INDOOR RADON CONCENTRATIONS FOR BUILDINGS OF DIFFERENT AGES IN UNIVERSITI TEKNOLOGI MALAYSIA

NGUI KA CHONG

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Faculty of Engineering
Universiti Teknologi Malaysia

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DEDICATION

This project report is dedicated to my brother who has always had my back and told me to climb back up even if I have a heavy fall. The dedication also goes to my mother who always believes in me and gives me the healing energy at all difficult times.

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ABSTRACT

Radon is a naturally-occurring radioactive noble gas with no colour, odour and taste to which humans are usually exposed. Prolonged inhalation of radon gas is the second main contributor to lung cancer among smokers and non-smokers. This study aimed to compare radon levels between the old (Faculty of Science) and new (Faculty of Civil Engineering) buildings of Universiti Teknologi Malaysia, and also to compare concentrations of radon between ground floor and second floor within the two types of buildings. The RAD7 was selected as the equipment to measure radon concentrations at the laboratories, meeting rooms and lecturer rooms at the monitored buildings. The radon content of both the old and new buildings did not exceed the WHO reference level of 100 Bqm^{-3}. However, radon at the new building was present at higher concentrations than that at the old buildings on average. In the old buildings, radon levels of the laboratory on ground floor were higher than those of the meeting room on second floor by 3.8 Bqm^{-3} but lower than those of the lecturer room on second floor by 9.7 Bqm^{-3}. Conversely, the structure laboratory at the new building on ground floor had markedly higher radon levels than those of the lecturer room but showed lower readings than the meeting room on second floor.

ABSTRAK

Manusia zaman kini selalu terdedah kepada sejenis gas bernama radon yang tidak mengandungi apa-apa warna, bau dan rasa. Pendedahan radon secara lama dikira sebagai faktor kritikal kedua kanser paru-paru dalam kalangan perokok dan bukan perokok. Kajian ini bertujuan untuk membandingkan tahap radon di bangunan lama (Fakulti Sains) dengan tahap lain di bangunan baharu (Fakulti Kejuruteraan Awam) yang terletak di kampus Universiti Teknologi Malaysia. Kajian ini juga melibatkan bandingan radon antara tingkat bawah dengan tingkat kedua di fakulti berkenaan. RAD7 telah diplih sebagai alat utama bagi pengukuran tahap radon dalam makmal, bilik mesyuarat serta bilik pensyarah di bangunan tersebut. Analisis data menunjukkan radon dalam tempat kajian itu tidak melebihi tahap ditentukan oleh WHO iaitu 100 Bqm^{-3}. Namun begitu, tahap radon dalam bangunan baharu adalah lebih tinggi daripada bangunan lama secara keseluruhan. Di bangunan lama, tahap radon dalam makmal nuklear di tingkat bawah adalah lebin tinggi daripada bilik mesyuarat di tingkat kedua. Akan tetapi, makmal nuklear mengandungi radon yang lagi kurang berbanding dengan bilik pensyarah di tingkah kedua bangunan lama. Sebaliknya, makmal struktur di tingkat bawah Fakulti Kejuruteraan Awam mempunyai tahap radon yang lebih tinggi daripada bilik pensyarah di tingkat kedua. Namun, bilik mesyuarat baharu di tingkat kedua menunjukkan tahap radon yang lebin tinggi daripada makmal struktur selepas analisis sampel.

