Ph.D. dissertation résumé

NATURAL RADIOACTIVITY IN ANGOLAN ADOBE HOUSES AND BUILDING MATERIALS

submitted to the

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by

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1. Introduction and objectives

Radiation exposure originates mainly from natural sources (Eisenbud and Gesell, 1997). Human population is exposed to two types of natural radiation: 1) internal exposure is due to inhalation or ingestion of radionuclides, which release alpha, beta and gamma radiation inside the human body, 2) external exposure is mostly due to the more penetrable gamma radiation from the surrounding environment. Radionuclides responsible for the internal exposure are mostly radon and thoron and their progenies. They are responsible for 52 % to the human annual average dose (UNSCEAR, 2008). As for the external exposures, amongst natural sources the most effective causes are terrestrial radionuclides and cosmic radiation (Eisenbud and Gesell 1997; UNSCEAR 2010). Building materials also significantly contribute to the exposure of the population to natural radioactivity (Trevisi et al., 2010) as they contain terrestrial radionuclides. The main radionuclides responsible for terrestrial radiation are the members of the U-238 and Th-232 series together with K-40 isotope (Eisenbud and Gesell 1997; UNSCEAR 2010).
Adobe is one of the most used building materials in Angola, both in villages and suburban areas, and it is the most widespread building material of families with low income. It is easily accessible and it has an advantage of keeping a favorable indoor temperature in tropical climate. Adobe houses are popular in Africa mostly in the sub-Saharan part. Nevertheless, research on their natural radiation is scarce. In Angola, no recorded studies were made on radon and thoron, or generally on natural radiation and especially not in adobe houses where the doses received by residents are potentially elevated due to the building materials expected high radon and thoron emanation potential.
The main aim of this research is to get information about potential radiological risks of the Angolan population living in adobe houses by evaluating the external and internal exposure. As this is the first time such investigation is done in the country, three places with highly different geological background and microclimate were chosen. Besides evaluating the external and internal exposure of residents, their spatial and seasonal distributions, further laboratory investigations were performed on the adobe building material samples evaluating their texture, mineralogy and radon and thoron sources and emanation properties. The outcome of this research is a useful contribution to the African database in terms of natural radiation in general, and it provides essential information for further investigations in Angola.

2. Study areas and sampling

Sampling

The field work was done in Angola at three different areas, namely in Cabinda in the North part of the country, Huambo in the central part and in Menongue the South part. Two surveys were necessary to achieve the goal of this study. The first was done between November 2014 and May 2015, which corresponds to the Angolan rainy season. During the first campaign 60 adobe blocks were collected, 270 ambient gamma dose equivalent rate measurements were performed, and 45 houses got monitored for radon and thoron indoor activity concentrations with Raduet etched track detectors (Radosys). The second round specifically intended to change the detectors in order to have measurements for the dry season took place between June and October 2015.

Geology and climate of study areas

Cabinda

The geology of Cabinda province is characterized by various formations aging from Precambrian to Holocene, including Pleistocene marine sand deposits at the coastal area (De Araújo, 1992). The study was done at the coastal part of the main city, where the humidity is very high in both seasons around 85 %. Higher temperatures are registered during the rainy season with an average of 27 ℃ than in the dry season with an average of 23 ℃. During the monitored year (2014-15), total precipitation was 244 mm for the rainy and 2 mm for the dry season.

Huambo

The geology of Huambo province consists of old (Archean to Proterozoic) metamorphic (gneiss, micaschist, metasediments) and igneous (granite, rhyolite to andesites) rocks. At Huambo city, Palaeocene-Eocene laterites were also mapped (De Araújo, 1992). The climate is highly influenced by the altitude, i.e. 1700 m above the sea. In the rainy season, the average humidity is 84 % and in the dry season, it is 51 %. The average temperature during the rainy season is 19 ℃ and during the dry season is 20 ℃. Precipitation registered during the monitoring period was 522 mm for the rainy and 79 mm for the dry season.

Menongue

The geology of Menongue study area is based on Archean gneiss, Proterozoic rhyolite-andesite and Tertiary-Quaternary Kalahari sediment formations (De Araújo, 1992). Menongue has a semi-desert climate influenced by the desert of Namibe. The humidity is much higher during the rainy (78 %) than during the dry season (33 %). The temperature difference between daytime and night is around 10 ℃ during the rainy season and 20 ℃ during the dry season. The average temperature in the rainy season is 21 ℃ and in the dry season is 22 ℃. Precipitation data registered during the monitored period gives a total of 573 mm and 24 mm for the rainy and the dry seasons, respectively.

3. Methods

In-situ technics

Ambient gamma-dose equivalent rate determination by a portable device

The investigation was done in 45 adobe houses (15 per area) by using a portable FH 40 G-L10 (Thermo Fisher Scientific Inc.) device. In living rooms 3 different points were measured taking two opposed corners and the center of the living room. At each sampling site two measurements were done, one on the floor and the other one at a height of 1 m. A total of 270 ambient gamma dose equivalent rate measurements were taken (in nSv h^{-1}) and for the external annual dose, the given value was converted to mSv y^{-1}.

