# RADON MEASUREMENTS WITH CR-39 TRACK DETECTORS AT SPECIFIC LOCATIONS IN TURKEY

by

**Asiye ULUG[1], Melek TUNCAY KARABULUT[1], and Nilgün ÇELEBI[2]**

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**Indoor radon concentration levels at three sites in Turkey were measured using CR-39 solid state nuclear track detectors. The annual mean of radon concentration was estimated on the basis of four quarter measurements at specific locations in Turkey. The measuring sites are on the active faults. The results of radon measurements are based on 280 measurements indoors. The annual arithmetic means of radon concentrations at three sites (Isparta, Egirdir, and Yalvac) were found to be 164 Bqm$^{-3}$, 124 Bqm$^{-3}$, and 112 Bqm$^{-3}$, respectively, ranging from 78 Bqm$^{-3}$ to 279 Bqm$^{-3}$. The indoor radon concentrations were investigated with respect to the ventilation conditions and the age of buildings. The ventilation conditions were determined to be the main factor affecting the indoor radon concentrations. The indoor radon concentrations in the new buildings were higher than ones found in the old buildings.**

*Key words: radon, indoor, CR-39, age, ventilation, Turkey*

## INTRODUCTION

Radon-222 is a radioactive gas derived from the decay of Radium-226, which itself is a decay product of Uranium-238. Public exposure to radon and its radioactive daughters, present in the environment, results in the largest contribution to the average effective dose received by human beings. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) and the International Commission on Radiological Protection reported that the radiation of radon and its daughters is known to be one of the major causes of lung cancer. Radon daughters can attach to tiny dust particles in the indoor air. These particles can easily be inhaled into the lungs and can adhere to the lining of the lungs [1, 2].

The radiation dose received by the human population through the inhalation of radon and its daughters is the highest indoors [3]. The regional distribution of radon concentration in buildings is primarily determined by the building materials, the water sources, the domestic gas supplies and in particular by the soil and the geological structures beneath the building. Temperature and pressure differences, wind velocity and humidity also effect the indoor radon concentration. Therefore, the most essential modifying factors are the type of building constructions, the ventilation conditions, the heating and the cooling systems [4].

Many researchers from almost all around the world have measured indoor radon concentration at various locations [5-7]. It is well known that there is a strong relation between radon and geophysical events [8, 9]. In this study, we measured the indoor Radon-222 levels in the dwellings of Isparta, Egirdir, and Yalvac (fig. 1) in west Mediterranean part of Turkey. These sites are on the active faults (fig. 2). This study is the part of the series of studies investigating the indoor radon concentrations in Turkey buildings.

## EXPERIMENT

All measurements were carried out using CR-39 solid state nuclear track detectors. This

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Authors' addresses:
[1] Akdeniz University, Faculty of Science & Art
Department of Physics
07058 Antalya, Turkey
[2] Cekmece Nuclear Research and Training Center
P. O. Box 1, Atatürk Airport
34149 Istanbul, Turkey

E-mail address of corresponding author:
aulug@akdeniz.edu.tr (A. Ulug)


**Figure 1. The studied sites**

technique is the most popular and reliable technique for integrated and long-term measurement of the radon activity inside houses [10]. The detectors were supplied by *Pershore Mouldings Ltd*., U. K., in the form of large sheets. Those large sheets were cut to 20.0 mm 20.0 mm in size and placed in a plastic container allowing radon to diffuse within. The container was closed with a plastic cap in order to avoid dust deposition on the detector foils. A pair of containers was distributed to the selected houses, one of which was placed in the living room and the other in the bedroom where the families spent most of their time. The exposure time was 90 days in each season. After exposure, for making the tracks visible, the CR-39 chips were immersed in 30% NaOH solution at 63 C for 16 h [11]. Track densities were counted manually using an optical microscope. Calibration measurement was done using a calibration chamber containing a Radium-226 source, maintaining a concentration of 3.2 $kBqm^{-3}$. The Radon-222 concentrations were determined by using a calibration factor of 7.23 kBq $track^{-1}h^{-1}$ and subtracting the background track density from each pit track density on the films. The data about characteristics of the buildings such as age, the number of floors, building construction, ventilation conditions, *etc*., were collected through questionnaires.

## RESULTS AND DISCUSSION

As mentioned above, indoor radon concentration levels were measured in randomly selected houses in the city of Isparta and the districts of Egirdir and Yalvac. At those locations, the seasonal variation of indoor radon concentrations and variation of indoor radon concentrations with number of stages and building constructions were reported at the Fifth General Conference of the Balkan Physical Union (BPU5) [12]. We determined that the radon levels were generally highest in the basements and in the first floor rooms which were in contact with the soil and in the west part of the buildings. The arithmetic means, geometric means, and geometric standard deviations of radon concentrations are shown in tab. 1. The average radon concentration levels in the city of Isparta are higher than those found in Egirdir and in Yalvac.

