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The study on the residential radon concentration in the rooms in the areas of the Republic of Moldova

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Abstract
Natural radioactivity is still a topic addressed at the international level with multiple segments interspersed in the upward pace of technological and economic development at the local level. The intensity of concerns in the aspect of radioprotection starts from a series of factors that condition the level and doses of exposure of the population to sources of ionizing radiation, thus determining the medical, social, economic and demographic effects in the characteristic of a medico-social problem. Radon, through its contribution to the creation of the natural radioactive background, has a crucial role in the etiology of oncological diseases of broncho-pulmonary origin, leukemias and other pathologies. Long-term exposure to increased concentrations of radon and the association of other risk factors, such as tobacco consumption, causes the alteration of cellular metabolism processes, the damage of DNA and RNA nucleic acids, the formation of free radicals and the appearance of mutations that can constantly trigger lung cancer. The continuous monitoring of residential radon concentrations is a primary objective within the strategy to control and reduce the long-term negative effects of radon, being a main element of the action plan of the EURATOM Directive 59/2013.

Keywords:. radon, concentration, tobacco synergism, detector.

1. INTRODUCTION

In 1988, the International Agency for Research on Cancer declared radon as a carcinogenic factor, a fact that is argued to this day through various case-control studies, analytical studies that tend to draw public attention to this silent killer in our homes.

Radon is a colorless, odorless, insipid gas, without being perceived by people, it makes its presence in our homes having negative effects on health due to its peculiarities. Radon is part of the Uranium decay series, being produced in all three series, it is the heaviest gas in nature, with a half-life of 3.82 days, it dissolves easily in organic solvents and water [1,2]. Scientific research on this element has confirmed its major contribution to the creation of the natural background of radiation, so that about 50% of the total irradiation of the body is caused by radon, thus also contributing to the total radiation exposure doses of the population, of which about 82% they are of natural origin.

The importance of radon is accentuated by its implications in the occurrence and development of oncological diseases, or radon is the first cause of bronchopulmonary cancer in non-smokers and the second cause for tobacco users. According to the World Health Organization, radon causes between 3 and 14% of broncho-pulmonary cancers worldwide. More than 1.3 million people are victims of lung cancer annually, of which about 16% die as a result of exposure to radon [1].

Long-term exposure and the association of other predisposing factors increase the risk of the pathological process. Indoor air pollution with radon is an initial factor in an entire pathogenic process, related to the inhalation of this gas, as well as its disintegration products, the accumulation of particles in the respiratory tract, their migration to the lower respiratory tract depending on the size and mechanical properties and the accumulation of these products over a period of time equivalent to the period of disintegration.

In the Republic of Moldova, the existence of this problem has a direct impact on the trend of morbidity indicators through respiratory oncological diseases, and the risk related to the population's exposure to increased concentrations of radon is practically the same throughout the country [2]. Simultaneously with the study of the concentration of residential radon, it is also necessary to estimate the exposure doses of radon from underground water and soil, in order to obtain a complete picture of its action on health. The individual risk of exposure to radon is different depending on the consumption of tobacco, both active and passive, type of housing, microclimatic factors and the association of an unhealthy lifestyle. Thus, approaching the radon problem only from the perspective of increased concentrations tends to omit relevant particularities of it, being insufficient to study exposure doses without analyzing the patterns of bronchopulmonary cancer occurrence in the context of the presence of other determined factors.

As part of the monitoring of radon concentrations in the air in homes in the territory of the Republic of Moldova in the period 2018-2020, a study carried out by ANSP with the support of the IAEA, over a period of 3 months through passive measurements, demonstrated that in 51% of the researched homes, the radon concentration exceeded the national/European norms of 300 Bq/m^3. Thus, according to the results of this study published in 2019, carried out throughout the country, radon concentrations were recorded inside homes that exceeded national norms (150 Bq/m^3), in about 25% of cases, another 26% exceeded European norms (300 Bq/m^3).

The average radon concentration in homes across the country was over 200 Bq/m^3, and in some homes over 1000 Bq/m^3 [1]. From what it has been presented, it follows that until now the research on radon in the air in the homes of the Republic of Moldova has only been carried out at the screening level, using equipment and active detectors (short-term (3-4 hours) for measuring the radon concentration (RTM 1800 radonometer from SARAD company) [2]. International studies point out that for exposure to radon with a concentration of 200 Bq/m^3, the estimated risk is 2.98-6.55% for men who smoke continuously and 0.19-0 .42% for men who never smoke, assuming a multiplicative relationship for the joint effect of radon and smoking [3].

The transposition of the objectives of the EURATOM Directive 59/2013 is an essential premise in the development of the national action plan and the implementation of the radioprotection measures corresponding to the country, and the continuous reassessment of the exposure doses makes the population protection models more effective in order to direct the appropriate information and guidance measures [4, 5].

