Field Experience of Indoor Thoron Gas Measurements in a Stable Rural Community in Yugoslavia

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ABSTRACT

Attempts were made in Yugoslavia to identify rural populations receiving an elevated natural radiation exposure that might be a potential cohort for a planned future health study. In Gornja Stubla at Kosovo in southern Yugoslavia many houses are built mainly from local rock of trachyte which has a uranium content of the order of 25g/t, Th of 61 g/t and K-40 of 5.4%. Thoron and radon gas measurements were carried out in 49 locations in 23 houses in this rural community. Taking into account the short half-life of thoron passive alpha track dual radon-thoron detectors were placed within 10-20 cm from the walls, which were considered the potential source of thoron. Thoron concentrations were found to be extremely high in Gornja Stubla with a maximum measured value of 1,156 Bq m^{-3}. Using another type of passive radon detector ,designed by SSI/NRPB, annual indoor radon concentrations were measured. The highest indoor radon concentration of 9,591 Bq m^{-3} was found in the same house, which had the highest thoron concentration. The absorbed dose rate in air,due to external penetrating radiation was also measured and the highest value found in Gornja Stubla was 430 nGy h^{-1}. Although high thoron concentrations were recorded it should be pointed out that due to its short half life large differences in thoron concentrations are to be expected as a function of the distance of the measuring point to the source. In addition, with the absence of information on thoron progeny concentration it is impossible to make any estimate of doses from the thoron series since the equilibrium factor between thoron and its progeny can vary greatly with time as well as location. However, the thoron measurements that have been performed in Gornja Stubla clearly indicate that the inhabitants there receive an elevated exposure not only from indoor radon and penetrating radiation but also from thoron.

INTRODUCTION

In recent years there has been a growing interest in the exposure of the general population to elevated levels of natural radiation (1). Attention has focussed ,in particular , on exposures due to radon gas (^{222}Rn, $T_{1/2}$ = 3.83 days) and its short-lived progeny. A number of large case-control epidemiological studies on exposure of the general population to radon in the indoor residential environment have been completed in recent years. Meta analyses of these studies indicate that the estimated risk from indoor residential radon exposure is similar to that expected on the basis of the miner radon epidemiological studies (2) While these radon studies are helping to increase our knowledge on the health effects of natural radiation exposure there has been almost no attempts to assess the health implications of exposure of the general population to indoor thoron (^{220}Rn, $T_{1/2}$= 55 s) and its progeny. Part of the reason is probably because due its short half-life the dynamics of thoron and its progeny in the indoor air environment is not well quantified or understood and also because measurement of thoron and to a lessor extent its progeny is more technically difficult than that for radon and its progeny. Even if good thoron progeny data is available difficulties exist in making meaningful dose estimates as lung dosimetry modelling for thoron progeny is presently in a less developed state that that for radon progeny. (3).

It has been long known that thoron can be a problem in the working environment in mines and in premises where Th-232 rich minerals, sands or products are handled in large quantities. In the past decade it was pointed out that under certain circumstances thoron may cause relatively high exposures in dwellings particularly in well insulated homes overlying geological formations with an elevated throrium content. Results of thoron concentration measurements in indoor environment show that only in a small number of countries have indoor thoron monitoring activities been conducted (1). This paper deals with the results of an intitial survey of indoor thoron concentrations made in a community in the south of Yugoslavia already known to have elevated levels of indoor radon and penetrating radiation doses.

SELECTION OF FIELD AREA

In Yugoslavia there exists uranium and thorium anomalies as well as former uranium mining districts and uranium ore deposits.The rural community of Gornja Stubla in the south east of the southern Yugoslav province of Kosovo was first identified as a potentially suitable field study area as a result of radiometric data acquired some years ago during a uranium prospecting campaign being then carried out in the area.

It has since has been found to be an area of high natural radiation exposure in the indoor environment with an estimated annual effective doses of 16.2 mSv /y due to the combined effect of indoor radon and external natural radiation exposures (4,5). It is located on the margin of the large Vardar Zone geotectonic unit. The community is built on a contact area of lower Cretaceous flysch and granite, Paleogene sedimentary rocks, trachyte and trachyte tuff. The underlying geology is a mixed uranium-thorium anomaly with a uranium content of the order of 392 Bq/kg, Ra-226 of 249 Bq/kg, Th-232 of 181 Bq/kg and K-40 of 1751 Bq/kg. In this community many houses are built mainly from local trachyte rock. The identification of high radon level houses and the presence of elevated Th-232 in the local geology and building materials gave a stimulus to initiate indoor thoron measurements.

