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Assessment of impact of urbanisation on background radiation exposure and human health risk estimation in Kuala Lumpur, Malaysia

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ABSTRACT

Kuala Lumpur has been undergoing rapid urbanisation process, mainly in infrastructure development. The opening of new township and residential in former tin mining areas, particularly in the heavy mineral- or tin-bearing alluvial soil in Kuala Lumpur, is a contentious subject in land-use regulation. Construction practices, i.e. reclamation and dredging in these areas are potential to enhance the radioactivity levels of soil and subsequently, increase the existing background gamma radiation levels. This situation is worsened with the utilisation of tin tailings as construction materials apart from unavoidable soil pollutions due to naturally occurring radioactive materials in construction materials, e.g. granitic aggregate, cement and red clay brick. This study was conducted to assess the urbanisation impacts on background gamma radiation in Kuala Lumpur. The study found that the mean value of measured dose rate was 251 ± 6 nGy h^{-1} (156–392 nGy h^{-1}) and 4 times higher than the world average value. High radioactivity levels of ^{238}U (95 ± 12 Bq kg^{-1}), ^{232}Th (191 ± 23 Bq kg^{-1},) and ^{40}K (727 ± 130 Bq kg^{-1}) in soil were identified as the major source of high radiation exposure. Based on statistical ANOVA, *t*-test, and analyses of cumulative probability distribution, this study has statistically verified the dose enhancements in the background radiation. The effective dose was estimated to be 0.31 ± 0.01 mSv y^{-1} per man. The recommended ICRP reference level (1–20 mSv y^{-1}) is applicable to the involved existing exposure situation in this study. The estimated effective dose in this study is lower than the ICRP reference level and too low to cause deterministic radiation effects. Nevertheless based on estimations of lifetime radiation exposure risks, this study found that there was small probability for individual in Kuala Lumpur being diagnosed with cancer and dying of cancer.

1. Introduction

Kuala Lumpur is one of the densely populated places in the world with a population density of over 6500 km^{-2} (EPU, 2016). For the past few decades, Kuala Lumpur has experienced rapid urbanisation, from a tin-mining town to national capital (Hamzah and Hassan, 1996). However, rapid infrastructure developments, i.e. expansion of new township, residential area and industrial in Kuala Lumpur (Bahrin, 1981) have altered the earth landscapes, particularly soil bodies. Uncontrolled soil exploitation for development purposes can cause irreversible damage to environmental sustainability, especially on geochemical grounds (Peña-Fernández et al., 2014). Numerous concerns have been raised over the issues of effects of contaminants and heavy elements in soils due to urbanisation, industrialisation and traffic (Zhang et al., 2005). This scenario is exacerbated with the utilisation of former tin mining areas or heavy mineral- and tin-bearing alluvial soil in Kuala Lumpur. During constructions, i.e. dredging and reclamation practices could have technologically enhanced naturally occurring radioactive material (TENORM) in the soil and subsequently increase the existing background gamma (γ) radiation exposure.

Generally, tin mining activities and former mine lands (e.g. tin tailings) in Peninsular Malaysia have been identified to pose adverse impacts on human radiological health and environment as a result of high γ radiation exposure and radioactivity contamination of ^{238}U series, ^{232}Th series and ^{40}K in soil (Subramanian, 1988; AELB, 1991; Udompornwirat, 1991; Hewson, 1996; Roberts, 1995; Bahari et al., 2007; Bahari et al., 2007; Yasir et al., 2007). In fact, the government initiatives to conserve the environment sustainability and rehabilitation of ex-tin mines in Selangor and Kuala Lumpur are through the

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development of new townships, housing estates, and recreational park (Hamzah and Hassan, 1996; Ang and Ho, 2004; Yap, 2007). In addition, it had been reported previously in the early-90s that a large amount of cheap rock aggregate, tin tailing sand and clay from the ex-tin mines were supplied as construction materials for infrastructural development in Kuala Lumpur and nearby districts of Selangor (Hamzah and Hassan, 1996; Yap, 2007).

Besides tin tailing construction materials, the utilisation of basic construction materials, i.e. granite aggregate, sand, red and white clay brick, cement brick and cement in construction site also could pollute the soil with the radioactivity of ^{238}U series, ^{232}Th series and ^{40}K. Numerous worldwide studies (Chong and Ahmad, 1982; Mustonen, 1984; Ibrahim, 1999; Lee et al., 2001; UNSCEAR, 2000; Yasir et al., 2007; Trevisi et al., 2012; Ali, 2012; Ravisankar et al., 2012; Lu et al., 2014) found that the radioactivity concentrations in the construction materials have increased the indoor γ radiation exposure. Ibrahim (1999) reported that the radioactivity concentrations for ^{238}U, ^{232}Th and ^{40}K in the red clay brick samples from Malaysia were 241, 51 and 7541 Bq kg^{-1}, respectively, whereas for the concrete samples were 51, 23 and 832 Bq kg^{-1}, respectively. For granitic aggregate sources, Zakaria et al. (1993) reported that the average concentrations of ^{238}U, ^{232}Th and ^{40}K in granite samples from The Main Range Granite in Peninsular Malaysia were 314, 221 and 1315 Bq kg^{-1}, respectively. These values are higher than the world's average concentration values (33, 45 and 420 Bq kg^{-1}) of ^{238}U, ^{232}Th and ^{40}K in soil (UNSCEAR, 2000).