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LIST OF ABBREVIATIONS

UTM	-	Universiti Teknologi Malaysia
PM	-	Particulate matter
API	-	Air Pollution Index
DOE	-	Department of Environment
APIMS	-	Air Pollutant Index of Malaysia System
EPA	-	Environmental Protection Agency
WHO	-	World Health Organisation
AQMA	-	Air quality management area
EEA	-	European Environment Agency
NMVOCs	-	Non-methane volatile organic compounds
NECD	-	National Emission Ceilings Directive
EU	-	European Union
DECCW	-	Department of Environment, Climate Change and Water
CAA	-	Clean Air Act
AQA	-	Air Quality Act
SIP	-	State Implementation Plan
NAAQS	-	National Ambient Air Quality Standards
DEFRA	-	Department for Environment Food & Rural Affairs
AQG	-	Air Quality Guidelines
OAQPS	-	Office of Air Quality Planning and Standards
IPAT	-	Impact-Population-Affluence-Technology
UPM	-	Universiti Putra Malaysia
ICRP	-	International Commission on Radiation Protection
TWA	-	Time-weighted average
HVAC	-	Heating, ventilation and air conditioning
VOCs	-	Volatile organic compounds
PTA	-	Packed-tower aeration
NRC	-	National Research Council

LIST OF SYMBOLS

SO_2	-	Sulfur dioxide
CO	-	Carbon monoxide
NOx	-	Nitrogen oxides
O_3	-	Ozone
NO_2	-	Nitrogen dioxide
Po	-	Polonium
NH_3	-	Ammonia
Rn	-	Radon
Th	-	Thorium
U	-	Uranium
V_f	-	Final surface potential
V_i	-	Initial surface potential
F	-	Calibration factor
t	-	Exposure time or time interval
C	-	Concentration
V	-	Volume of the detector chamber
n	-	RAD7 efficiency
Bqm^{-3}	-	Becquerel per cubic metre

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CHAPTER 1

INTRODUCTION

1.1 Background of the study

Outdoor air pollution occurs due to the introduction of harmful pollutants including dirt and chemicals into Earth's atmosphere chiefly through human actions such as consumption and production activities (Razak *et al*., 2013). These pollutants are further categorized into primary or secondary pollutants based on the emission sources. Primary pollutants are directly released from the source into the air, which include carbon monoxide (CO), nitrogen oxides (NOx), particulate matter (PM) and sulfur dioxide (SO_2). In contrast, secondary pollutants e.g ozone (O_3) and nitrogen dioxide (NO_2) are by-products of chemical reactions either between the primary contaminants or between the primary contaminants and other constituents in the air (Razak *et al*., 2013). Over the past five years, outdoor atmospheric pollution has increased by 8% globally where developing regions including Middle East, Southeast Asia and the Western Pacific are identified as the worst affected areas (Muneer, Kolhe and Doyle, 2017).

Air Pollution Index (API) has been established by the Department of Environment (DOE) in Malaysia to implement the measurement of ambient air quality in terms of good (0 to 50), moderate (51 to 100), unhealthy (101 to 200), very unhealthy (201 to 300) and hazardous (> 300) levels. The latest measurement of API takes the highest value from among the six main air pollutants: O_3, CO, SO_2, NO_2, PM with an aerodynamic diameter < 10 μm (PM_{10}) and PM with an aerodynamic diameter < 2.5 μm ($PM_{2.5}$) (APIMS, 2019). The primary sources of most atmospheric contamination cases in Malaysia are mobile sources (70-75%), stationary sources (20-25%) and open burning sources (3-5%) (Rani *et al*., 2018). The mobile sources include

emissions from motor vehicles, airplanes and locomotives; while stationary sources contain pollutants from power plants, factories and refineries.

Indoor air pollution is defined as the deterioration of air quality inside and surrounding buildings and constructions, specifically affecting the well-being and enjoyment of building occupants in a negative manner (EPA, 2020). Radon has been recognized as one of the most common pollutants indoors by organizations such as Environmental Protection Agency (EPA) and World Health Organization (WHO). Radon does not usually pose as a health concern in outdoor environments given its high dilution rates in the open air. Nevertheless, hazardous levels of radon can occur within indoor spaces such as basements, bedrooms, offices and houses, especially as it enters via openings in damaged pipes, floor-wall joints or grounds or via cracks in concrete floors and walls (WHO, 2008a).