Including its immediate surroundings it has a population of approximately 3000 people. A particularly interesting feature of the area from a radiological health study perspective is that it is very unpolluted environment with no industrialisation . The population is also quite homogeneous and stable having living for many generations there with very little outside influence on its genetic pool. Having fortunately largely escaped the effects of the recent conflict it is gratifying to note that this situation has not significantly changed.

ANNUALISED INDOOR RADON MEASUREMENTS

Indoor radon gas concentrations were measured using closed passive diffusion alpha track type radon detectors. The alpha track registration medium is CR-39 mounted inside a black conducting plastic shell of NRPB/SSI design. For the etching and optical microscopy procedures used the detector sensitivity to radon exposure was determined to be 2.7 tracks cm^{-2} /kBq m^{-3} hour.
The mean annual indoor radon concentrations in a total of 65 dwellings in Gornja Stubla were obtained by placing a detector in a living area in each dwelling every three months to form a sequence of four such measurements over a twelve month period. The results obtained are summarised as follows both in terms of annual mean radon gas concentrations and estimated annual effective doses.

The arithmetic mean annual radon concentration was found to be 447 Bq/m^3 while the geometric mean was 336 Bq/m^3 . On an individual dwelling basis the highest annual radon concen tration measured was 6010 Bq/m^3. The annual effective doses were estimated using the recently suggested dose conversion factor (DCF) of 7.3 mSv WLM^{-1} as this value is probably more applicable to the aerosol conditions found in dwellings than the DCF of approx 4.2 mSv WLM $^{-1}$ as suggested by the ICRP for high aerosol conditions (6). When the radon levels and estimated annual effective doses in Gornja Stubla are compared to world and European average values it is clear that this may be considered as a high radon exposure community (7).

COMBINED RADON AND THORON INDOOR MEASUREMENTS

Thoron (^{220}Rn) gas measurements were made using a special passive alpha track dual thoron/radon gas detector type which consists essentially of two interconnected plastic hemispheres (8). As the air diffusion exchange time rate from the first hemisphere into the second is much greater than the radioactive decay constant of thoron ($T_{1/2}$ = 55s) the alpha track signal recorded by an alpha track detector within the second hemisphere is essentially due only to the radon series while that in the first hemisphere is due to both the radon and the thoron series. Analysis of the track densities allows separate determinations of the radon and thoron concentrations to be made.

Using these detectors measurements of thoron and radon were made in a total of 22 dwellings in Gornja Stubla. The majority of these measurements were of a duration between 1 and 6 weeks. Due to seasonal variations the values obtained cannot be considered as being representative of long term or annual values. The measurements took place in two phases. Phase 1 measurements were carried out in 14 dwellings during the period September/October 1998 and Phase 2 ,involving 8 dwellings was carried out during the period December 1998/January 1999. Because of its short half life the indoor air thoron levels can be reasonably expected in most normal dwellings to mainly originate in the wall or floor materials. In Gornja Stubla these are largely composed of the local stone with high Thorium content. Again due to its short half life thoron air concentrations will be greatest closest to its source and in this work the detectors were all placed between 10-20 cm of the walls. The results of these combined thoron/radon measurement in the rooms of the 22 dwellings are shown in Table 1a (Phase 1) and Table 1b (Phase 2). . In the last column of Tables 1a and 1b, for comparison purposes,are shown the annual radon concentration previously obtained in the same dwellings using NRPB/SSI radon detectors. Notwithstanding the large uncertainties in individual thoron determinations the short-term thoron concentations as a group are unusually high with the majority of them being some hundreds of Bq/m^3 and with an individual thoron concentration as high as 1,156 Bq m^3 Bq/m^3 being recorded. The short-term radon concentrations also obtained by the combined thoron/radon detectors are also unusually high with a maximum value of 2053 Bq/m^3 being recorded. This latter value was found in the same dwelling which also had ,within this group of 22 dwellings, the maximum determined annual radon concentration of 6010 Bq/m^3. Due to a number of factors such as seasonal and other short term variations as well as aspects of the responses,calibrations and sensitivities of the different detector types used it cannot reasonably be expected that the short term and annualised radon concentrations will be in agreement. Nevertheless it is clear that the exposures to occupants of these dwellings from indoor thoron/radon and their progeny are high and warrant further and more detailed investigations. During these short-term measurements NRBB/SSI radon detectors were also exposed together with the dual thoron/radon detectors. The results obtained from these are shown in the second last column of Tables 1a,1b . While these detectors also recorded high radon values there is not good agreement in absolute concentration terms with the radon values determined during the same time period using the combined thoron/radon detectors. This aspect of the results is being currently examined at present and when resolved will be reported elsewhere.

