Sources and Protective Measures of Indoor Radon

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Abstract This paper presents the relative contribution to indoor radon ^{222}Rn of various sources in twenty three rooms of three kinds in Taiyuan area. The results show that the major sources in this area are radon emanation from surfaces of soil and building materials and that from outdoor air, while the contribution of water and gas consumed in the rooms is less important. These results suggest a basis for taking suitable protective measures against indoor radon . Some materials are also recommended which are effective in restraining radon exhalation and low in price, by testing more than ten kinds of materials and comparing them using cost-effectiveness analysis technique, such as painting materials, polyvinyl alcohol $(CH_2{:}CHOH)_n$, etc. Their sealing effects on radon exhalation were examined with home-made REM-89 Radon Exhalation Monitor. The deposition effects of negative ion generator and humidifier on radon progeny were also tested. The maximum deposition may reach 70-90%, which proves they are also effective and economical in radon protection.

(key words: indoor radon, radon sources, protective measures)

Introduction

In recent years, awareness of the health risks due to exposure to radon and its progeny has led to numerous surveys to establish radon concentrations within domestic buildings, but because of indoor radon concentration depends on several factors which are different in various areas. Therefore, it is necessary to estimate the relative contribution to indoor radon of various sources in dwellings in certain area and to search for protective measures against indoor radon, which are reasonable and practical for the area.

Sources and protective measures

Sources of indoor radon

According to the UNSCEAR report 1982 [1], The main source of indoor radon is the emanation from the surfaces of soil and rock, the other sources of significance are building materials, water outdoor air. Natural gas, liquid petroleum gas and coal gas are less important. The radon from water depends on radon concentration in water, the total amount of water consumed and the ways of using it. The transfer coefficients for the release of radon from water to air for some ways of using it are summarized in reference [2].

Protective measures

The protection of indoor radon should be based on the primary principles recommended by ICRP publication 60[3]. The concentrations of radon and its progeny should be kept as low as reasonably achievable,. The fundamental mitigation methods of indoor radon fall into four categories. The first is source removal, which is practicable only in cases where the sources have been introduced into the local environment by human activities. The second is to increase the resistance of the building fabric to soil gas entry, generally called "sealing". The third is to increase the rate of removal of radon and its daughters from the building by increasing the structure ventilation rate or to reduce the soil gas flow by reducing the pressure differential (called soil ventilation) between the room air and the soil gas. The fourth is the use of various air treatment (such as filtration, electric field method, radon adsorption, etc.) to directly remove radon progeny or in some cases the radon gas itself. Among these methods, ventilation is a very useful method, but it is not practicable in areas where it is extremely cold. Sealing is a practical method. soil ventilation are not practicable for existing houses. Source removal generally is expensive. Air treatments are difficult to perform in some cases. Negative ion generator and humidifier are two useful and practicable methods. Restraining people from smoking in rooms is helpful for deposition of radon daughters. The selection of protective measures should be based on the relative contributions of various radon sources. According to ALARA principle, the measures which have higher ratio of effectiveness to cost should be selected.

Experimental methods and results

The concentrations of radon and its daughters in indoor and outdoor air were measured with balloon monitor. The radon exhalation from the surfaces of the ground and walls was measured with REM-89 Radon Exhalation Monitor. The γ-exposure rates in indoor and outdoor air were measured with environmental γ-Exposure Rate Meter. The concentrations in domestic water and coal gas were measured with FD-125 Radon Gag Analyzer. The results on effectiveness of some sealing materials are listed in tables 1-2 and on negative ion generator and humidifier plotted in figures 1-2.

Discussion

The relative contributions of various indoor radon sources in rooms of different kinds are calculated and the results are plotted in figure 3. It can be seen that the radon emanation from the surfaces of soil and building materials is the major source in cave dwelling. The radon from outdoor air, water and coal gas is less important. The situation in one story building is similar to that in a multiple story building. The major source of indoor radon is also the radon emanation form the surfaces of soil and building materials. The relative contributions of the radon from water and coal gas in buildings are greater than that in cave dwellings, hence it is not negligible. Considering rooms of same kind, they have different surface radon exhalation rates when they are painted with different painting materials. For different floors of a multiple story building, the relative contribution of the same radon source is also different. For example, in the first floor the contribution of soil and building materials is more important than that in above floors.

The ratios of effectiveness to costs are calculated and listed in table 2. In the calculation, it is assumed that the expense in construction of various coating materials is the same. From the table we can conclude that the painting material and polyvinyl alcohol are the best sealing materials against radon because of their higher effectiveness to cost ratio. In some cases, some other materials can also be sued, however it should be based on cost-benefit analysis. From figures 1-2, we can see that both negative ion generator and

Table 1 The sheilding effect of various materials on radon exhalation

material kinds	mass thickness of covering layer ($g \cdot cm^{-2}$)	coverng way	radon exhalation ($10^{-3}Bqm^{-2}s^{-1}$) before covering	radon exhalation ($10^{-3}Bqm^{-2}s^{-1}$) after covering	radon protective efficiency (%)
painting	0.06(one layer)	painting	6.15	3.69	40.00
material	0.32(two layer)	painting	6.21	2.19	64.73
laquer	0.006(one layer)	painting	13.90	4.02	71.08
C03-1	0.012(two layer)	painting	13.90	1.86	86.62
lacquer	0.007(one layer)	painting	23.68	10.63	55.11
enemal	0.014(two layer)	painting	23.68	7.40	68.75
	0.009(one layer)	laying	4.67	2.69	42.40
plastic film	0.018(two layer)	laying	4.67	1.21	74.09
	0.03(three layer)	laying	4.67	0.53	88.65
rubber	3mm(thickness)	laying	18.30	7.87	56.99
plastic	2mm(thickness)	laying	18.30	9.79	46.50
plate	3mm(thickness)	laying	9.81	3.04	69.01
polyamide	0.079(wet weight)	painting	36.70	20.73	43.51
polyavinyl	0.013(thickness)	painting	39.10	15.24	61.02
alcohol	0.039(thickness)	painting	39.10	5.72	85.37
expoxy	0.079(wet weight)	painting	32.30	2.26	93.00
wall paper	0.036	laying	10.79	1.76	83.69
floor leater	1mm(thickness)	laying	6.50	3.20	50.77
floor brick	1mm(thickness)	laying	23.40	10.20	56.41

