Planned approach for indoor radon mapping in the West Rand Region, South Africa

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Abstract. The West Rand area is dominated by abandoned tailings dams from gold and uranium mines, which could be the potential source for elevated radon levels in the environment. Radon gas has long been identified as a human carcinogen and accounted to be the second largest cause of lung cancer after smoking. A recent small-scale study conducted in some parts of the West Rand area, indicated that the abandoned gold and uranium mine tailings found in the area result in elevated radon levels in the outdoor environment. Therefore, there is a need to assess indoor radon levels and identify radon prone areas in the West Rand area. This work presents the radon mapping approach to be used for indoor radon measurements in the West Rand area. The radon risk maps that will be produced will be of importance in the regulatory of indoor radon exposures and assist the National Nuclear Regulator of South Africa to ensure effective control measures are taken to protect members of the public from high radon level concentration exposures.

KEYWORDS: abandoned gold mine tailings dams, indoor radon mapping, radon, West Rand

1 INTRODUCTION

Radon (^{222}Rn) forms as an immediate decay product of radium (^{226}Ra), which is derived primarily from radioactive decay of uranium (^{238}U). It is the longest-lived radon isotope with a half-life of 3.82 days and decays into ^{218}Po and ^{214}Po which irradiates lung tissues and causes lung cancer. Studies performed across the world established a strong correlation between radon and lung cancer [1-6]. Naturally, radon is found in variable quantities in all media; rocks, soils, water, air and building materials. Some undertakings such as mining and mineral processing result in increased radon levels in the environment. The mining and milling of uranium ore is the most common industry which result in high radon exposures [7,8].

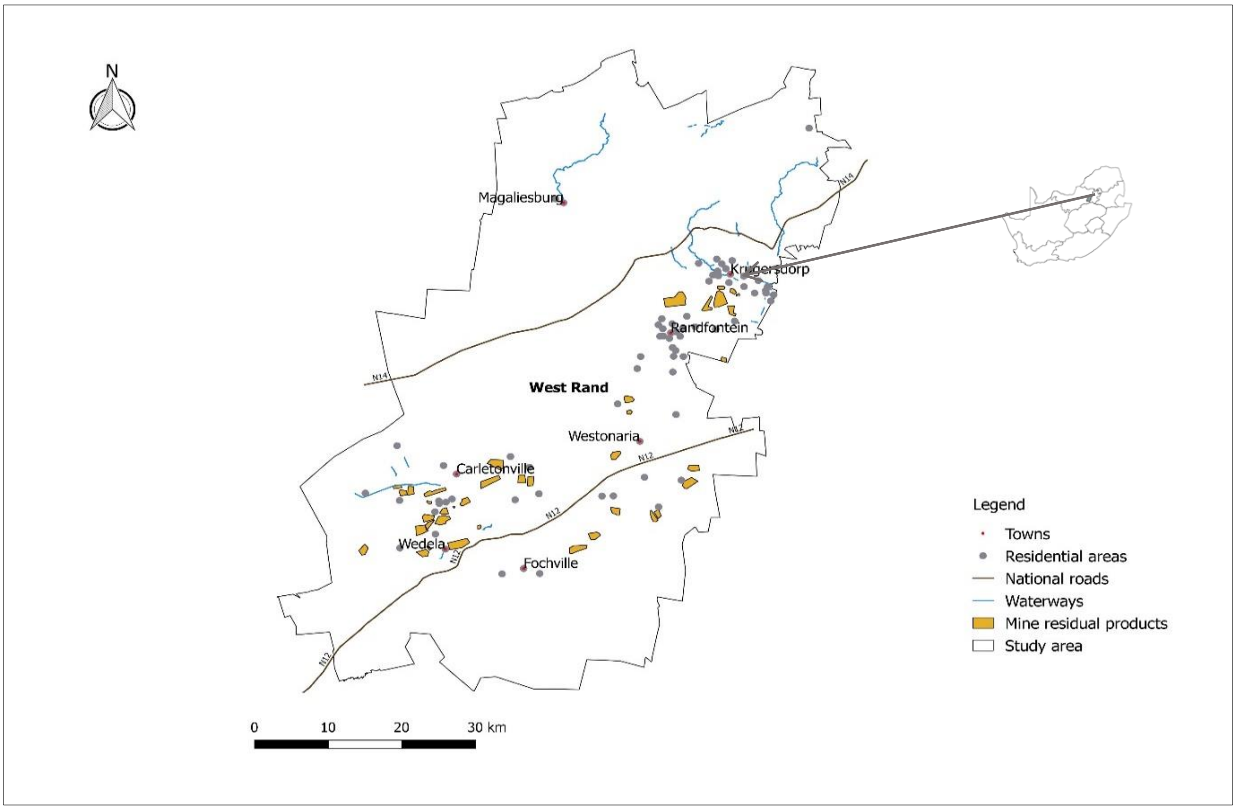
In the West Rand area, the majority of uranium was produced in the past as a by-product of gold mining and processing. The historic mining and processing of gold led to the deposition of large tailings dams, which are enriched with long-lived naturally occurring radioactive elements and considered potential sources of radon [9-11]. A small scale study conducted in some parts of the West Rand area, revealed that the abandoned gold and uranium mine tailings result in elevated radon levels ranging between 32 Bq/m^3 and 1069 Bq/m^3 and effective doses that could result in high lung cancer risks to the populations residing nearby mine tailings dams. Also, the study showed that lung cancer was common in the area [11]. On a large scale, the West Rand area is dominated by abandoned gold and uranium mine tailings, with a greater number of dwellings in close proximity to the mine tailings. Under such circumstances, radon rich air exhaled from mine tailings and soils that may be highly concentrated with uranium-238 and radium-226 leached from mine tailings may result in elevated radon concentrations in nearby dwellings. Therefore, this could result in substantial indoor radon exposure to the members of the public. Currently, there are limited studies on radon exposures for the members of the public residing in close proximity to abandoned gold mine tailings in the West Rand. Therefore, there is a need to investigate the indoor radon exposure levels in the vicinity of gold mining regions of the West Rand.

