A seismic factor of radon danger on a case study of Armenia

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Abstract

For the first time, on the basis of Spitak earthquake experience (Armenia, December 1988), it was found out that an earthquake causes intensive and prolonged radon releases, that are quickly dispersed in the open air, and that is why they are not usually registered but contrastingly displayed in covered premises (dwelling houses, schools, kindergartens) even if they are at considerable distance from the epicenter of the earthquake. The duration of the release includes the period starting from the first foreshock and ending with the last aftershock, i.e. several months. The radiation intensity and duration of the influence are in direct correlation with the force of earthquake. The area affected by radiation is larger than the territory of Armenia. The scale of this impact on the effected population is 12 times higher than the number of people injured in the Spitak earthquake.

1. Introduction

The reality of the radon problem is universally recognized today. According to IAEA data, natural sources of radiation are responsible for the main contribution (up to 70%) to the total radiation dose. The main contributions are materials with increased content of natural radionuclides, and radon accumulating in buildings. About 44% of the total radiation dose arise from radon and its daughters. Mortality attributable to this is about 80000 people per year. Among the main consequences of radon exposure are cancer of the upper respiratory tract and lungs, and leukemia in children. In many countries (e. g. United States of America, Sweden, United Kingdom) this problem has become the subject of national programs.

The attention of studies in other countries is focused on the harmful effect of radon for those who inhabit houses with high radon concentrations for long period. The main sources of radon are building materials, mainly soils. According to IAEA data, localities with a high content of radioactive elements in rocks are considered as "hot points" with increased content of radon.

There is no information in literature about the influence of earthquake epicenter and the radius of its effects on radon concentration in dwellings. There are no data concerning the radiological implications of dust during destruction caused by earthquakes.

The problem of populated areas in the general sphere of problems connected with earthquakes is usually considered only in one aspect, namely, that of seismically stable building and structures. But, as the results of our mainly ecological investigations have shown, catastrophic destruction caused by earthquakes, with all ensuing consequences, is only the tip of the iceberg. It is possible to predict an earthquake correctly, to have seismically stable houses, and to avoid direct fatalities, but it is impossible to avoid danger of death, when there is no knowledge of such danger - this danger is radiation [1].

However, as the results of our investigations have shown, the same houses at the same time of the year are characterized by different concentrations of radon at stable and extreme (earthquake) conditions of the Earth's crust [2, 3].
The fact that the earthquakes in Armenia are often weak, small-depth and occur in swarms [4], served an impetus for subsequent investigations during 2005 to 2007.

2. **Subject and Methodology of measurements**

The research is underpinned by the results of indoor radon monitoring conducted in Yerevan (Armenia) and its surroundings from 1987 to 1993 and from 2005 to 2007 (during stable and unstable situation of the Earth's crust). The area is characterized by low activity volcanogenic sedimentary rocks. Armenia is a highland region, characterized by young volcanism. The volcanic regions have not yet cooled and the region is seismically active. These active geotectonic processes and the increasing industrialization make public safety an issue with regard no natural and industrial catastrophes. Measurements were made using a radon meter (model FAS-P-2 model supplied with a filter type AFA-PSP-20, manufactured in Russia). The instrument assures a 95% efficiency of radon aerosols gathering and a measurement error of about 40%.
Air samples were taken in basements and measured in underground, single-and multi-storied buildings throughout the study period. While carrying out investigations, recommendations were made on the methodology for measuring the volume activity of radon and its daughter products in the air of dwellings and other buildings in Armenia.
The total number of samples taken and analyzed for 1987 to 1993 time periods was 5228. Mean monthly values of measurements were generated, irrespective of the type of building, through a moving average formula, and graphs were constructed from the data obtained.
Measurements for 2005-2007 time periods were done on a RAD-7 radon meter (USA).
For these time period 1442 measurements were done. Wholly, 6670 measurements were done.

3. **Results and discussion**

Statistical processing of the radon monitoring data 1987-1991 (Fig.1) superimposed on the dynamics of the earthquake showed clearly that, irrespective of seasonal oscillations, the radon concentration in dwellings during 1987 was within normal levels. A growth in radon concentration occurred from the beginning of 1988, and in July and August exceeded by 8-10 times the concentration during the previous year. In January 1989, the mean radon concentration had increased by nearly 14 times. As follows from Fig.1, three spikes are evident, characterizing intensive releases of radon corresponding, with some delay in time, to the first foreshock, the main shock, and the late aftershocks. The time interval between the first foreshock and the last aftershock, characterized by multiple increases in radon concentration in closed buildings, could be clearly seen.