Tabl 2 The cost of various materials

type of material	reduction Δ R of radon exhalation ($10^{-3}Bqm^{-2}s^{-1}$)	reduction times of radon exhalation	cost of reducing radon exhalstion ($yuan \cdot sBq^{-1}$)	cost of reducing radon exhalation ($yuan \cdot m^{-2}$)	the ratio of effectiveness to cost(10^{-3} $Bqs^{-1}yuan^{-1}$)
coating material(1)	2.46	1.67	48.78	0.07	20.50
coating material(2)	4.02	2.84	59.70	0.09	16.75
lacquer Co3-1(1)	8.91	1.79	53.87	0.27	15.36
lacquer Co3-1(2)	15.91	4.68	59.71	0.20	13.72
lacquer enamel(1)	13.05	2.23	70.50	0.41	14.18
lacquer enamel(2)	16.28	3.20	112.41	0.57	8.90
plastic film(1)	2.01	1.74	587.06	0.68	1.70
plastic film(2)	3.46	3.86	682.08	0.61	1.47
plastic film(3)	4.17	8.81	848.92	0.40	1.18
rubber	10.43	2.33	9204.22	41.20	0.11
plastic plate (2mm)	8.51	1.87	2926.44	13.32	0.34
plastic plate (3mm)	6.77	3.23	5518.46	11.57	0.18
polyamide	15.97	1.77	3442.71	31.06	0.29
poyvinyl alcohol(1)	23.86	8.57	10.90	0.10	91.77
poyvinyl alcohol(2)	33.38	6.84	23.97	0.12	41.73
epoxy	30.04	14.29	1103.20	2.32	0.91
wall paper	9.03	6.13	387.60	0.57	2.58
floor leather	3.30	2.03	2524.24	4.10	0.40
floor brick	13.2	2.29	3787.88	21.83	0.26

Note: the mass thickness of plastic film is $0.0091 g/cm^2$

humidifier have a notable deposition effect. The maximum deposition of radon daughters may reach 70-90% which proves they are also effective and economical in radon protection.

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References

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[2] William W, Nazaroff and Anthroy V, Nero, Radon and Its Decay Products in Indoor Air, page 137.

[3] ICRP publication 60, 1990.

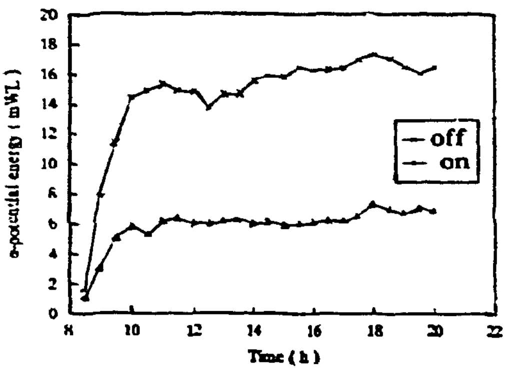


Fig.1 The deposition effectiveness of negative ion generator on radon daughters

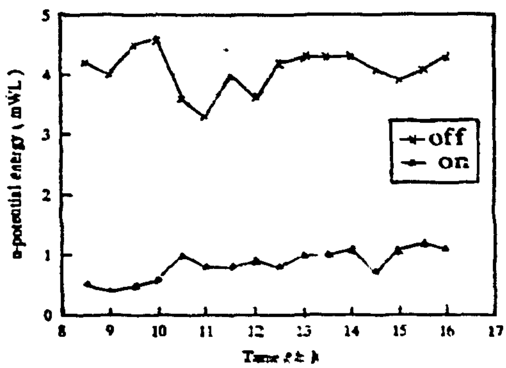
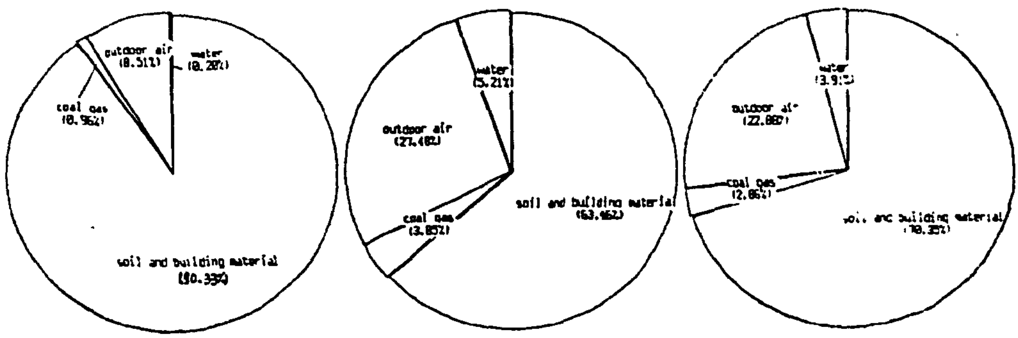


Fig.2 The deposition effectiveness of humidifier on radon daughters



cave dwelling　　one story building　　multi-story building

Fig. 3 The relative contributions of various radon sources in different kinds of rooms