5448

RADON

by F.J. Webb, Environmental Health Department, Teignbridge District Council

Introduction

One of my roles with Teignbridge District Council is to assimilate fresh developments and to recommend the resources to deal with them. It was therefore natural that I should be given the task of assessing this new health risk and recommending the Council's response.

It has not been easy. From an administrative point of view we have had three major Acts of Parliament in the last two years, each demanding increased output from already over stretched staff. Thus, having got to what I thought an appropriate stage in my researches I found that I could not give the subject away. No-one had the time for it and I therefore remain the Council's response to radon.

The second part of the problem is that I am neither nuclear physicist or doctor, whilst the subject requires some understanding of a new science, a new technology and an appreciation of health risks of an unusual dimension.

I hope I have coped like a good Environmental Health Officer; that is, to stand between the general public and the health threat, and to provide some form of solution in local terms. I have not done this alone and I am indebted to the assistance given by officers of the National Radiological Protection Board (NRPB) and the Building Research Establishment, and also my colleagues in local Authorities throughout Devon and Cornwall.

I would add that radon, as a new subject, has a steep learning curve at all levels and some of my views may well be changed before this paper is presented.

If I may be technologically platitudinous for a moment longer I have to explain that radiation is measured in the United Kingdom in Becquerels per cubic metre (Bq/m^3) whilst the total dose effect upon the average human body is measured in Sierverts per annum (Sv/pa); normally milli Sieverts per annum, (mSv/pa). One Becquerel represents one atomic decay in one cubic metre of air per second. The average indoor level of radon activity is about $20Bq/m^3$. Thus, while you have been listening to me there may have been some 360,000 atomic decays in this room due to radon. I hope this makes you feel at home with the subject.

You will see from the pie chart (figure 2) that radon represents most of the natural radiation to which we are exposed. You will see also that the nuclear centres we usually worry about, such as Sellafield and Chernobyl, pale into insignificance.

Risk Factors

Radon was first discovered in 1900 but its threat to human life was not realised until much later. At one time and even today in certain localities there were and are beliefs that radon is beneficial in certain forms.

But here it is necessary to quote the NRPB statement on risks.

(l) *There is sufficient evidence, from epidemiological studies of miners exposed appreciably to radon at work and from experimental studies of animals, to demonstrate the carcinogenicity of radon decay products. Several epidemiological studies are also being undertaken in various countries of persons exposed appreciably at home, some of which will come to fruition within a few years.

(2) Lifetime risks from common causes:**

Fire and flames:	1 in one thousand
Pedestrian Accidents:	3 in one thousand
Average radon in houses (20Bq/m^3):	3 in one thousand
Indoor accidents:	8 in one thousand
Lung cancer :	6 in one hundred
All cancers:	25 in one hundred

* NRPB Board Statement on Radon in Homes. Volume 1 No 1 – 1990.

** Householders Guide to Radon

Distribution

I have mentioned that the national average indoor level of radon is about 20Bq/m^3. In the open it is diluted and quickly dispersed by air currents, resulting in an average outdoor level of 6 Bq/M –3

Our problem is that buildings, particularly houses, tend to attract radon laden ground air; hence the higher levels in buildings. Since there are greater ground concentrations in areas such as parts of Devon and Cornwall, the resultant indoor levels are higher. As a result of a series of surveys by the National Radiological Protection Board, Radon concentrations on a country–wide basis have been identified (figure 3).

In Devon and Cornwall it has been possible to show concentrations on a 10km grid basis (figure 4). Those of you who know the area will see that the concentrations are on or around the granite areas. In Cornwall hot spots are also evident where mining activities have taken place.

We are not alone. Many countries, in particular the USA, Sweden, Germany and China, have their own radon problems. A common approach is bedeviled by differences in domestic structures and the political attitude.

Nearer home, figure 5 shows the results of the directed survey carried out in Devon and Cornwall in 1888/89.

Work by Dr Denis Henshaw of Bristol University and Sussex University has indicated some link between radon and breast cancer, melanoma, prostate cancer and certain types of leukaemia. (l)

Further, a study of occupants of houses in Strete, Somerset, which were subject to moderately high levels of radon indicated an increase in white blood cells, albeit the subjects were otherwise healthy.

I believe we are only on the threshold of knowledge of radon. It may well be answerable for more than we first thought.

(l) Lancet, April 1990, June 1990

(2) Lancet, May 1991.

Measurement

The risks previously quoted are based on life-time exposures and it is sensible that any measurements on which decisions can be made should be capable of similar expression. Further to this, radon levels vary considerably from day to night and from season to season (figures 6 and 7).