Radon and thoron activity concentration monitoring by etched track detectors

A pair of passive radon and thoron detectors were used in 15 adobe houses per area, in total 45 houses were monitored per season. The exposure time was 180 +/- 5 days. The distance of the detector from the wall, was around 8-10 cm accounting for thoron measurement. All detectors were placed in living rooms as the only place made available by the owners. Analysis of etched track passive detectors, reading results as well as radon and thoron activity concentration calculations were all performed by the manufacturer Radosys Ltd. (Budapest, Hungary). Spatial and seasonal variation of radon and thoron were calculated.

To evaluate the health risk of the population living in the monitored houses, inhalation dose from radon and thoron were calculated based on the European Commission report (EC, 1999).

Laboratory methodologies

Radium-226, Th-232 and K-40 content determination by gamma-ray spectroscopy and calculations

Sixty adobe samples from Angola were prepared at the Lithosphere Fluid Research Laboratory at the Eötvös Loránd University and measured by gamma-ray spectroscopy at the Centre for Energy Research, with the aim of assessing the spatial distribution of the radionuclides and calculating the radium equivalent (Ra_{eq}) and the activity concentration (I) indexes what would allow the qualification of the building material regarding the external radiation. Excess external dose from adobe building materials was also estimated based on radionuclide concentrations.

Radon and thoron emanation measurements by RAD7 and calculations

The emanation measurements of Angolan adobe samples were done at the Lithosphere Fluid Research Laboratory at the Eötvös Loránd University using the RAD7 detector. The radon emanation determination of 30 samples followed the so called growth curve method, which considers the radon leakage from the measurement setup after what 12 reasonable results were retained, and the 30 thoron emanation calculations were based on the method of Csige et al. (2013) and Szabó (2013) and took into account the decay of thoron in the setup and that diluted air goes back to the sample holder.

Grain size distribution evaluation

Grain size distribution measurements were conducted on 19 Angolan adobe samples by a Horiba Partica 950-V2 LA Analyzer at the Laser Diffraction Particle Size Distribution Analyzer Laboratory of the Research and Instrument Core Facility of Eötvös Loránd University.

X-ray diffraction analysis (XRD)

From Angola 29 adobe samples were prepared and measured by XRD at the Institute of Mineralogy and Geology of Miskolc University. Samples were powdered under acetone then measured with a Bruker D8 Advance powder diffractometer. Evaluation of recorded patterns was done in Bruker DiffracPlus EVA software, applying Search/Match algorithm. Amorphous amount can be refined to +/- 1wt% percent accuracy, whereas crystalline phases are quantified to +/- 10 % relative error.

Statistical methods

Data were analyzed using the person correlation coefficient to check the geochemical affinity among the radionuclides. Hypothesis tests were used for the analysis of the sample distribution (Shapiro-Wilk test) and the comparison of the sample groups medians (Mann-Whitney).

4. Thesis points

1. My doctorate project is the first to investigate natural radiation in Angolan adobe dwellings measuring ambient gamma dose equivalent rate, Ra-226, Th-232 and K-40 activity concentrations in building materials (following experiences published with my participation in Völgyesi et al., 2016) and indoor radon and thoron levels at three areas of the country with different geological background, geographical location and microclimate. These areas are Cabinda in the north, Huambo in the central and

Menongue in the south part of the country. The results show a spatial distribution: most of the values from Huambo are significantly the highest compared to the other studied areas, which is explained by its geological background composed mostly of granitic rocks (Salupeto-Dembo et al. accepted; Salupeto-Dembo et al. 2020).

2. I concluded that external radiation from adobe building material in Angola is not hazardous for the local population. This is confirmed by calculated radium equivalent (Raeq), activity concentration (I) indexes of 45 samples from the three studied areas and also by calculated and measured external doses. The influence of the altitude on the elevated external dose was also clearly demonstrated (Salupeto-Dembo et al. 2020).

3. I described a seasonal variation of indoor radon and thoron activity concentrations in adobe dwellings of Angola. Radon showed higher values in the rainy season than in the dry season, whereas thoron showed no statistically significant variation between the two seasons. I concluded that the moist content of the soil during rainy season and the behavior of the residents are the main reasons of elevated radon activity concentrations during rainy season (Salupeto-Dembo et al. accepted).

4. I estimated the percentage of adobe houses in Angola with annual radon and thoron activity concentrations above reference values. For this, I described the statistical distributions of results. Accepting a lognormal distribution for both radioactive noble gas isotopes, I concluded that for annual radon activity concentration average there is a 95 % probability that 10 to 32 % of adobe houses in Angola are above the recommended 100 Bq m-3, assuming the representativity of sampling. However, none of the houses exceed the stronger recommendation of 300 Bq m-3. For thoron, no limit exists, but it is estimated that 59 to 81 % of adobe houses in Angola are over 100 Bq m-3 and 6 to 28 % are over 300 Bq m-3 at around 9 cm from the walls with 95 % confidence (Salupeto-Dembo et al. accepted).

5. I have estimated the internal radiation dose of the Angolan population living in adobe houses and confirmed that radon and thoron may cause a non-negligible contribution to the radiation exposure. The residents of Huambo have a higher radon inhalation radiation risk (2±0.8 mSv y-1) than the world average (1.15 mSv y-1). The presently best available estimation shows that thoron contribution to the inhalation dose is significant, around 50 % in average in adobe houses of Angola. With thoron contribution, the

average inhalation dose for the population living in adobe houses in Huambo rises up to 4.5±1.5 mSv y-1 (Salupeto-Dembo et al. accepted).

Publications

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