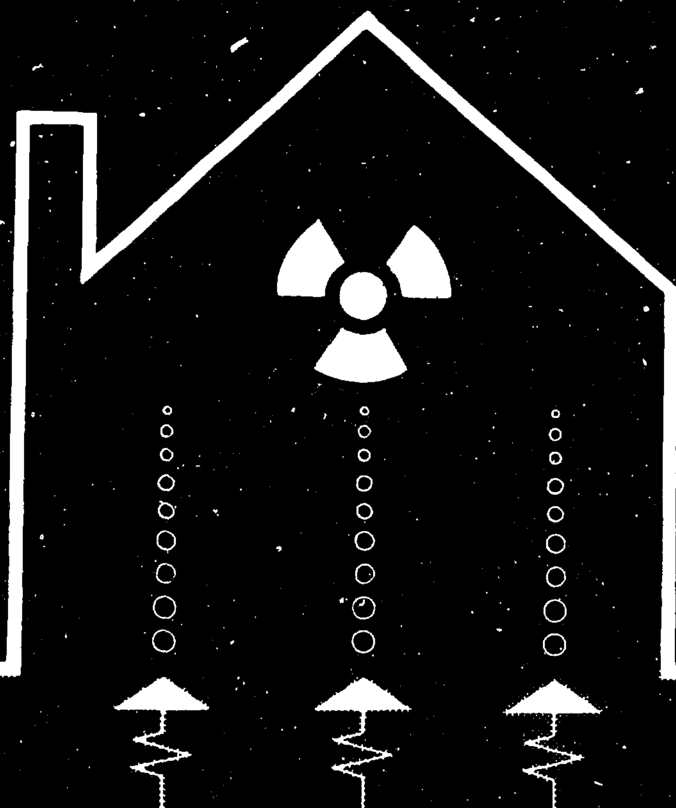
RADON
IN BUILDINGS



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Contents

Introduction

This guide has been prepared at the request of the Minister for the Environment. It is intended to inform designers, householders and other building owners about the radon problem and to help in deciding if there is need to take any action to reduce radon levels in their homes or other buildings. It explains what radon is, how it enters buildings and what effect it may have on health. Reference is made to some of the usual ways of reducing the level of radon and guidance is given on some sources of assistance. It is not intended as a comprehensive document covering all aspects of radon and indoor radiation exposure, but rather as a source of basic information to assist in making informed decisions on the subject.

James J. Connell
January 1991

1. Facts about Radon

The main sources of radiation are of natural origin. The combined effect of all natural radioactivity contributes considerably more to the overall dose (87% of total) than do all of the artificial sources including medical diagnostics, nuclear energy production and weapons testing. Exposure to any form of radiation may cause harm to the exposed person or his or her descendants and there is no intrinsic difference between artificial and natural radiation in their biological effects. In contrast to the demand for strict controls over exposure to radiation from artificial sources, relatively little attention has been given to control of exposure to natural sources. However, in recent years there has been a growing concern among those dealing with radiation matters about the long term effects of radiation at all levels and from all sources and the circumstances where exposure could, and probably should, be reduced. This is particularly so in the case of indoor exposure to radon and its decay products which accounts for over 30% of our total radiation.

Radon is a natural radioactive gas that has no taste, smell or colour and requires special equipment to detect its presence. It is found to some degree in all soils and rocks but the amount can vary in different parts of the country and at different times of the year. Radon is formed in the ground by the radioactive decay of small amounts of radium which itself is a decay product of uranium. It is said to have a half-life of 3.8 days, which is the time it takes for one-half of the radioactive atoms to decay to the next member of the decay sequence. Being a gas, it can move through porous media such as fractured rock and soil and some is exhaled at the surface. When this occurs in the outdoor air it is quickly diluted in the atmosphere to low and harmless concentrations. However, once it percolates into an enclosed space, such as a building, it can accumulate to dangerous levels because dispersion is restricted by limited ventilation. The concentration will depend on the radon levels in the underlying soil, the construction details of the building and the available ventilation. It may also be introduced indoors by way of ground water supplied from a well, or from building materials containing traces of radium, but normally the amounts from these sources are not of any consequence in this country.

2. Indoor Radon - Points of Entry

The levels of radon in indoor air appear to have increased in recent decades, most likely due to the desire for "tighter" building enclosures in order to reduce energy consumption.