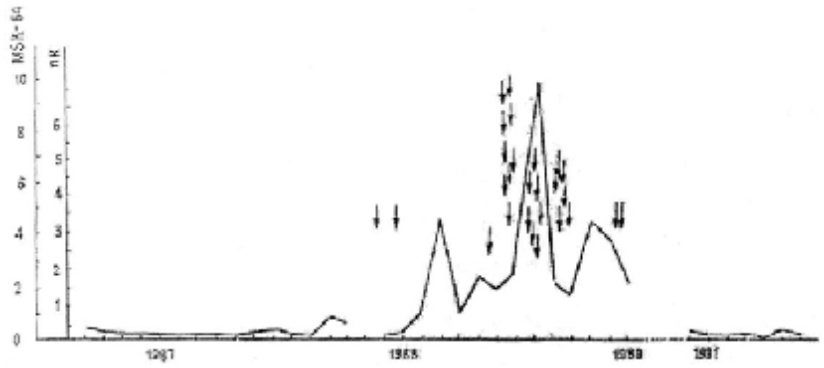

Figure 1 Dynamics of changes in the concentration of indoor radon and The intensity of the Spitak earthquake, Yerevan

Annual average indoor radon concentrations in Yerevan in 1987, 1988, 1989, 1991, and the indices of the variations, are shown in Table 1. They show clear differences between stable periods (1987, 1991) and unstable periods (1988, 1989) of the Earth's crust.

Table1. Indoor radon concentrations in Yerevan

Year	Mean concentration pCi/l	Dispersion α^2	Root mean square dispersion, d	variation coefficient V%
1987	0.25	0.0106	0.0103	41.32
1988	1.126	0.864	0.924	82.5
1989	2.977	4.444	2.109	70.81
1991	0.17	0.004	0.069	37.05

It is important to note that actually there is no vivid central spike, and, according to the results of daily measurements, this whole interval before and after the earthquake is characterized by dozens of spikes

Fig.2 shows the effective dose calculated at monthly intervals and projected to an annual figure. Here also, curves characteristic of the stable state and for the state during the earthquake are distinctly seen. In January 1989, the projected annual dose from radon and its daughters was about 16 mSv. If the 1987, 1991, 1992, and 1993 data, showing doses from 0.183 to 0.435mSv (less than twice the global average), are taken as typical, then the dose in January 1989 was 50 times more than that in the 'stable' periods and 16 times more than the global average.

Near the epicenter of the earthquake (Nalband, Spitak and alongside the whole disaster zone), the indoor radon concentrations, and hence the effective dose from radon, were many times higher.

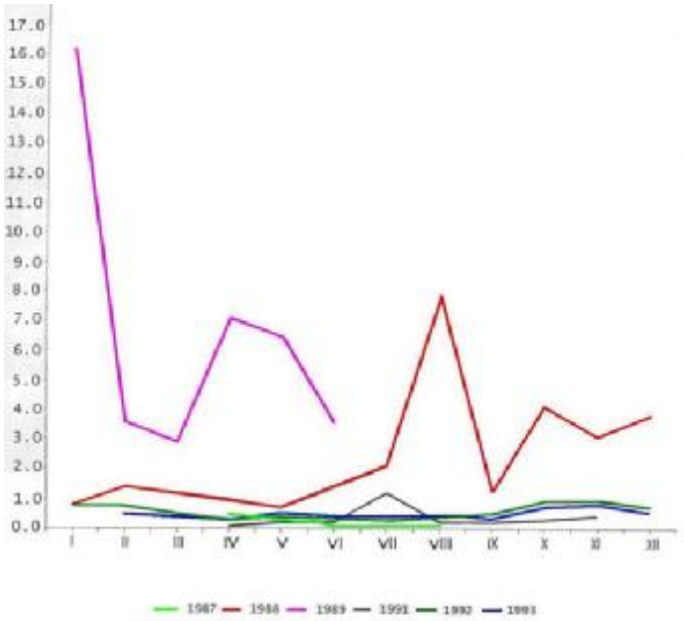

Figure 2 Annualized effective doses from exposure to radon in Yerevan

The effect of radon is different in diverse environments. A contrasting increase in indoor radon concentration became a carcinogenic risk factor which consequences have s been lasting still. In accordance with annual statistical reports of Ministry of health of RA the first flash of cancer diseases was recorded in 1989-1990, the second – the most intensive of tumor diseases was recorded 15 years later up to present (Fig.3).

