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POTENTIAL HEALTH EFFECTS FROM EXPOSURE TO INCREASED RADON LEVELS IN AZERBAIJAN

Aliyev Ch.S., Mahmudova F.F.

Ministry of Science and Education of the Republic of Azerbaijan,
Institute of Geology and Geophysics Baku, Azerbaijan,
119, H.Javid ave., Baku, AZ 1143: aliyev_chingiz47@gmail.com

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Summary. The radiation safety of the population is a global and important problem of our time. The main radiation background of the Earth is formed due to natural radiation sources. Numerous explorations conducted abroad have convincingly proven that radon and its short-lived daughter decay products create about 40-75% of summary doze that a human gets from all natural sources of ionizing radiation. In 1987, radon and its decay products were classified by experts of the International Agency on Cancer Research as a group of elements carcinogenic to humans. People's protection from exposure to radioactive natural gas – radon and its decay products is the national problem and requires studying a number of issues related to radon source and radon availability in the buildings. The paper presents the characteristic results of the analysis of the relationship between the incidence rates of the population with malignant neoplasms of the lungs and the distribution of indoor radon. The obtained results confirm the role of radon as a dominant factor leading to a high risk of lung cancer, which should be taken into account in the development and implementation of appropriate preventive social and health measures, construction standards, especially for certain regions of Azerbaijan with a high level of natural radon radiation.

1. Introduction

Medical geology is a new, strategically significant direction in geology, studying the relationship between the features of the geological environment and the incidence of the population, the state of the flora and fauna. The target of the medical geology is to identify harmful geological factors and their conditions of impact that contribute to the deterioration of health, as well as to develop rational principles, strategies, programs and approaches necessary to eliminate or minimize health risks.

Azerbaijan is known for its natural resources, mainly oil and gas, which has been the reason for the rapid industrial growth of the country since the end of the 19th century. The exploitation of oil fields, accompanied by pollution of the soil and water basins, has caused a rather dangerous radiation environmental situation for human life in certain regions. In addition, Azerbaijan is located in a seismically active geological zone, which leads to the presence of certain regions with a high level of radiation background, especially in connection with the intensive release of radon from active faults to the Earth's surface. The main objectives of researches in medical geology in Azerbaijan are the zoning of the territory of the republic from the standpoint of environmental problems and the studying of radiation, geochemical and environmental features of these territories. One of the main directions of medical geology in Azerbaijan is the problem of radon safety of the population.

Indoor radon studies in Azerbaijan were firstly conducted in 2010-2011 with the financial support of the Swiss National Science Foundation (SNSF). These studies were carried out jointly by the Radon Competence Center (RCC) of the University of Applied Sciences and Arts of Southern Switzerland (SUPSI) and the Institute of Geology and Geophysics of the Azerbaijan National Academy of Sciences (ANAS) (Алиев и др., 2017).

Based on the obtained data, the maps of the distribution of indoor radon activity and maximum volumetric activity of radon were made (Fig.1) (Aliyev et al., 2018).

The obtained data were processed using purely statistical methods since no geological or soil measurements (usually a radon source indicator) were available (Hoffman et al., 2016). The frequency distribution of the measured radon concentrations is shown in Fig. 2 indicating a log-normal character

with a median of 58 Bq/m³ and a mean of 84 Bq/m³. The upper background limit calculated as twice the median amounted to around 116 Bq/m³. All of the above values can be considered as statistically elevated, but compared with the maximum allowable concentration (MAC) for indoor in Azerbaijan, which is 200 Bq/m³, only the buildings with radon concentrations exceeding the MAC are interesting from public of view.

