

The average of terrestrial gamma radiation dose-rate in Kota Tinggi is 180 nGy h^{-1}. The Malaysian average is 92 nGy h^{-1} and world average is 59 nGy h^{-1} (UNCEAR, 2000) [21]. Using the conversion factor of 0.7 Sv Gy^{-1} (UNSCEAR, 2000) [21] the average dose from such terrestrial gamma radiation dose-rate to an individual assuming a tropical rural setting is estimated to be 1.12 mSv per year, which is considered to be within the normal range for doses from natural sources. It is not expected to cause statistical significance in radiological health impact.

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