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BRONCHUS AND LUNG CANCER INCIDENCE IN POPULATION LIVING AROUND THE FORMER URANIUM MAINING AND MILING SITES

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The indoor radon concentrations and lung cancer incidence in Eleshnitza village and Blagoevgrad district of Bulgaria were examined in the study reported here. The Eleshnitza was the second largest uranium mining and milling region of the country. The geometric mean of indoor radon concentration in Eleshnitza (465 Bq/m^3) was higher than the geometric mean of Blagoevgrad district (78 Bq/m^3). Retrospective analyses on lung cancer incidence, covering the period 1995–2012 have been shown the same trend. The results were suggestive of an existing relationship between the two variables. Possible effects attributable to age and gender on lung cancer incidence were examined and found to be significant.

INTRODUCTION

The potential health effects associated with uranium mining are no different than the risks identified in other types of non-radiation-related mining activities. Uranium mining, however, adds another risk related to the potential exposure to elevated radioactivity, conclusion obtained from environmental pollution surveys, remediation as well as from epidemiological study.[1–4] Long-term exposure to radon and its decay products generally represents the greatest radiation-related health risk from uranium-related mining and processing operations.

Radon (^{222}Rn) is a radioactive gas decay product of ^{226}Ra, which are present in all terrestrial materials. The generated radon emanates from the material surface and can be accumulated in an enclosed space. Accumulation of radon (Rn) in a building is controlled by many factors but its concentration primarily depends on radium (Ra) content in the soil under the building and construction materials.[5, 6] Exposure to Rn and its decay products contributes half of the annual dose received by the public from all sources.[5] Many epidemiological studies have been carried out to estimate the risk of lung cancer due to chronic radon exposure.[6–9]

The extraction and processing of uranium ores in Bulgaria were closed in 1992. The remediation actions on the sites and environment rehabilitate are being implemented until now. However, the underground uranium mining and exploration sites twenty years after closure are still having a potential radiological impact on population and environment.[10–12]

The most significant terrenes are waste rock piles and mill tailing ponds with high Ra content, which are potential contaminators of air (as a result of radon emanation). The water, soil and some non-controlled activities like usage for buildings construction are other exposure ways.[10, 11]

This paper presents the results of indoor radon measurement and retrospective survey, covering the period 1995–2012 of lung cancer incidence in Eleshnitza village—the former uranium mining and milling sites. The radon concentrations and incidence of lung cancer were compared with those for Blagoevgrad district.

MATERIAL AND METHOD

Investigated site

The Eleshnitza village was centre of the southern mining region of Bulgaria and it is one of the sites with high radiation risk.

The main ore deposits for underground extraction and uranium-milling factory with tailing pond have been situated there. The proximity revealed the high radioactive and chemical pollution in the ground and surface water, agricultural land, roads as well as in the living areas. It is situated in Blagoevgrad district (Figure 1).

The territory of Eleshnitza village covers an area of 300 km^2, with mostly mountainous and hilly nature of the south. Due to manufacturing activities, the village was more populated in comparison to today, when around 1600 inhabitants live there.

Radon measurement

The time-integrated Rn measurements in Eleshnitza village were carried out during the period from

Figure 1. Geographical position of Eleshnitza village in Blagoevgrad district.

August 2008 to January 2009 using passive electret detectors. The detectors were exposed for 6 months on the ground floor of 20 randomly selected houses in different parts of the village. The Rn data for Blagoevgrad district from the National survey were used. The Rn measurements in the National survey were done with nuclear track detectors over period: April 2015–April 2016. The analysis and processing of the results were performed in 'Radon Monitoring and Prevention' laboratory of the National Centre of Radiobiology and Radiation Protection of Bulgaria for both surveys, following the international standards.(13)

Bronchus and lung cancer study

The retrospective study on the incidence of bronchus and lung cancer (BLC) and among the population of Eleshnitza village and Blagoevgrad district was conducted for the period 1995–2012. Data for BLC incidence in Eleshnitza and Blagoevgrad district were available from the Bulgarian National Cancer Registry.(14) Data of the population in regions are from the National Statistical Institute of Bulgaria. The standardised (according to the world standard) incidence per 1000 for the period 1995–2012 for Eleshnitza and Blagoevgrad district, excluding data for Eleshnitza village, was calculated.