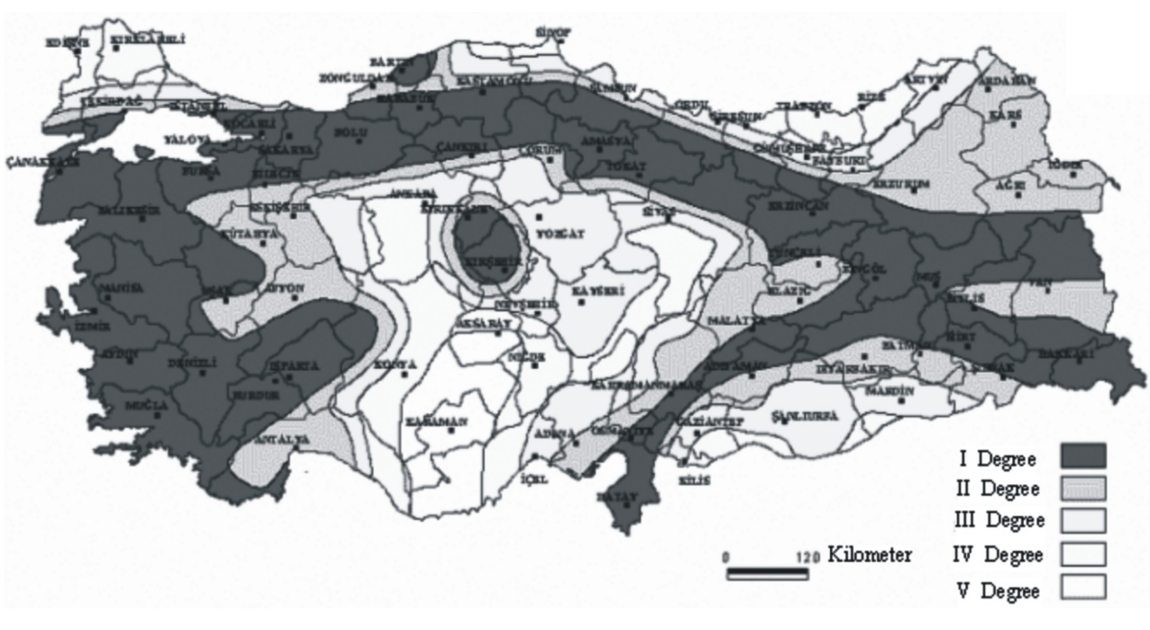


**Figure 2. The seismic hazard zoning map of Turkey**

**Table 1. Measured arthmetic mean, geometric mean and geometric standard deviation of indoor radon concentration levels at three sites in Turkey**

| Region | Number of houses | Arithmetic mean [$Bqm^{-3}$] | Geometric mean [$Bqm^{-3}$] | Geometric standard deviation |
|---|---|---|---|---|
| Isparta | 25 | 164 | 160 | 1.56 |
| Egirdir | 25 | 124 | 122 | 1.76 |
| Yalvac | 20 | 112 | 109 | 1.63 |

Figure 3 gives a clearer picture of the variation of indoor radon concentrations at each site. In 84% of the houses in Isparta, the average radon concentrations varied from 100 to 200 $Bqm^{-3}$. There were three houses that had the indoor radon concentration levels higher than 200 $Bqm^{-3}$ and in only one house the indoor radon concentration level was higher than 250 $Bqm^{-3}$. In Egirdir, in 22 houses (88%) average radon concentration levels were between 50 and 150 $Bqm^{-3}$. In three houses indoor radon concentrations were higher than 150 $Bqm^{-3}$. In Yalvac in all houses the average radon concentration levels were within the range of 50-150 $Bqm^{-3}$. Such average radon concentration levels could be attributed to the ventilation conditions, since the dwellings in Isparta were poorly ventilated, while in Egirdir and in Yalvac the dwellings had better ventilation conditions, as seen in fig. 4. Good ventilation means that the windows were generally opened, while bad ventilation means that the windows were closed most of the time. Natural ventilation decreases radon levels by reducing pressure difference between the indoor and the outdoor air; therefore, ventilation is the key factor which affects the indoor radon concentration.

The average radon concentrations were also found to be building age dependent, as shown in fig. 5. We determined that the indoor radon concentrations in the new buildings were higher than those found in the old buildings. Many of new buildings use concrete as building material with higher radionuclide contents than old buildings. We can also see in fig. 5 that the average radon concentration in the bedrooms was found to be higher than that in the living rooms. The annual arithmetic mean of radon concentration was 124 $Bqm^{-3}$ in the living rooms, while the annual arithmetic mean of radon concentration was 142 $Bqm^{-3}$ in the bedrooms at three sites. This may be due to poor ventilation of the bedrooms.