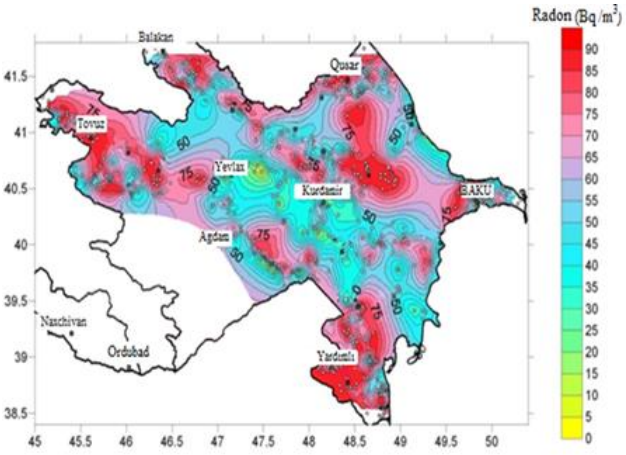

Fig. 1. Distribution of indoor radon in Azerbaijan

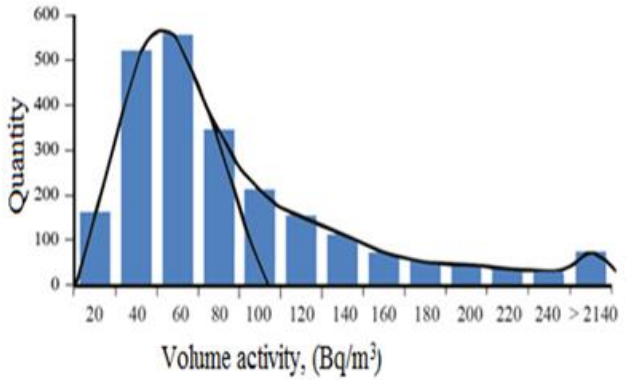

Fig. 2. Frequency distribution of the indoor radon concentration

Increased values of concentration of indoor radon are characteristic of the mountain-folded regions of the Greater and Lesser Caucasus, Talysh, composed of more ancient and deployed rocks, and relatively low values of radon volumetric activity are confined to the Kura and Caspian-Guba depression zones represented on the surface of the Earth by rocks of quaternary age (Aliyev et al., 2014). As a result of the research, the territory of Azerbaijan was divided into 4 zones by the degree of radon hazard (indoor radon activity): dangerous (200-400 Bq/m³), moderately dangerous (100-200 Bq/m³), conditionally safe (50-100 Bq/m³) and safe (<50 Bq/m³) (Mahmudova, 2021).

In 1987 experts of the International Agency of Cancer Study classified radon and its daughter decay products as a group of elements definitely carcinogenic to humans. Numerous explorations conducted abroad convincingly proved that radon and its short-lived daughter decay products create about 40-75% of the summary that human gets from all natural sources of ionizing radiation (Тихонов, 2006). Radon is the only gaseous product formed during the decay of all radioactive families. In nature, radon occurs in three main forms: in the form of ^{222}Rn, half-life T = 3.8 days, formed in the radioactive family of uranium-238; ^{220}Rn (side), half-life T = 55 seconds, member of thorium-232 radioactive series; ^{219}Rn (actinone), decay period T = 4 seconds, is formed in the radioactive family of actinium. Radon-222 gives the greatest contribution to the total radiation dose.

The long half-life and chemical inertness of ^{222}Rn, located in the decay chain of uranium-238, increases its content in the air of the areas. Most of the radiation comes from short-lived daughter products of radon decay. Short-lived daughter decay products of radon-222 actively irradiate internal human organs with alpha particles.

Materials and methods: In order to analyze the link between the development of lung malignancies and the population living in radon-hazardous zones, relative risk indicators were determined (Dupont, Plummer, 1996). At the same time, the indicator of relative risk made it possible to assess how many times living in conditions of radon-hazardous zones increased the likelihood of getting malignant lung neoplasms.

For the analysis two databases were formed. The first one contained information about number of newly diagnosed cases of malignant neoplasms among the population in the regions of Azerbaijan for the period from 2005 to 2015. Population of the studied regions of Azerbaijan in 2005-2015 was determined according to official state statistics. The second database contained information on the values of indoor radon in the regions of Azerbaijan.

Results and discussion: To determine the relationship between the incidence rates of the population with malignant lung formations and the distribution of indoor radon in Azerbaijan, two groups were formed. The main group included persons living on the territory of radon hazardous zones of Azerbaijan (Shamakhy, Tovuz, Shamkir and Zakatala regions) and the control group included persons living on the territory of Azerbaijan, which is not radon hazardous, with the lowest arithmetic mean values of indoor radon (Barda, Agjabadi, Imishli and Gadabey regions) (Table 1).

Relative risk (RR) is calculated using the following formula:

$$RR = \frac{\frac{A}{A+B}}{\frac{C}{C+D}} = \frac{A\cdot(C+D)}{C\cdot(A+B)}, \quad (1)$$

where A – patients with lung malignancies from radon-hazardous zones over the period of 2005-2015;
B – patients with malignant lung neoplasms from non-radioactive zones over the period of 2005-2015;
C – persons without detected malignancies from radon-hazardous zones over the period of 2005-2015;
D – individuals without detected malignancies from non-radioactive zones over the period of 2005-2015.