The life-time risk for lung cancer was estimated following the methodology is given in the ICRP Publication 115.(15) The estimated risk per unit of exposure is based on a time-weighted average exposure for a window period 5–30 years prior to diagnosis. The increased risk (excess relative risk, ERR) is about 1.08 (95% CI 0.97–1.20) per 100 Bq/m^3, on condition of exposition duration of about 30 years for Europe.(7) The life-time cumulative risk of lung cancer for life-long smokers by 75 years of age is close to 12% for radon activity concentrations 100 Bq/m^3.(15)

Table 1. Descriptive statistic of Rn in Eleshnitza village and Blagoevgrad district.

Statistic	Eleshnitza village	Blagoevgrad district
N	20	102
Minimum	117	27
Maximum	2500	334
Median	500	77
Arithmetic mean	676	96
Standard deviation	643	69
Geometric mean	465	78
Geometric standard deviation	2.43	1.88

RESULTS AND DISCUSSIONS

Radon measurement

Descriptive statistic of radon concentrations measurements performed in 20 dwellings of the Eleshnitza village and 102 dwellings of the Blagoevgrad district is presented in Table 1.

The results have been shown noticeable higher values for Rn in Eleshnitza village in comparison with values in Blagoevgrad district (Mann–Whitney test, $p < 0.0001$). The Rn results for Blagoevgrad district were similar to those from studies carried out in neighbouring countries. The arithmetic (AM) and geometric (GM) means are lower than the AM (105 Bq/m^3) and GM (84 Bq/m^3) reported for 437 dwellings in Macedonia.(16) and slightly higher than the AM (82.5 Bq/m^3) obtained from Transylvania (Romania).(17) The values of Blagoevgrad district are lower than obtained AM (158 Bq/m^3) and GM (99 Bq/m^3) from a pilot survey in four districts in Bulgaria during the 6 months measurement from October 2011 to May 2012.(18)

Contrary, the AM and GM of measurement in Eleshnitza village are higher than all previously compared values. The same order of magnitude Rn average value was reported from a survey in Gornja Stubla (500 Bq/m^3) but the AM in Niška Banja (1200 Bq/m^3) is higher than Rn in Eleshnica village.(19)

The histograms of Rn values in Eleshnitza and Blagoevgrad district are given in Figure 2. Both data sets well fitted by a log-normal function (Kolmogorov–Smirnov test, $p > 0.05$). The Rn values above the National reference level of 300 Bq/m^3(20) in Eleshnitza were 70% while in Blagoevgrad district dwellings 2%.

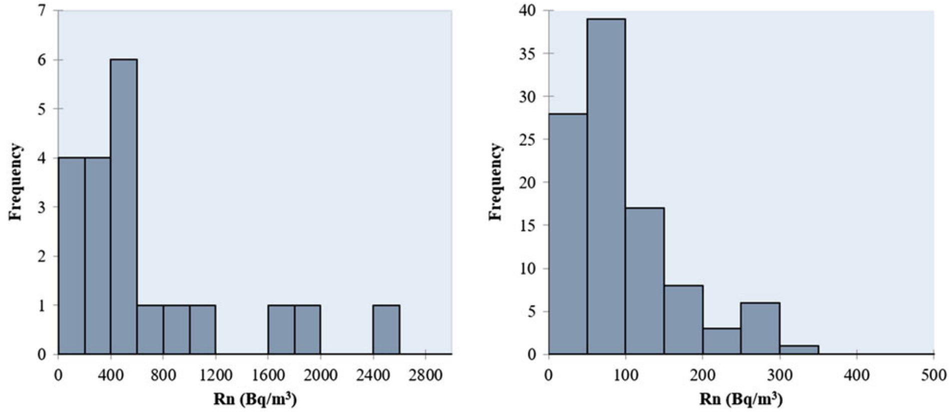

Figure 2. Histograms of indoor radon concentrations (Rn) in: (**left**) Eleshnitza village and (**right**) Blagoevgrad district.