These levels depend mainly on the concentration of the sub-floor soil gas and the available entry points in the ground floor area of the building. As these factors usually vary from building to building each case must be considered separately. The more fragmented and porous the underlying rocks and soil the greater the amount of radon gas that can rise to the surface. This gas can enter a building in a convective flow through cracks and holes in the floor area and any gaps

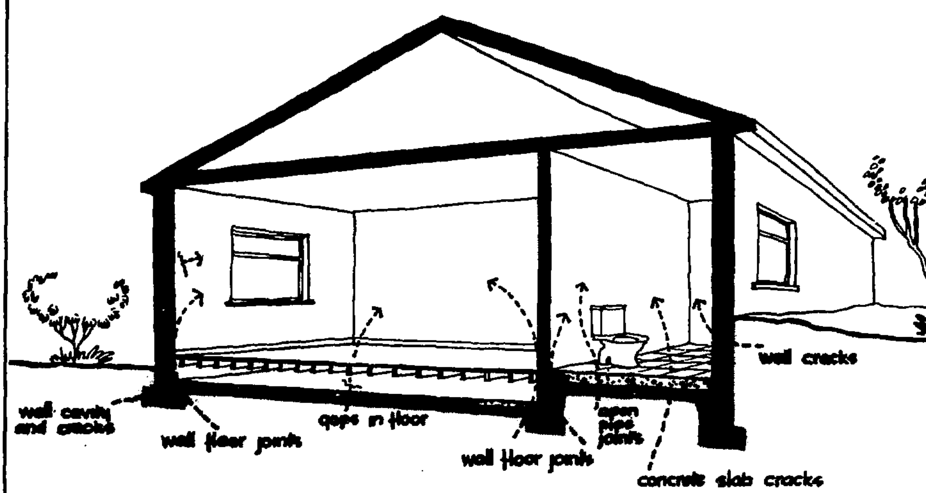

Figure 1: MAJOR RADON ENTRY ROUTES

around service pipes and cables (Figure 1). It is usually pressure-driven due to the slightly lower indoor air pressure compared with that under the floor, a result of wind and temperature difference. As might be expected, elevated levels of radon resulting from soil gas are found mainly in basements and at ground floor levels. Also, radon gas is nine times heavier than air, and therefore tends to remain close to the ground. Radon is not normally a problem in the upper stories of high rise buildings and if an elevated level is found it is likely to have been caused by emission from the building materials used.

3. Occurrence in Ireland

Radioactivity in air resulting from radon is measured in becquerel per cubic metre (Bq/m^3). This unit of measurement indicates that radon is present at a concentration that emits one particle of radiation per second in a cubic metre of air. A survey carried out by Dr. J.P. McLaughlin of University College Dublin of a random sample of approximately 1300 houses in the State shows a median level of indoor radon of about 35 Bq/m^3 throughout the country. However, levels in excess of 400 Bq/m^3 were found in 1.5% of cases with individual peaks rising as high as 1700 Bq/m^3. Most of these were located in parts of counties Clare, Galway, Mayo and Cork, but even in these counties the vast majority of the sample houses had a low radon level. A more recent survey of over 500 houses in some western counties was carried out by the Nuclear Energy Board and U.C.D. to identify the distribution of elevated concentrations in these areas. The results indicate that about 2.8% had radon levels above 400 Bq/m^3 and that 9.4% were above 200 Bq/m^3.

4. Reference Level

Having a screening measurement carried out is the only way of knowing if a building has a radon problem. A recommended Reference Level for Ireland has been set by the Government at 200 Bq/m^3 for the annual average radon gas concentration in an existing home. Above this level action should be taken to reduce it. The level of 200 Bq/m^3 is also intended to apply to all future dwellings which ideally should be constructed so that radon concentrations are as low as reasonably practicable and be at least below this level. In existing dwellings, for levels up to 500 Bq/m^3 it would be desirable to take action within a few years and where levels are over 1000 Bq/m^3, within a year or so.