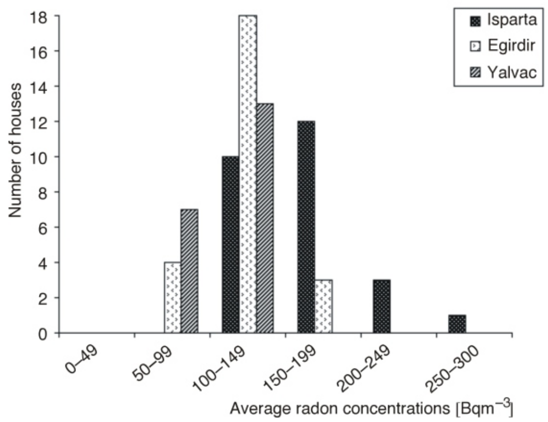


**Figure 3. Variation of the frequency distributions of indoor radon at each site**

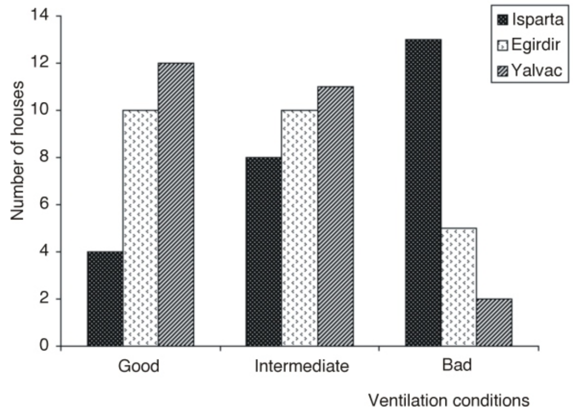


**Figure 4. Ventilation conditions in the dwellings**

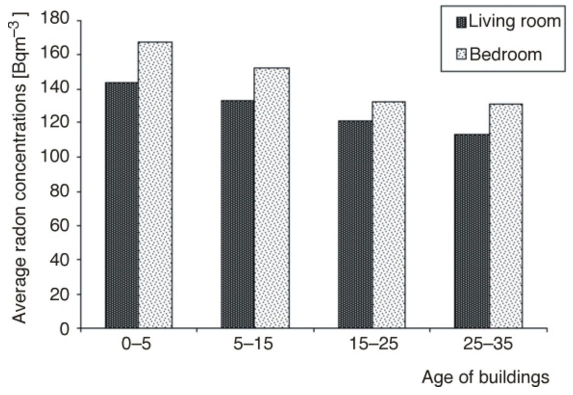


**Figure 5. Variation of indoor radon concentrations with the age of buildings**

## CONCLUSION

Radon measurements were performed indoors in the West Mediterranean part of Turkey by using CR-39 solid state nuclear detectors. The annual arithmetic means of radon concentrations at three sites (Isparta, Egirdir and Yalvac) were found to be 164 $Bqm^{-3}$, 124 $Bqm^{-3}$, and 112 $Bqm^{-3}$, respectively. The average radon concentrations in the city of Isparta are higher than those found in Egirdir and in Yalvac. A positive correlation has been obtained between indoor radon concentrations and ventilation conditions. The indoor radon concentrations in the new buildings were higher than those found in the old buildings. The average radon concentrations in the bedrooms were found to be higher than those found in the living rooms. The average radon concentration in the living rooms was 124 $Bqm^{-3}$, while the average radon concentration in the bedrooms was 142 $Bqm^{-3}$.

From all experimental data measured at three sites the arithmetic mean of indoor radon concentration has been found to be 133 $Bqm^{-3}$. This value is above the average worldwide indoor radon concentration of 40 $Bqm^{-3}$ [1]. None of the location exceeds the Turkish Atomic Energy Authority's (TAEK) intervention limit of 400 $Bqm^{-3}$ [13].

The arithmetic mean of indoor radon concentrations at these sites are higher than in the other cities in Turkey, such as 68 $Bqm^{-3}$ in Şanliurfa, 85 $Bqm^{-3}$ in Erzurum, 50 $Bqm^{-3}$ in Istanbul and 29 $Bqm^{-3}$ in Antalya [14]. The studied sites are on the active faults; therefore, indoor radon concentration was found to be higher than in the other cities in Turkey. Radon emanation is known to be anomalously large on active faults and to show temporal variations related to changing atmospheric conditions and possibly nearby seismic activities.

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**Асије УЛУГ, Мелек ТУНКАЈ КАРАБУЛУТ, Нилгун ЧЕЛЕБИ**

## МЕРЕЊЕ РАДОНА КОРИШЋЕЊЕМ CR-39 ТРАГ ДЕТЕКТОРА НА ОДРЕЂЕНИМ ЛОКАЦИЈАМА У ТУРСКОЈ

Коришћењем чврстих нуклеарних траг детектора CR-39 измерени су нивои концентрације радона у затвореним просторијама на три места у трусном подручју Турске. На основу четири квартална периода оцењене су средње годишње концентрације радона, засниване на резултатима 280 мерења. Утврђена је годишња аритметичка средина концентрације радона за Испарту, Егирдир и Јалвац од 164 $Bqm^{-3}$, 124 $Bqm^{-3}$ и 112 $Bqm^{-3}$, респективно, а у опсегу 78-279 $Bqm^{-3}$. Испитан је утицај услова проветравања и старости зграда на концентрацију радона и потврђено је да је проветравање главни чинилац који утиче на концентрацију радона у затвореним просторијама, као и да је у новим зградама концентрација радона виша него у старим.