2. EXPERIMENTAL

In order to monitor the concentration of radon on the territory of the Republic of Moldova, a study was initiated with the aim of estimating the health risk associated with exposure to radon and developing measures to control the influence of the interaction of the radiostress factor with tobacco as a trigger factor for the development of bronchopulmonary cancer, in the context of the EURATOM/59 Directive /2013. The objectives underlying the realization of this research assume the measurement of the radon concentration in the three geographical areas of the country, the establishment of the correlation links of the increased concentrations with the abiotic environmental factors and the formulation of the appropriate recommendations and measures to reduce the negative effects.

In order to achieve the aim and objectives, we proposed to carry out a study measuring radon concentrations in 1100 homes, according to the sample established following the calculations based on the formula, from rural and urban areas targeting different types of constructions. According to the methodology for determining the concentration of radon in the indoor air, radon detectors were placed in the inhabited area of the house: on the ground floor, in the bedroom or in the guest room, using passive RADTRAK2 detectors. The study material is the air from the homes of the Republic of Moldova, from the Center, North and South areas, the random selection criterion of the radon concentration measurement points, according to the methodology of the European Commission (EC).

3. RESULTS AND DISCUSSION

Following the calculation of the representative sample that constitutes 1100 dwellings, according to the housing stock at the end of 2019, from the Statistical Yearbook and the distribution of this sample on the three geographical areas of the Republic North, Center and South, according to the number of individual dwellings registered in each area , it was established the need to carry out 396 measurements for the Northern area, which constitutes 36% of the total number of measurements, in the Northern region being included in the Statistical Yearbook 321 859 units from the housing fund. For the Center area, 451 measurements were made in the 364,495 homes, which is 41%, and for the South area, 23%, i.e. 253 measurements, with 198,844 homes being recorded.

Table 1. Descriptive statistical indicators for the three zones of the country regarding the registered radon concentration (in Bq/m^3).

STATISTICS			
	CENTER	NORTH	SOUTH
N VALID	450	396	253
MEAN	211.67	240.55	285.57
MEDIAN	140.00	180.00	250.00
MODE	110	110	230
STD. DEVIATION	199.240	207.783	202.773
MINIMUM	12	11	13
MAXIMUM	1160	1260	950
A. MULTIPLE MODES EXIST. THE SMALLEST VALUE IS SHOWN			

Based on the analysis of the results of measuring the concentration of radon in the indoor air of the homes of the three areas of the Republic of Moldova, a variability of the concentrations was established, thus in some homes values below the international reference standards are found, while in some residential spaces the radon reached critical values for the health status of the population.

This dispersion of values is directly related to the type and geological structure of the soil, the location of the house, the effectiveness of the ventilation methods, the type of construction materials [2]. The calculation of the descriptive statistics indicators reveals the following: the average value for the three areas is 211.6 Bq/m^3 for the Center, 250.5 Bq/m^3 for the North area and 285.57 Bq/m^3 for the South area. According to table 1, the maximum values recorded far exceed the reference values, being above 1000 Bq/m^3 for the Center and North area, and for the South, the maximum value recorded is 950 Bq/m^3, a fact that does not diminish the essence of the problem, having for this area the largest median of 250.0 Bq/m^3 and the largest module of 230.0 Bq/m^3.

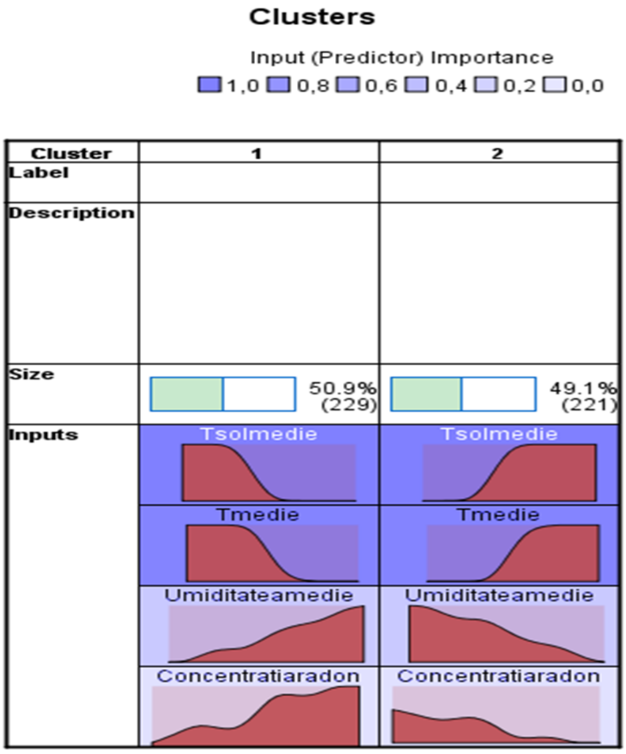

Fig.1. Cluster analysis of the interaction of radon concentration with environmental factors, a.2021. var1-month of the year, var2-day, var3-average air temperature, var4-max air temperature, var5-min.air temperature, var6-average relative humidity of the air, mm col. Hg, var7-minimum relative humidity of the air, mm col. Hg, var8-average soil surface temperature,0C, var9-maximum soil surface temperature,^{0}C, var10- minimum temperature at the surface of the soil,^{0}C, var 11-radon concentration, Bq/m^3.