5. Risks of Lung Cancer

The reason for concern about radon is its association with an increased risk of developing lung cancer. There is considerable evidence available both from studies of underground uranium miners and from animal experiments to make this link with certainty. Radon being radioactive disintegrates and gives off decay products known as daughters or progeny which are also radioactive. These are minute particles which when released in the air may be inhaled and deposited in the lungs. As they in turn decay they give a radiation dose to the lung tissues which may eventually cause lung cancer. This is not a matter that should cause immediate anxiety as it takes many years for the disease to develop and is normally considered as a lifetime risk. Not everyone exposed to elevated levels of radon is certain to develop lung cancer and while few people these days spend a lifetime in the same house it would be foolish to ignore the risk completely.

For most people, the risk of developing lung cancer from radon is insignificant compared with other everyday risks. Nevertheless, despite the lack of complete agreement among experts on the precise risk, it has been calculated that exposure to the Reference Level of an annual average of 200 Bq/m^3 corresponds to a lifetime risk of lung cancer of about 2.5%. The normal lifetime risk of contracting lung cancer in Ireland from all sources is about 3%.

While smoking has been accepted as the single most important cause of lung cancer, international estimates now suggest that between 5% and 10% of lung cancer deaths may be caused by indoor radon exposure alone. There is also strong evidence which indicates a much higher risk from radon for cigarette smokers than for non-smokers. The National Radiological Protection Board in the U.K. in a recent publication puts this risk at 10 times that for non-smokers at all levels of exposure. This arises from a synergistic or multiplicative interaction of both carcinogens, which means that the combined effect exceeds the sum of the two effects taken independently.

6. Dose

Exposure to a given concentration of radon gas may be converted into an annual radiation dose. The unit used to measure this dose is the milli Sievert (mSv). The average annual dose to an Irish person from naturally occurring radiation is about 2.5 mSv. Exposure to the Reference Level of 200 Bq/m^3 over a full year would correspond to an annual dose of 10 mSv. The radiation limit currently enforced by the Nuclear Energy Board in its general licensing to protect the public is 1 mSv. For comparison, the dose arising during the first year from the Chernobyl accident in 1986 was between 0.1 and 0.16 mSv in Ireland and the annual dose to the average consumer of fish from the Irish Sea is 0.002 mSv.

7. Methods of Detection

The two most common devices used for measuring indoor radon concentrations are the charcoal canister and the alpha track detector. The charcoal canister is a small container of activated carbon which absorbs radon. It is exposed in a living area for about a week and then sent to a laboratory for analysis. The alpha track detector gives a more accurate reading of the average exposure but must be left in place for a longer period, usually three months, to cover the widely fluctuating daily and seasonal variations. The detector consists of a small container which allows the alpha particles released by the radon to come in contact inside the container with a small piece of a special plastic in which tracks are formed by the radiation striking it. After exposure for the recommended time it is also sent to a laboratory for analysis. The initial screening measurement may indicate that there is no need for further action, but in some cases it may be necessary to take measurements over a longer period to get a more accurate estimate of the average level. Remedial action should be undertaken only after long-term measurements have been taken using alpha track detectors as the shorter period measurements obtained with charcoal canisters may not give a reliable indication of average levels. There are other techniques requiring operation by trained personnel which can be used to give "instant" readings, but they are more expensive and, due to the normal variation in concentrations over a short period of time, would be less reliable in determining the average radon level.

It is possible to take radon measurements in the ground on a prospective building site, but the results may be of limited value. Alfa track detectors may be buried in holes about 600 mm deep and recovered after exposure for one week. If high readings are found there is no doubt about the need for preventative measures. Low readings in the ground, however, may not be taken as a guarantee of low concentrations inside a future building on the site, as any excavation necessary during construction may increase the release of soil gas which could result in high indoor concentrations. After construction it would probably be necessary to have indoor measurements taken in both cases to find out the actual level inside the building.

8. Prediction and Measurement of Levels

One of the difficulties at present with the occurrence of radon gas is that no reliable method has been found for identifying the geographical areas most at risk. There is evidence linking high radon levels with underlying areas of uranium-bearing granite, shales, phosphate and certain sandstones, but this pattern is not entirely reliable which makes it difficult to prepare maps predicting areas of high concentrations based on geological data. As an alternative, national surveys based on map grids are extremely expensive and lengthy exercises and result in only very general indications due to the variations in radon concentrations that may occur within small areas. In the absence of trustworthy maps or other methods of indicating places most at risk, it rests with individuals to consider having their sites and buildings tested if they are preparing for new building works or are concerned about existing structures. Measurements may be arranged by applying to either of the following:-

Nuclear Energy Board
3 Clonskeagh Square
Clonskeagh Road
Dublin 14.