For this reason the "track etch" detector is normally used for assessing overall radon levels. It records minute damage to a sensitive plate as a result of bombardment by alpha particles and therefore can be left in a house for any reasonable length of time; not usually longer than six months. The application of seasonal correction factors allows measurement to be limited to as little as two or three months.

Another passive detector is available in the form of an activated charcoal canister. This may be opened and left for about four days before resealing and returning to the processor. It can be understood that there is some question as to the validity of this device in assessing an overall average concentration. It has particular use in measuring pre and post mitigation levels in "closed room" conditions.

Finally, there are various types of active "grab samplers" which will give immediate readings. These are solely used for diagnostic or monitoring purposes.

RADON SOUTH WEST COMMITTEE

A TREATISE ON RADON MITIGATION

The purpose of this Paper is to bring together the sum of learning, advice and experience in a form that can be used as an aid to Local Authority Officers and maybe others, in the pursuit of Radon reduction throughout the South West.

On 19 January 1990, Mr David Trippier, Environment Minister, whilst accepting the NRPB's recommendation to reduce the Action Level to 200Bq/m3, promised the publication of further data on Radon reduction within a few months. Over a year has passed and the only relevant Government publication has been the Householders Guide to Radon (2nd edition). This is not what was hoped for, nor, we believe, what was promised. Thus the South West Radon Committee has felt obliged to take this initiative with the intention of cultivating an effective approach to Radon reduction. The information contained in these pages should help to guide professionals and builders to avoid inappropriate schemes or poor workmanship.

It is not the intention of this Paper to discuss the nature and the occurrence of Radon, or the risks presented. However, a clear understanding of the factors affecting the entry of Radon into buildings is an essential pre requisite to Radon reduction.

4. Depressurisation of Buildings

Pressure driven flow, the movement of gas from a high pressure area to a low pressure area is the most active and dynamic ingredient in Radon entry and its mitigation. This is brought about by various factors which reduce pressures within buildings and these are discussed below:–

(i) Temperature

Indoor heating will cause hot air to rise, drawing cooler air from beneath the building if all other entries at ground floor level are closed or restricted. This stack effect is greatest during the winter when internal and external temperature differences will be more pronounced and there is greater likelihood of ground floor openings being closed for longer periods.

(ii) Wind

Depending on wind velocity and direction areas outside and within a building will become depressurised. The syphonic action on chimneys and other openings will contribute to this.

(iii) Ventilation

Mechanical devices such as exhaust fans and tumble dryers can also create a significant draw on indoor air. Winter and night time requirements to close all ground floor windows and permit ventilation at first floor level only will increase the stack effect.

Enter Radon

Ground air carrying Radon enters buildings by a number of routes. Subsequent indoor levels will depend upon:-

1. High Trace Levels of Uranium 238 in the Ground

Whilst this is a natural precondition to high indoor levels a simple relationship between the ground potential and indoor Radon level is unpredictable due to the further factors discussed below.

2. Porosity of the Sub-Soil

The passage of ground air is dependant on the porosity of the ground. This can include the presence of faults and fissures, man made or natural, which can create major differences in Radon levels in buildings in the same locality, or even in adjoining rooms.

3. Permeability of the Oversite Structure

Normally, no buildings are proof against entry of ground air/Radon although reduced entry has been demonstrated where oversite damp proof membranes have been installed.

Ground air/Radon can enter a building by a variety of routes as shown in Figure 8

DIAGNOSIS

Correct diagnosis, the recognition of the reasons why a building has significant levels of Radon is, perhaps, the most important step in Radon mitigation. Regard must be had to the factors discussed in the previous Sections.

Normally, there are no prospects of mitigation by attention to trace levels in the ground or its permeability, although it is on record that made up ground containing high levels of uranium was removed from beneath houses in the USA with some success.

Thus, initial examination should concentrate upon the following:–

(i) Porosity of the Oversite Structure

A study of the structure of the building is essential. Examination may reveal a lack of oversite concrete beneath timber floors in older buildings or granite slabs may be bedded direct on earth. Oversite concrete or finished concrete floors may reveal settlement cracks or gaps at

(iv) Occupancy Patterns

Shops and offices, normally closed at night may show high Radon levels by morning and these will rapidly decline during a normal working day due to constant traffic in and out of the premises and from one room to the next. The double glazed home owner who justifies his investment by excluding all fresh air may be collecting Radon in a big way.