Analyzing the graph in Figure 1 regarding the cluster analysis of the interaction of radon concentration with environmental factors, such as the average, maximum and minimum air temperature, average and minimum relative humidity, the temperature recorded on the soil surface and the radon concentration, the presence of a correlation is identified the tight relationship between these environmental factors and the variations in indoor radon concentration, forming cluster one with a large Euclidean distance and linkage distance of 4250. This fact is mentioned in numerous international theses according to which the transfer rate per surface unit in the atmosphere of radon is dependent not only by the amount of radium in the soil, the porosity of the soil, the emanation coefficient, but also by a series of variable factors such as the upward currents of air from the surface due to the inversion of temperature as a result of the transition from the night to the day period, the gradients of the temperature in the soil and on its surface, atmospheric pressure and relative air humidity, wind speed.

An important element involved in the variations of radon concentrations in the air are the vegetation crops that, according to studies, extract radon from the soil together with water, but this fact is of minor importance for residential radon.

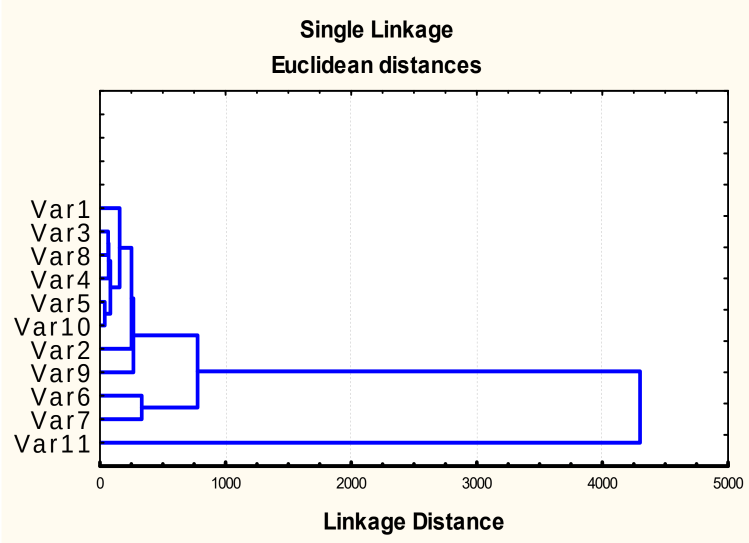

Fig.2. Cluster analysis of the interaction of radon concentration with environmental factors.

The cluster analysis of the dependence of the radon concentration on the average temperature at the soil surface, the average air temperature and the average relative humidity recorded (Fig.2), shows the formation of two clusters with a strong connection between these variables.

Thus, according to the ascending and descending curve related to the radon concentration, we can see that high residential radon values are recorded during the period when the average temperature on the soil surface and the average air temperature are low, the curve has a downward trend, and the average relative humidity of the air is in growth. This fact is recorded in the cold months of the air, being directly related to the types of ventilation in the houses, or due to heat losses, manual ventilation is less used and the number of houses equipped with suction-rejection ventilation is very small. A different process is attested in the warm months of the year, thus, when the temperature gradient is increasing on the surface of the soil and in the atmosphere the concentration of radon decreases parallel to the average relative humidity of the air. The importance of this phenomenon is related to the need to direct preventive measures related to seasonality, microclimatic factors and the sanitary-hygienic aspects of living rooms. The development of population information strategies and awareness of the risk of exposure to high doses of ionizing radiation and the systematic updating of legal regulations regarding individual and collective exposure doses are the objectives of the research in order to obtain the optimal level of radioprotection according to WHO and IAEA recommendations.

The radon problem in the Republic of Moldova has a double connotation in terms of the analysis of studies on tobacco consumption and the trend of morbidity indicators through oncological diseases of the respiratory type. Lung cancer mortality in the Republic of Moldova is the second cause of death from malignant tumors and tobacco exposure for the country's residents reaches maximum levels according to the STEPS 2013/STEPS2021 study FACT SHEET: Prevalence of risk factors for non-communicable diseases in the Republic of Moldova, so that better a quarter of the adult population is exposed to smoking, all those exposed in the context of increased radon concentration present a risk factor for the regional public health system being a multidimensional problem with negative social, economic and medical impact.

4. CONCLUSIONS

1. Following the statistical processing of the collected data, the following results were obtained for a uniform distribution of the variables, thus maximum values of 1160 Bq/m^3 are recorded for the Center area, 1260 Bq/m^3 for the North area and 950 Bq/m^3 for the South area.

The average concentration of radon in the indoor air is 211.67 Bq/m^3; 240.55 Bq/m^3 and 285.57 Bq/m^3 for the Center, North and South, respectively. The share of homes that exceeded the reference level of radon (300 Bq/m3) constituted 25.3% for the Center area, 31.06 - North and 38.58% - South.

2. The study of the dependence of the radon concentration on the abiotic factors of the environment established the existence of a close correlation link with the formation of the cluster with a large Euclidean distance, and the linkage distance constituting 4250 for the radon concentration and the maximum air temperature and the soil surface temperature.

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