Next, we find the values of the boundaries of the confidence interval – 95% CI.

The formula for calculating the upper limit of the confidence interval is:

$$\ln(RR) + 1.96 \cdot \sqrt{\frac{B}{A\cdot(A+B)} + \frac{D}{C\cdot(C+D)}}. \quad (2)$$

The formula for calculating the lower limit of the confidence interval:

$$\ln(RR) - 1.96 \cdot \sqrt{\frac{B}{A\cdot(A+B)} + \frac{D}{C\cdot(C+D)}}. \quad (3)$$

Relative risk indicators are compared with one: if the relative risk indicator is equal to one, it can be concluded that exposure does not affect the outcome (there is no relationship between the factor and the result). When the values are greater than one, it is concluded that the risk of the outcome is increased by the exposure, which is a "risk factor" (direct relationship). If the values are less than one, it indicates that the risk of the outcome is decreased by the exposure, which is a "protective factor".

In addition, the boundaries of the 95% confidence interval are also necessarily determined. If the lower and upper limits are on the same side of one, or, in other words, the confidence interval does not include one, then a conclusion is made about the statistical significance of the identified relationship between the factor and the result with a probability of error $p < 0.05$.

If the lower limit of the 95% confidence interval is less than one, and the upper limit is greater, then it is concluded that there is no statistical significance of the influence of the factor on the frequency of outcomes, regardless of the relative risk value ($p > 0.05$).

The RR calculated from Table 1 was RR = 1.915 (CI 2.183-1.679), $p < 0.05$. Thus, with a probability of 95%, we can claim that there is a significantly pronounced and statistically reliable link between the development of lung malignancies and living in the conditions of radon-hazardous zones of Azerbaijan.

Relative risk indicators were also determined for the Greater and Lesser Caucasus and Talysh in comparison with the Kura depression (table 2).

The main group included persons living on the territory of radon hazardous zones of Greater Caucasus (Shamakhy, Zakatala, Sheki, Gakh and Guba regions) and the control group included persons living on the territory of Kura depression, which is not radon hazardous, with the lowest arithmetic mean values of indoor radon (Barda, Agjabadi, Imishli, Shirvan and Saatly regions).

The RR calculated from Table 2 was RR = 2.316 (CI 2.062-2.603), $p < 0.05$. Thus, with a probability of 95%, we can claim that there is a significantly pronounced and statistically reliable link between the development of lung malignancies and living in the conditions of radon-hazardous zones of Greater Caucasus.

The main group included persons living on the territory of radon hazardous zones of Lesser Caucasus (Shamkir, Gazakh, Tovuz and Terter regions) and the control group included persons living on the territory of Kura depression, which is not radon hazardous, with the lowest arithmetic mean values of indoor radon (Barda, Agjabadi, Imishli, Shirvan and Saatly regions).

The RR calculated from Table 3 was RR = 1.623 (CI 1.450-1.816), $p < 0.05$. Thus, with a probability of 95%, we can claim that there is a significantly pronounced and statistically reliable link between the development of lung malignancies and living in the conditions of radon-hazardous zones of Lesser Caucasus.

The main group included persons living on the territory of radon hazardous zones of Talysh (Masally, Lankaran, Astara, Yardimly and Lerik regions) and the control group included persons living on the territory of Kura depression, which is not radon hazardous, with the lowest arithmetic mean values of radon volume activity (Barda, Agjabadi, Imishli, Shirvan and Saatly regions).

The RR calculated from Table 4 was RR = 1.542 (CI 1.355-1.755), $p < 0.05$. Thus, with a probability of 95%, we can claim that there is a significantly pronounced and statistically reliable link between the development of lung malignancies and living in the conditions of radon-hazardous zones of Lesser Caucasus.

The obtained results confirm the role of radon as a dominant factor leading to a high risk of lung cancer, which should be taken into account in the development and implementation of appropriate preventive social and health measures, construction standards, especially for certain regions of Azerbaijan with a high level of natural radon radiation.