CONCLUSION

While in some cases very large uncertainties are associated with the thoron values nevertheless these thoron measurements indicate that elevated exposures to thoron progeny are likely in Gornja Stubla dwellings. While no measurements of thoron progeny were made it is planned to do so in the future.

In the present absence of information on thoron progeny levels in the dwellings it is impossible to make any estimate of doses from the thoron series. Even if thoron progeny data were available it is clear that it will be very difficult to make meaningful dose estimates (3). These and other similar surveys showing the presence of high thoron levels in normal dwellings should help to provide a stimulus to improve our understanding of thoron lung dosimetry.

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Table 1a : Indoor Thoron (Tn) and Radon Measurements in Gornja Stubla . Phase 1.

DETECTOR AND HOUSE CODES	DUAL DETECTOR (Short-term) Tn (Bq/m^3) ±s.d.	DUAL DETECTOR (Short-term) Rn(Bq/m^3) ±s.d.	NRPB/SSI Detector Short-term Rn (Bq/m^3)	NRPB/SSI Detector Annual Average Rn (Bq/m^3)
Y1(1)	1156±573	2053±149	3947	6010
Y2(1)	603±248	818±66	1119	1534
Y3(1)	364±109	291±29	411	718
Y4(1)	331±96	296±25	312	409
Y5(1)	425±85	243±22	296	438
Y6(1)	358±87	258±23	361	282
Y7(1)	357±91	220±24	389	943
Y8(1a)	14±36	127±10	690	186
Y9(2)	708±217	689±57	1082	1223
Y10(2)	527±223	725±59	339	1795
Y11(3)	635±169	502±44	727	796
Y12(4)	113±48	125±13	29	297
Y13(4)	103±43	107±12	14	300
Y14(5)	467±113	294±29	485	781
Y15(5)	122±29	52±7	83	138
Y16(6)	534±127	339±33	433	718
Y17(7)	172±57	154±15	109	207
Y18(8)	1116±173	467±42	809	844
Y19(8)	1034±167	451±41	1880	621
Y20(8)	752±184	614±47	1272	594
Y21(9)	945±127	300±30	456	973
Y22(10)	N/a	823±66	1287	1031
Y23(10)	750±243	846±63	1761	1245
Y24(11)	416±102	256±27	468	671
Y25(11)	93±50	172±13	172	58
Y26(12)	386±79	223±20	268	424
Y27(12)	97±43	108±12	n/a	456
Y28(13)	934±409	1428±107	2594	2719
Y29(13)	96±48	164±13	223	162
Y30(13)	118±44	146±12	320	214

Table 1b : Indoor Thoron (Tn) and Radon Measurements in Gornja Stubla . Phase 2.

DETECTOR AND HOUSE CODES	DUAL DETECTOR (Short-term) Tn (Bq/m^3) ±s.d.	DUAL DETECTOR (Short-term) Rn(Bq/m^3) ±s.d.	NRPB/SSI Detector Short-term Rn (Bq/m^3)	NRPB/SSI Detector Annual Average Rn (Bq/m^3)
Y2-1(32)	461±252	903±66	1680	1096
Y2-2(32)	162±130	443±35	690	351
Y2-3(50)	747±125	385±31	766	940
Y2-4(50)	279±70	203±18	373	706
Y2-5(6)	231±63	177±16	259	152
Y2-6(6)	523±77	206±19	248	164
Y2-7(8)	230±50	128±13	179	164
Y2-8(19)	558±286	1029±74	2192	978
Y2-9(19)	482±336	1227±88	2594	1571
Y2-10(33)	359±154	526±40	765	646
Y2-11(33)	146±136	470±37	706	365
Y2-12(53)	195±60	171±16	258	182
Y2-13(53)	65±74	236±21	1161	513
Y2-14(23)	-300±128	462±36	712	523
Y2-15(10)	698±288	1031±75	2274	1711
Y2-16(16)	759±89	260±21	405	345
Y2-17(16)	351±79	253±20	504	1337
Y2-18(15)	213±111	385±29	548	540
Y2-19(15)	163±141	504±37	780	785