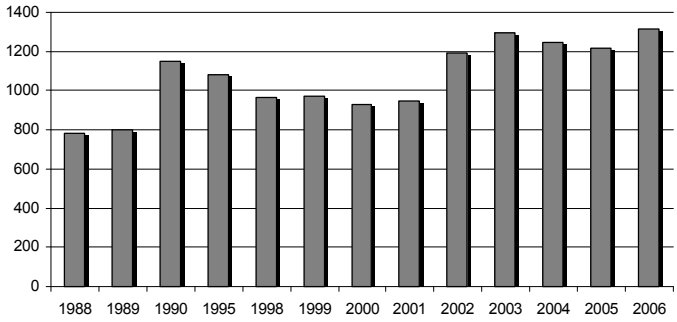

Figure 3 Malignant cancer diseases of adults and teenagers (Per 100000 adults and teenagers)

Radon flashes in near-earth atmosphere intensively ionized the air with formation of air ions which provoked total respiratory diseases with a peak falling on 1990(Fig.4).

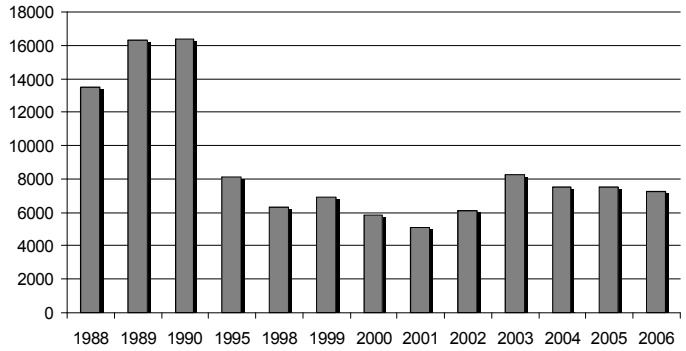

Figure 4 Respiratory diseases in adults and teenagers (Per 100000 adults and teenagers)

The increase in radon in water sources induced digestive diseases with a peak also falling on 1989(Fig.5).

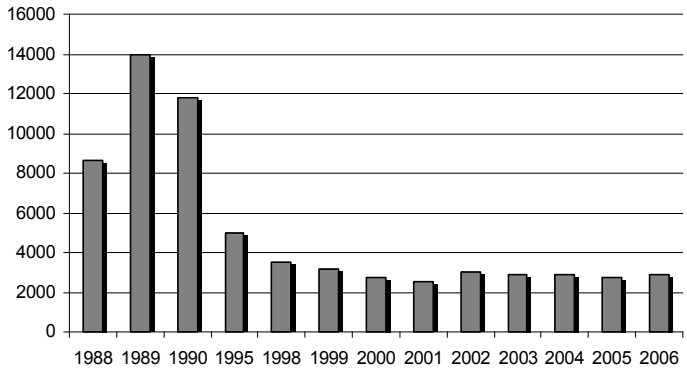

Figure 5 Digestive system diseases of adults and teenagers (Per 100000 adults and teenagers)

In upper lithosphere layers the increase in alpha-radiation increased the level of neutron radiation of the Erath which induced mental diseases (Fig.6).

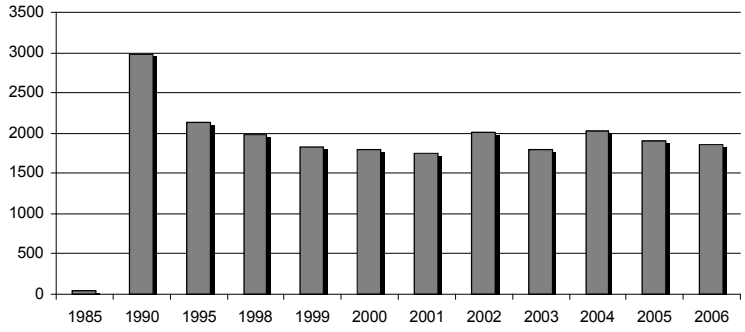

Figure 6 Mental diseases of adults and teenagers (Per 100000 adults and teenagers)

This phenomenon was established also during the Noemberian earthquake of 1994, entailing no human loss or ravages. The radiation intensity and duration of the influence are in direct correlation with the force of earthquake.

The indoor radon monitoring data for 2005 to 2007 indicate that at weak and medium magnitude earthquakes indoor radon concentrations show 3 to 8 time increases which remain unchangeable for several days only[4].

4. Conclusion

The danger of the influence of natural radiation provoked by the earthquake exists for all urban territories of seismic active regions, and it requires coordination of investigations in different countries according to precisely-elaborated programs.

5. References

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