Table 1

Distribution of patients with malignancies of lungs and other persons depending on residence in radon active and non-radon active zones

Presence of lung malignancies (LM)	Groups		Summary	RR	p
	Basic	Control			
Patients with cases of LM	716 (A)	323 (B)	1039	1.915 (2.183-1.679)	<0.05
Persons without cases of LM	575 634 (C)	497 477 (D)	1 073 701		
Total	576 350	497 800	1 074 150		

Table 2

Relative risk indicator for the Greater Caucasus compared to the Kura depression

Presence of lung malignancies (LM)	Groups		Summary	RR	p
	Basic	Control			
Patients with cases of LM	959 (A)	401 (B)	1360	2.316 (2.062-2.603)	<0.05
Persons without cases of LM	636 455 (C)	616 977 (D)	1 253 422		
Total	637 414	617 378	1 254792		

Table 3

Relative risk indicator for the Lesser Caucasus compared to the Kura depression

Presence of lung malignancies (LM)	Groups		Summary	RR	p
	Basic	Control			
Patients with cases of LM	1250 (A)	401 (B)	1651	1.623 (1.450-1.816)	<0.05
Persons without cases of LM	1 184 612 (C)	616 977 (D)	1 801 589		
Total	1 185 862	617 378	1 803 240		

Table 4

Relative risk indicator for Talysh compared to the Kura depression

Presence of lung malignancies (LM)	Groups		Summary	RR	p
	Basic	Control			
Patients with cases of LM	536 (A)	401 (B)	937	1.542 (1.355-1.755)	<0.05
Persons without cases of LM	534 227 (C)	616 977 (D)	1 152 141		
Total	534 763	617 378	1 153 078		

Currently, there is a number of methods of anti-radon protection in residential buildings with increased concentrations of indoor radon. Reducing of indoor radon concentrations in the air of rooms can be achieved due to the following technical solutions:

- Selection of a site for construction on the territory with a minimum yield of natural radon from the soil;
- Application of various design solutions that prevent radon entering from the soil into the building;
- Forced and natural ventilation to remove radon from indoor air.

The first and the second versions are used at the stage of design and construction of structures in areas with increased emanations of radon from soils. For houses under construction, at the design stage, a comprehensive environmental and geophysical control should be carried out, including the study of the natural radiation background, the identification of active tectonic zones, distribution of the radon volumetric activity when choosing sites for the construction of residential and industrial buildings.

As the character of the regional radon field of Azerbaijan is determined according to a limited number of residential objects, to identify a more

real picture, detailed work must be done in anomalous zones in order to measure radon in residential objects without previous researches. It is recommended to carry out comprehensive work, including a selective medical examination of people who have long lived in houses with abnormal concentrations of radon.

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ОЦЕНКА ПОТЕНЦИАЛЬНОГО КАНЦЕРОГЕННОГО РИСКА РАДОНА ДЛЯ ЗДОРОВЬЯ НАСЕЛЕНИЯ АЗЕРБАЙДЖАНА

Алиев Ч.С., Махмудова Ф.Ф.

Министерство науки и образования Азербайджанской Республики, Институт геологии и геофизики, Баку, Азербайджан AZ 1143, Баку, просп.Г.Джавида, 119: aliyev_chingiz47@gmail.com

Резюме. По данным Международного Комитета по Радиационной защите на радон и дочерние продукты его распада приходится 40-75% от суммарной дозы облучения, получаемого от природных источников. В 1987 г. радон и продукты его распада были отнесены экспертами Международного Агентства по изучению рака к группе элементов, безусловно канцерогенных для человека. В настоящее время защита населения от воздействия радона, природного радиоактивного газа, является важной проблемой, обуславливающей необходимость проведения ряда исследовательских работ по выявлению источников этого газа, определению его количества в населенных пунктах. В статье приводятся характерные результаты анализа зависимости между показателями заболеваемости населения злокачественными новообразованиями легких и распределением радона. На основе выполненных исследований территория Азербайджана была разделена на 4 зоны по степени радоноопасности (объемной активности радона внутри помещений): опасная (200-400 Бк/м^3), умеренно опасная (100-200 Бк/м^3), условно безопасная (50-100 Бк/м^3) и безопасная (<50 Бк/м^3). Выявлено, что заболеваемость со злокачественными новообразованиями особенно высока в пределах горно-складчатой зоны Большого и Малого Кавказа и Талыша, где зафиксированы повышенные значения объемной активности радона. Наиболее высокие показатели заболеваемости со злокачественными новообразованиями органов дыхания зафиксированы в опасных и умеренно опасных зонах радонового облучения. Для проведения анализа зависимости между развитием злокачественных новообразований легких и проживанием населения в радоноопасных зонах были определены показатели относительного риска. Показатели относительного риска позволили оценить, во сколько раз проживание в условиях радоноопасных зон увеличивало вероятность заболеть злокачественными новообразованиями легких. Полученные показатели относительного риска свидетельствуют о наличии прямой связи между развитием злокачественных новообразований легких и проживанием в условиях радоноопасных зон Азербайджана.