To date, no available data or studies particularly related to environmental radioactivity and radiological impact assessment due to urbanisation have been carried out in Kuala Lumpur. Globally, most of the studies involved only measurements of indoor γ radiation exposure and radioactivity of radon and thoron gases in dwellings (Niewiadomski et al., 1985; Saito et al., 1997; Amrani and Tahtat, 2001; Righi and Bruzzi, 2006; Trevisi et al., 2012; Lu et al., 2014). In 2010, a comparative study of indoor radon levels between Kuala Lumpur and Kerala, India was conducted by Mahat et al. (2011) to investigate the relationship between highly distributed heavy mineral areas and radon concentrations in dwellings. However, the study is localized, small sampling and not implying the outdoor radiation exposure and soil radioactivity in Kuala Lumpur.

This study is conducted to assess the impact of urbanisation on background γ radiation in Kuala Lumpur. The main approaches used in this study is based on measurements of outdoor γ radiation dose rate and radioactivity concentration level in urban soil. Statistical analyses of ANOVA, *t*-tests and cumulative probability plots are adopted in this study to statistically verify the dose enhancements due to urbanisation impacts. The statistical verification techniques used in this study are mainly based on statistical hypothesis tests of comparison of background dose rate for similar geological features in Kuala Lumpur and other states. The cancer risk is estimated to assess the probability of hazard of ionizing radiation attributable to urbanisation impacts. The obtained baseline data are important for radiological protection and safety, radioactive contamination and waste control enforcement, and for formulating policies related to occupational and public safety due to nuclear energy practices.

2. Experimental materials and methods

2.1. Study area

The study involved an area of 243 km^2 of Federal Territory of Kuala Lumpur. Kuala Lumpur comprises 3 geological background, i.e. carboniferous, Silurian-Ordovician and granite acid intrusive. The geological map of Kuala Lumpur is shown in Fig. 1 and the information of their formation ages as well as types of rock are summarised in Table 1. Kuala Lumpur terrain area consists 89% disturbed land, i.e. township sites (DAPM, 2002). Meanwhile, according to the land use report in 2000 (DBKL, 2016) the undeveloped land in Kuala Lumpur was about 24% of the total land area. Fig. 2 shows the land use map of Kuala Lumpur (DBKL, 2016).

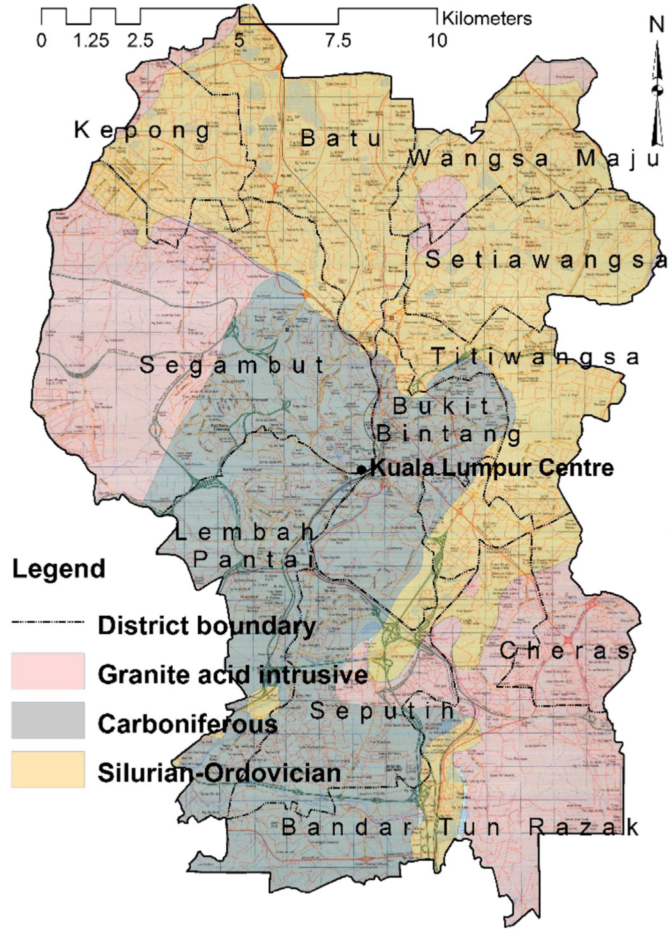

Fig. 1. Geological map of the study area.

The study area also involved few areas of former tin mines. Historically, tin ore in Kuala Lumpur was started mined in Ampang in 1857 (Tan, 2005). Roughly 30–50% of the world's annual tin production in the mid-1960s were majorly produced from two major tin ore resources in Malaysia (Hails, 1976), i.e. Kinta Valley (Perak) and Klang Valley (known as Kuala Lumpur and nearby districts in Selangor) (Wong, 1970; Tan and Ibrahim, 1990; Schwartz et al., 1995; Hamzah and Hassan, 1996). Fig. 3 shows the distributions of former tin mines in Kuala Lumpur (DMM, 1980). Note that not all tin mining areas in

Table 1
The geological backgrounds in Kuala Lumpur (Ingham and Bradford, 1960; DGSM, 1985).

Geological background	Age of formation (1×10^6 y)	Compositions
Carboniferous	350	Known as the Kenny Hill formation, comprises significant interbedded quartzite and phyllite. The sedimentary rocks of Kenny Hill formation i.e., shale and sandstone have been regionally metamorphosed into metasediments i.e., schist, quartzite and phyllite.
Silurian-Ordovician	435	The region is underlain by the alluvial soil (heavy mineral and tin-bearing soil). Locally prominent development of limestone, called the Kuala Lumpur Limestone. Most of the limestone formations have been metamorphosed into marble.
Acid intrusive	>500	Locally known as the Kuala Lumpur granite. Consists of medium coarse, porphyritic muscovite-biotite granite.