In recent years, radon gas has been classified as a common radioactive substance to which humans are usually exposed. Radon is a radioactive noble gas without colour, odour and taste that forms naturally in the air due to the decay of radium (Ra), thorium (Th) or uranium (U) in rocks, soil and groundwater (Ahmad *et al*., 2017). Radon has no stable or nearly stable isotopes, but the most stable isotope is ^{222}Rn, with a half-life of 3.82 days, which comes from the decay of ^{226}Ra and ^{238}U (Neidherr *et al*., 2009). The radon daughters such as polonium (Po) isotopes — ^{218}Po, ^{214}Po and ^{210}Po release high doses of ionizing alpha rays. Following inhalation of radon gas, the particulate radon attaches to the lung surface and decays to emit highly ionizing alpha particles that bind to cells in the lung tissue, resulting in damage of DNA (Ahmad *et al*., 2017).

Prolonged inhalation of radon gas is the second root cause of lung cancer among people who smoke and never smoke, and hence a significant health threat to public. It is revealed that high doses of radon gas in residence are related to around 21,100 lung cancer mortalities annually in the USA (WHO, 2008b). In addition, Gray *et al*. (2009) has reported that the death toll from radon exposure reaches 1,100 per year across the UK. However, there is no existing proof that provides the minimum

allowable limit of exposure to radon gas when low-dose exposures are also likely to result in lung cancer (Ahmad *et al*., 2017). In both West and East Malaysia, many research groups and professionals have participated in the estimation of radon levels in various samples, including indoor and outdoor air, building materials, water sources and soil during a period of 1994 to 2017.

1.2 Problem statement

The Malaysian government has yet to acknowledge the carcinogenic effect of short- and long-term indoor radon exposure on human health to a satisfactory degree. Although the Ministry of Health in Malaysia has attempted to collaborate with many university researchers and professional testers in the measurement of radon content, efforts to engage all participating parties and stakeholders are still in progress. In fact, many studies in Malaysia generally focus on samples of water and soil rather than indoor air for determination of overall radon concentrations. It shows that there is a significant lack of investigations into indoor radon levels across most parts of Malaysia.

Radon concentrations across Universiti Teknologi Malaysia (UTM) have remained a potential risk of health concerns because the old facilities on campus may contribute to the generation of radon gas (Sohrabi *et al*., 1993). According to National Cancer Institute (2011), more than 10 percent of cancer mortality cases are associated with radon exposures among non-smokers. Smokers plus exposure to high radon levels have even higher cancer death rates. The examination of radon levels across UTM buildings of different ages offers much research potential and value since radon sources include building materials, soil, rocks and groundwater.

Radon exposure has negative associations with health and comfort of building occupants in UTM, and the asymptomatic and unnoticeable radon poisoning is becoming an area of increasing concern. Students and staff who spend the most time

in the basement or on the ground floor are most likely to breathe in the highest concentration of radon. In this context, radon measurement and testing will provide regular occupants of UTM buildings with practical benefits and raise knowledge of this radioactive air pollutant indoors.

1.3 Research objectives

(i) To examine indoor radon concentrations between the old and new buildings within UTM.

(ii) To identify levels of radon at different elevations in UTM buildings.

(iii) To identify mitigation strategies of radon exposures especially for people in the basement or on the ground floor.

1.4 Scopes of the study

This study involved the measurement of an indoor air pollutant – radon and comparison of radon concentrations between the old and new buildings at the Faculty of Science and Faculty of Civil Engineering in UTM. Radon levels in the basement or on the ground floor were the primary focus of this study, which required the use of a radon detector – RAD7. This study aimed to compare radon concentrations between the ground floors and higher floors in the sampling locations by the end of each test run.

1.5 Significance of the study

(i) This study provided interventions to reduce the exposure to high radon levels among frequent occupants of UTM buildings and structures.

(ii) This study contributed to the understanding of this widespread phenomenon of radon exposure and poisoning.

(iii) This study promoted efforts of the Malaysian government to mitigate radon-related cancer deaths through identification of possible radon sources.

(iv) This study increased awareness of people on indoor air pollution in relation to radon gas.

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