Ключевые слова: *медицинская геология, облучение радоном, злокачественные новообразования легких, относительный риск, радоновые зоны, радон внутри помещений*

AZƏRBAYCAN ƏHALİSİ ÜÇÜN RADONUN POTENSİAL KANSEROGEN RİSKİNİN QİYMƏTLƏNDİRİLMƏSİ

Əliyev Ç.S., Mahmudova F.F.
Azərbaycan Respublikası Elm və Təhsil Nazirliyi, Geologiya və Geofizika İnstitutu
AZ1143, Baku, H.Javid prosp., 119: aliyev_chingiz47@gmail.com

Xülasə. Beynəlxalq Radiasiyadan Mühafizə Komitəsinin məlumatlarına əsasən təbii mənbələrdən alınan ümumi radiasiya dozasının 40-75%-i radon və onun parçalanma məhsullarının payına düşür. 1987-ci ildə radon və onun parçalanma məhsulları Beynəlxalq Xərçəng Araşdırmaları Agentliyinin mütəxəssisləri tərəfindən insanlar üçün mütləq kanserogen olan elementlər qrupuna daxil edilmişdir. Hal-hazırda əhalinin təbii radioaktiv qaz olan radonun təsirindən qorunması bu qazın mənbələrinin müəyyən edilməsi və yaşayış məntəqələrində miqdarının müəyyən edilməsi üçün bir sıra tədqiqat işlərinin aparılmasını zəruri edən mühüm problemdir. Məqalədə əhalinin ağciyərlərin bədxassəli törəmələrinin rastlaşma nisbəti və radonun paylanması arasındakı əlaqənin təhlilinin xarakterik nəticələri təqdim olunmuşdur. Yerinə yetirilmiş tədqiqatlar əsasında Azərbaycan ərazisi radon təhlükəsi (daxili məkanlarda radonun həcmi aktivliyi) dərəcəsinə görə 4 zonaya bölünmüşdür: təhlükəli (200-400 Bk/m^3), orta təhlükəli (100-200 Bk/m^3), şərti olaraq təhlükəsiz (50-100 Bk/m^3) və təhlükəsiz (<50 Bk/m^3). Müəyyən edilmişdir ki, radonun həcmi aktivliyinin yüksək göstəriciləri xarakterik olan Böyük və Kiçik Qafqaz və Talışın dağlıq-qırışıqlıq zona hüdudlarında ağciyərin bədxassəlli törəmələri ilə xəstələnmə xüsusilə yüksəkdir. Tənəffüs orqanlarının bədxassəli xəstəliklərinin ən yüksək göstəriciləri radon şüalanmasının təhlükəli və orta təhlükəli zonalarında qeydə alınmışdır. Ağciyərlərin bədxassəli törəmələrinin inkişafı ilə əhalinin radon-təhlükəli zonalarda yerləşməsi arasındakı əlaqəni təhlil etmək üçün nisbi risk göstəriciləri müəyyən edilmişdir. Nisbi risk göstəriciləri radon-təhlükəli ərazilərdə yaşayanlarda ağciyərlərin bədxassəli törəmələrinin inkişaf ehtimalını neçə dəfə artırdığını təxmin etməyə imkan verir. Alınmış nisbi risk göstəriciləri insasnlarda ağciyərlərin bədxassəli törəmələrinin inkişafı ilə Azərbaycanın radon-təhlükəli zonaları şəraitində yaşamaq arasında birbaşa əlaqənin olduğunu göstərir.

Açar sözlər: *tibbi geologiya, radon şüalanması, ağciyərlərin bədxassəli törəmələri, nisbi risk, radon təhlükəli zonalar, yaşayış yerlərində radon*