Summary

Attention to these variable factors, permeability of the oversite structure, pressure differential and occupancy patterns will inevitably enable some reduction in Radon concentration. Whether the reduction will be acceptable as being as low as reasonably practicable (ALARP) will depend upon the recognition and appreciation of the importance of the various factors affecting a given building. This essential activity may be called diagnosis.

MITIGATION

Attention to contributory factors such as sealing of fireplaces, disuse of extract fans and sealing of ground air entry points will have a reducing effect upon Radon levels but not normally sufficient to bring about satisfactory reductions. Nevertheless, they may have a part to play. Advice on such matters and the provision of some permanent ground – floor ventilation will achieve immediate, interim reductions.

Beyond these marginal items attention must focus upon (i) sealing of buildings against entry of ground air Radon or (ii) reducing or reversing the pressure differential above and below ground floor.

Sealing of Ground Floors

The proposal that the provision of a Radon proof membrane (figure 9) can bring about satisfactory reductions in existing buildings is suspect for the following reasons:–

(i) Experiments have demonstrated that, unless a perfect seal is achieved, reductions may only be in the order of a few per cent.

(ii) The chances of achieving a perfect seal, particularly against walls, around service entries or sheet overlaps are extremely remote.

(iii) There are additional problems when dealing with hearths and fitted units.

junctions with walls or around service entries. Radon may also enter via rubble filled walls or avity walls. Earth retaining walls will present a special problem.

(ii) Factors Affecting Pressure Differential

These have already been discussed and, whilst there is little that can be done about wind effects, the position of openable windows should be noted. The methods of heating, fire places in use or still open should be recorded, as also should the use of extract fans.

A record should be made of the position and number of sub-floor vents since, whilst affecting the pre-mitigation Radon levels, may be of help in making further reductions.

The presence of "leaky" windows, such as double-hung sashes, and doors will tend to break the stack effect whilst "tight" buildings, such as those fitted with double or secondary glazing, will enhance the stack effect and may be a help or hinderance in planning mitigation work.

The study of a building and the way in which it is used is an essential step. A knowledge of the structure, particularly at ground level is also necessary and will have a strong influence on the chosen method of mitigation.

REDUCTION OF PRESSURE DIFFERENTIAL

The "reversal" of pressure differential may not be practicable and is therefore omitted from the heading to this Section.

Sub Floor Depressurisation

Normally achieved by the provision of a sump, connecting pipework and fan (Figure 10). Whilst the main objective is to depressurise the ground immediately below a building the system also removes Radon laden ground air. The exhausted ground air will contain high concentrations of Radon and care must be taken to ensure that the system terminates at a safe point, normally roof level.

There are variations to this system, such as the branching of the main suction pipe to several points below the oversite concrete slab. A further method involves an external sump connected to the under slab by a pipe inserted through the footings. Experiments are in hand to achieve a similar arrangement without the external sump.
(figure 11).

Suspended Timber Floors

These require special mention since, due to the number of sub-floor vents normally present, sub-floor exhaustion is hardly likely to affect pressure differentials. Instead, the system relies upon evacuation of Radon laden air. The blocking of selected vents has been recommended to create

(iv) Radon may still enter in significant volume up or through cavity walls, stud partition walls, rubble filled walls and retaining walls

(v) There is always the chance of damage during future alterations/improvements.

Notwithstanding, there may be isolated occasions when a membrane may be indicated. Its application should therefore be discussed. Such schemes have the advantage of nil operating costs.

Membranes vary from the standard 1000 gauge polythene sheet to more substantial reinforced sheets. There is yet some doubt as to whether such products are totally impervious to Radon. Only one product, metal foil sandwiched between polythene was found to be totally impervious during laboratory tests.

A variety of jointing compounds are available, either specific to a particular product or generally available for use with a variety of materials.

All membranes except the strongest require surface protection, usually in the form of tempered hardboard sheets. Gaps at skirtings or any other abatement should be sealed with a mastic sealant.

OTHER METHODS

1 Heat Exchange Units

Originally intended as heat scavengers from outgoing air these provide a form of constant ventilation at ground floor level whilst not reducing comfort levels.

Outgoing and incoming air is propelled by two separate fans turned by a common electric motor. Heat from the outgoing air is transferred to incoming air by means of a series of fins or baffles. Several devices were installed in the Tavistock area with, I believe, moderate results in radon mitigation. I consider that performance would be improved by uprating the incoming air fan.