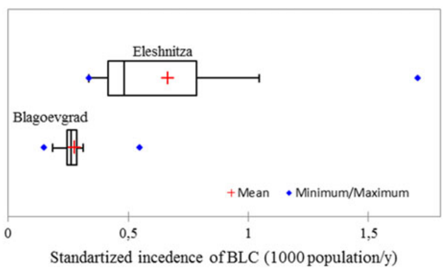

Figure 3. Box plot of standardised incidence of BLC yearly in Eleshnitza village and Blagoevgrad district for the period 1995–2012.

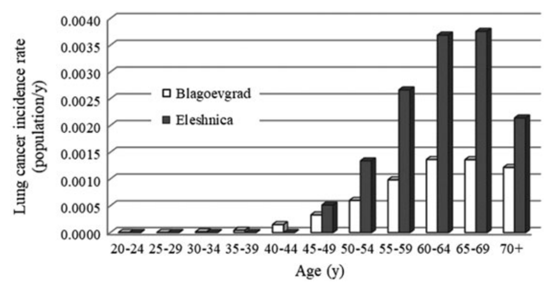

Figure 4. Age specific BLC incidence rate of in Eleshnitza village and Blagoevgrad district for the period 1995–2012.

Bronchus and lung cancer incidence

The settlements around uranium extraction in Bulgaria are characterised with various contaminations by origin and levels. In those regions, it could be differentiated population groups with different dose loadings and, respectively, different risks. The living environment parameter, which is obviously dominated in these regions, is radon. The excess relative risk of lung cancer, evaluated based on Rn measurement and the European residential analysis up to age 75 years for Blagoevgrad district is 0.08 and for Eleshnitza is 0.54.

The incidence of BLC per 1000 population reported for each year between 1995 and 2017 ranged: 0.34–1.70 for Eleshnitza and 0.15–0.55 for Blagoevgrad district (Figure 3).

There is a difference between standardised BLC incidence in Eleshnitza and Blagoevgrad district (Mann–Whitney test, $p < 0.0001$). The results indicate that the higher values for Eleshnitza village could be related to contamination on the sites from former mining activities. Similar results of highest cancer frequency in North Kazakhstan, where uranium mining sites are located, in comparison with the other regions of the country, have been also reported.[21] Furthermore, our analysis showed a significant relationship between age and lung cancer incidence.

Figure 4 shows the effect of an incidence rate increase with age up to age 69 years then decreases slightly. On the other hand, the trend of lung cancer incidence rate related to age for Eleshnitza and Blagoevgrad is the same.

The effect of the gender on BLC incidence rate in both regions was significant. The higher incidence ratio has occurred for males in comparison to females. But, like in the previous case, the contributions of the gender in both regions were similar. The lung cancer incidence rate was 90.6% males and 9.4% females in Eleshnitza village and 87.7% males and 12.3% females in Blagoevgrad district. The registered BLC cases by sex and age in the two studied regions follow the same trend as the spontaneous frequency of this localisation, according the Bulgarian National Cancer Register.[14] The studies of BLC incidence by age and gender require more in-depth epidemiological studies. The occupational risk and smoking habits should be taken in account in the survey.

CONCLUSION

The mean indoor radon concentration and geometric mean in Eleshnitza village are higher than Bulgarian reference level, as well as the percent of houses with values above 300 Bq/m^3 indicated that Eleshnitza could be a region with high radon risk. The results of BLC incidence in Eleshnitza comparing with cases in Blagoevgrad district show a probably association between radon and lung cancer incidence. The ability to detect this association is a rigorously designed epidemiological study in order to be made more accurate assessment of health radiation risk in order to implement appropriate measures for the population radiation risk-reducing.

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