This work outlines the planned strategy to be used for indoor radon mapping in the West Rand area. The results of this work will add to the national radon mapping study which is conducted by the National Nuclear Regulator in South Africa. The projected outcome will assist in making decisions about where appropriate action and mitigation measures should be implemented with priority.

2 STUDY AREA

The West Rand area is situated in the north-central part of South Africa in Gauteng Province and covers the western part of the Witwatersrand area. It is located about 70 km west of the city of Johannesburg and covers a total area of approximately 4087 km^2. The area is dominated by the abandoned mine residual products from gold and uranium mining activities, which are currently found in close proximity to highly populated residential areas (Fig. 1). It has a total population of about 838 594 and approximately 330 572 households. The area generally experiences warm summers and cold winters with an average maximum temperature of 26 ^{0}C and average minimum temperature of about 2 ^{0} C. The highest temperatures are experienced between October and February, whereas the coldest months are June and July. The area receives a mean annual rainfall of about 704 mm and monthly rainfall of about 2 mm to 132 mm. A high amount of rainfall in the area commonly occurs in summer months between October and March. The geology of the area is characterized by the basement granitic rocks which are non-conformably overlain by the meta-sedimentary rocks of the Witwatersrand Supergroup, deposited between 3074 and 2714 Ma [12, 13]. These rocks are overlain by the sequences of the Ventersdorp Supergroup which accumulated between 2714 and 2665 Ma and the Proterozoic formations of the Transvaal Supergroup [12, 14]. The Karoo Paleozoic sediments of the Dwyka and Ecca Group are rarely encountered within the selected area of study.

Figure 1: The location of the study area



3 METHODOLOGY

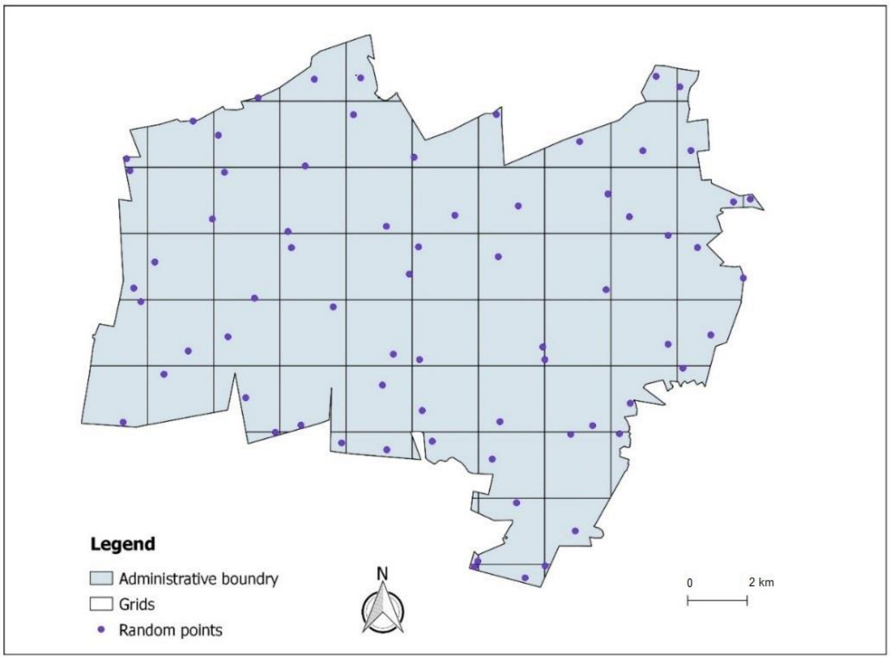
3.1 Planned strategy and approach for indoor radon mapping