2 Liquid Applications

In view of the problems encountered when providing plastic membrane barriers in existing houses the possible use of paints in appropriate circumstances has been considered. These may be of particular use in treating retaining walls, cavity walls, and solid floors. They have the advantage of being jointless. The work carried out in the USA showed air flow reductions of between 95% & 99% after painting concrete blocks with a variety of paints i.e. rubberised, expoy-resin.*

*Radon Fundamentals and the Effectiveness of Coating in Reducing Soil Gas Flow through Block Basement Walls.

John Ruppersberger USA EPA

a degree of depressurisation but this may result in "short- circuiting", leaving unventilated sections of the floor structure. Greater diffusion may be possible by positive pressure ventilation and experiments are indicated to assess this potential.

Where an oversite slab is present a sump and extraction system may be installed.

Positive Pressurisation

There are a few systems already being marketed which rely upon blowing filtered air into a building from its roof space. The "tighter" the building, the greater the pressure and the greater the likely reduction in Radon levels. Hence, a building which, by virtue of a "leaky" ground floor, has Radon levels which would otherwise be higher will not benefit to any great degree from attempts at pressurisation.

Attention is now being given to preheated air intakes, with variable flow and finer filtration. Satisfactory achievements in these areas may bring about ideal living environments and, together with reductions in condensation, will provide an attractive alternative to sub-floor ventilation, albeit Radon reductions will not normally be as great.

ADMINISTRATIVE AND POLITICAL ASPECTS

From the Local Authority viewpoint in Devon and Cornwall there exists a degree of frustration and disappointment. Having collaborated in the directed survey, having studied the results and having considered the stated risks, we felt that the topic required a greater degree of priority than that granted by the Department of the Environment.

In almost an administrative vacuum, we, the Local Authorities, have sought to organise ourselves. We set up a forum, now called the Radon South West Committee and over the past eighteen we have studied all aspects of radon. We have experimented in our own council-owned properties and exchanged our experiences. One of our members went to the USA on a scholarship funded by the South Western Centre of the Institution of Environmental Health Officers and gained good experience from that quarter. We begged, borrowed and stole information from many sources and became a recognised centre of 'sharp end' expertise. We have encouraged training seminars and made representations to the Government. We have kept up a fruitful dialogue with the NRPB and the BRE.

Why have we done this, since we have no general remit from Central Government. The only reference in print connecting radon with Local Authorities is contained in the Householders Guide to Radon (2nd edition) whereby readers are told that we are available to give advice. Advice is a big word when dealing with radon yet, thus stated, who is going to train us so that we can give meaningful advice. We have had to train ourselves with considerable support from the NRPB.

I am not aware that the system has been used anywhere in this country but these results indicate another method of treating areas such as basements.

3. Passive Sub-Floor Ventilation

This system is at present under the scrutiny of the Building Research Establishment. It entails similar sump and pipework as already discussed except that the pipe would terminate with a cowl or other syphonic arrangement which would induce some level of depressurisation. If successful this system has the benefit of requiring no power and no maintenance.

The Department of the Environment is the responsible government body in relation to radon in houses. The NRPB act as the Government's advisers on all radiation risks. The BRE are commissioned to research methods of radon mitigation and prevention. What is missing is an agency to deal with the problem at local level.

It may be that the Government, if only by default, intends that the problem should be met by normal market forces, namely consultants and the building industry.

A private firm are currently offering two day courses for builders and the Radon South West Committee have presented a few one day seminars. Neither of these initiatives, albeit the best that can be offered, will produce experts. The courses only give a broad understanding of the subject.

The Building Employers Confederation has expressed its concern and has joined the Radon South West Committee in presenting 2 day courses for builders (management & tradesmen). These have been programmed with the intention of offering short follow-up courses every six months when new developments can be considered and current practices reviewed.

In view of the size of the problem and the risks presented, I feel very strongly that the preliminary initiative should have come from Government. Courses should have been arranged through the polytechnics; they should have been structured to permit ongoing training.

All we have for the moment is a private concern giving training over two days at the end of which the recipient is given a 'licence' to operate in an area of considerable technical uncertainty and highly emotive profile. I cannot question the quality of the lectures since these are in the main, given by members of the Radon South West Committee!

The vacuum is further enhanced by the lack of local administration; someone, to pull all the ends together, to ensure that training courses are structured properly, to respond to specific problems. The NRPB and the BRE are trying to achieve something like a shadow of this at the cost of prolonged telephone calls and considerable mileage. I do not know whether the cost effectiveness of this and a more sensible arrangement have been properly considered.

In truth, there are already certain areas where local authorities have responsibilities in connection with radon, as follows:

Council Houses
Other Council owned property
Health & Safety at Work Act
Environmental Protection Act 1990
Improvement Grants

Most local authorities have accepted the duty of monitoring council houses and putting mitigation in hand. They also have a duty to deal with other council property such as offices and depots.