3.1.1 Sampling size and technique

The study will employ the geographically based and a grid square mapping method to select the sampling units. The measurements will be conducted on a basis of 2 km x 2 km grid. This sample size provides a fair representation of average radon exposure levels and minimize the geographically based variations which may be introduced by geological strata, physical conditions and artificial features. In addition, it will provide a better understanding of the distribution of radon sources and identify any potential radon hazard areas. In each grid, one dwelling will be selected as a representative. The dwelling will be selected randomly within each primary grid square. The advantage of this approach is that it is unbiased and the random nature provides all dwellings within the sampling unit with the same probability of being selected as a representative. This sampling approach will result in regular grids with random points as depicted in Fig. 2. The sampling selection procedure to be used in this study is outlined as follows:

- The administrative map of the region to be sampled will be selected. The targeted area will then be partitioned into 2 km x 2 km square grids.
- Sampling points will then be randomly selected within each square grid. QGIS research tools for random selection in vector analysis will be used. For this purpose, random points inside polygons (fixed) will be used. This algorithm creates random points inside every grid when the number of points is assigned to 1.
- The corresponding coordinates of the randomly selected points will then be logged and be used as points of measurements during the survey. Should there be no existing or accessible dwellings at the notated area, the nearest dwelling in the same grid cell will be selected.
- The door to door campaign will be the main method used to recruit participants in the sampling points selected.

Figure 2: Random sampling procedure to be used for indoor radon mapping in this study.



3.1.2 Measurement techniques

There are different types of instruments and methods used for measuring radon, which include short and long-term techniques [15]. This study is aimed at measuring the long-term radon concentrations and the alpha-track detectors are best suited for this purpose. These detectors are commonly used in many countries which conducted indoor radon mapping programs [15, 16]. This study will use the alpha-track detectors to measure radon in dwellings (Fig. 3). The device encompasses a CR-39 plastic material, which is sensitive to alpha particles. The detector operates in such a way that when alpha particles from radon are generated, they leave microscopic tracks on the film. Following exposure, the film is etched in NaOH. The etching process increases the visibility of tracks on the film. The alpha tracks are then individually counted using a computer-automated counting system. The number of tracks per unit surface area is equivalent to radon exposure. The advantage of the alpha track detectors is that they are suitable to measure radon concentrations for long periods. The detectors are small, light-weight and tied with cables which allow the laboratory to identify if the device has been tampered with during the monitoring period. The detector has a lower limit of detection of 5 Bq/m^3 over a three-month exposure period. They are suitable to be used in high temperature and moist environments. The alpha-track detectors are simple to use and found at relatively low cost.

Figure 3: Example of radon alpha track detector to be used (Source: PARC RGM)

3.1.3 Deployment of detectors in dwellings

The measurements will be conducted under normal living conditions and in the mainly occupied rooms of the household such as bedrooms and living rooms. Two (2) detectors will be placed in every selected household at a typical breathing height of 1 m to 1.5 m above the floor and about 0.5 m away from the wall. The measurement location will be situated approximately 1 m away from windows, doors and other potential openings for the detector to give a better representative of indoor exposures. Radon detectors are sensitive to heat, therefore, they will be positioned away from heat sources. The minimum deployment period of the detectors will be 3 months to account for temporal variations. The measurements will be performed during the cold (winter months) and warm (summer months) periods to obtain average exposure levels. During the investigation, information related to the characteristics of the dwelling and lifestyle of occupants will be acquired.

3.1.4 Delineating radon hazard areas and potential sources

Radon risk maps are regulatory tools defining areas projected to be at particular risk from radon and exceed the recommended indoor exposure limits [17,18]. This study will use the measured radon data to establish radon risk maps which will indicate low, medium and high risk areas. The classified radon risk areas will be correlated with multiple parameters such as; underlying geological units, mining residual products, the concentration of uranium-238 and its decay products thereafter, identify radon sources and controls.

4 CONCLUSION

This work established an approach to be used for indoor radon measurements in the West Rand area, which is considered a high priority area due to the presence of the abandoned gold and uranium mine tailings dams which are located nearby residential areas. Through the application of methodologies specified in this work, radon risk maps will be established. The maps will serve as a regulatory tool to delineate regions where precautionary measures in buildings should be implemented. This will ensure the protection of the members of the public against the risk associated with exposure to radon gas in dwellings.

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