We have, with the Health & Safety Executive the duty of improving standards under the Health & Safety at Work Act. Radon in the work place is a new issue and, for this reason, Teignbridge Council are currently offering a one-day training seminar for EHOs and Technicians.

We are also looking at the Environmental Protection Act 1990, in particular Part III which requires local authorities to serve abatement notices where a 'statutory nuisance' exists. One definition of such a nuisance is "any premises is such a state as to be prejudicial to health or a nuisance". This piece of legislation may be useful in dealing with recalcitrant landlords who refuse to carry out radon mitigation. This particular use of the law has yet to be tested in the courts.

Information flow is another problem. The articles issued by the Environment Protection Agency fill more than one suitcase. In this country we have the Guidance to Part C of the Building Regulations and the Householders Guide to Radon. More technical information promised last year never materialised.

I should mention that the DOE organised a postal leaflet drop to all householders in Devon and Cornwall earlier this year advising them to have their houses tested. The response was much greater than expected; around 75,000 requests for tests. Since this demonstrates some initiative on the part of householders one can assume that there will also be a heavy demand for advice and mitigation services. This raises, once again, the question of adequate training.

Continuing this line of thought, we wonder what else the government could be doing about radon. It is stated that Improvement Grants are available for radon mitigation. However, the new grant system includes a mandatory means test which, to my knowledge, no one has succeeded in passing to date. A recent survey by IEHO has confirmed this. Radon mitigation

work is of relatively low cost compared with other improvements and this is a disqualifying factor. I do not believe in throwing money at every problem but, reviewing the risks from radon and the comparative priority of other, more expensive improvements, I feel that the means test should be removed. It is the only further overt measure available to government.

The 6th Report of the Environment Committee.

The preceding issues, amongst others, were considered by the Select Committee chaired by Sir Hugh Rossi. We were not surprised by its findings as below:

THE VIEWS OF THE SELECT COMMITTEE
[SUMMARISED]

Conclusion	Recommendation
1. Rate of progress in identifying houses with high radon levels is too slow.	Identification of majority of houses with high levels to be achieved by the year 2000.
2. Laissez faire system of survey.	Householders in vicinity of house found to have high levels to be approached and offered free survey.
3. Because of confidentiality house vendors not obliged to reveal that home has high radon levels.	Provide opportunity for education on radon to members of Law Society and RICS to ensure proper advice to client purchasers.
4. Lack of take-up of improvement grants due to means test.	Review take-up of grants and, if necessary, develop a mandatory system of grants in Affected Areas.
5. Lack of detailed guidance on radon-proofing.	Production of such advice be rapidly accelerated.
6. Current lack of information could lead to situation in which cowboy builders could flourish.	Establish a list of specialist radon-proofing contractors with appropriate knowledge, training and experience.
7. No action link between exposure to radon at work and at home.	Those exposed to high levels at work advised to have surveys at home.

SUMMARY

In this paper I have tried to give a picture of this new threat from the point of view of a generalist.

It must be apparent that we have a long way to go in terms of information and action.

I am thankful for one particular factor not previously mentioned; that of the public response. On the whole this has been slow occasioned by degrees of apathy or uncertainty. This has given us the time to assimilate knowledge on radon and organise ourselves into a framework of information exchange.

The risks as quoted are real although we won't have an accurate assessment of these until the results of current surveys are known.

The technology exists, and is still developing to deal with houses with high radon levels. Prevention in new houses is a reality.

These two factors together raise the question as to whether prevention and mitigation should be nationwide issues. If one accepts that there are 2,400 deaths per year from radon related lung cancer, then it may be that at least 2,000 of these are in areas where radon levels are low. Thus the problem in Devon and Cornwall may be regarded as the tip of the iceberg (Figure 12).

It is accepted that mitigation of low levels may not be cost effective but even this statement is questionable. The risk may be taken as a multiple of radon levels and exposure times. If the level is only halved the risk is halved.

If this argument is not acceptable for mitigation it must surely hold good for prevention in new houses. Add to this the indication that radon may be responsible for other illnesses and the argument must become more compelling.

Further, the technology of radon mitigation introduces the concept of preventing entry of ground air with whatever else may be regarded as contaminants such as methane.

Maybe we now have a new concept of the living environment. Should not all houses be capable of reducing the entry of all contaminants. I do not propose to give the answer, merely to raise the question.

Radon may be responsible for more than lung cancer. Maybe it has given us the answer to more than radon mitigation. We still have a lot more to learn.