Physics Department
University College Dublin
Belfield
Dublin 4.

A measurement will involve receiving by post an alpha track detector with instructions on how it should be exposed in a building for some months before being returned for processing. The results will then be sent by post to the applicant and will remain confidential. The charge for this service is currently £15. The applicant will be told either that no further action is necessary or, where a potential hazard has been indicated, that additional testing over a longer period would be advisable. Should it be necessary to undertake remedial measures to reduce the levels found, it may be necessary to seek professional advice from an architect, radiation scientist or engineer who is properly qualified to deal with this type of work, in order to decide on the appropriate action.

9. Corrective Options

Compared to existing buildings, it is relatively easy when designing a new building to take precautions to deal with radon should the problem arise. The selection and design of a cost-efficient reduction system will depend on a number of factors specific to the individual building.

Reduction techniques fall into two main categories: those aimed at preventing radon entering the building and those aimed at removing radon or its decay products after entry. Techniques which prevent radon entry include: sealing soil gas routes into the building, sub-floor ventilation to draw or force soil gas away from the building before it can enter, and adjustment of the air pressure inside the building to reduce or reverse the driving force which assists the entry of soil gas. Techniques which remove radon after entry include: ventilation of the building, and air cleaning devices to remove radon decay products. For persons who smoke cigarettes and are concerned about lung cancer attributed to radon, probably the most effective first action would be to give up smoking. For others, it may be prudent to begin by installing the simplest and least expensive method which offers reasonable potential for achieving the desired reduction. If this does not work, the system could then be expanded in a series of pre-designed steps until the level is reduced to that required.

10. Reduction Techniques

A solution to high indoor concentrations of radon should ideally:

1. Limit the infiltration of soil gas;

2. Avoid if possible "active" solutions which require long term energy expenditure (fans that must run constantly to remove the radon);

3. Not compromise attempts to limit energy use in the house.

(a) Sealing

Tests have established that the concentration and pressure of soil gas is the dominant factor contributing to indoor radon problems and that the most common method of infiltration is through cracks and other openings in the ground floor and adjoining walls, particularly when the floor slab is in contact with the ground.

(i) Existing Buildings

To prevent this infiltration in an existing building the normal recommendation is to make the floors and walls a more effective barrier by sealing all the points of entry. Unfortunately, this is easier said than done. Experience has shown that missing even minor openings in the sealing process will compromise the exercise. Since the gas flow is pressure driven, it is similar to mending punctures in a tyre tube - if you miss sealing just one hole you may still have a flat tyre. Nevertheless, by a combination of careful inspection and thorough workmanship, it should be possible to seal all major entry routes and reduce the main inflow of radon and, at worst, end up with the equivalent of a slow puncture rather than a totally flat tyre. In many cases it will not be possible to carry out a full inspection due to existing floor coverings, skirtings etc. and the chances of successful sealing will be further reduced.

Materials for this sealing work should be flexible, permanently elastic and capable of adhering to a variety of surfaces. Buildings are to some degree dynamic in the sense that minor movement may occur from year to year and, unless the sealant is able to flex with the building, cracks will reappear. High quality sealants such as silicone, polysulphide and polyurethane are those most likely to be successful.

In existing buildings with timber floors having wall to wall carpeting it may be possible to provide a barrier by installing a sheet of 1000 gauge polyethylene film directly on the timber flooring under the underlay or foam-backed carpet. Any joints in the film as well as junctions between floor and walls must be taped or otherwise sealed to provide an airtight joint. Precautions must be taken to avoid tears in the film and, in general, great care is required in the workmanship. Other existing floors with relatively impervious sheet or tile materials may only require sealing at joints and edges to provide a barrier. In most cases it will be difficult, if at all possible, to achieve a totally airtight seal, but nevertheless, this must be the objective if radon entry is to be reduced.

(ii) New Buildings

In a new building it should be possible to provide a barrier against rising gas by installing an impermeable membrane across the total floor and wall sections. It is important that this barrier prevents radon from rising in wall cavities and in voids of hollow concrete block walls. To achieve this it will be necessary to modify traditional construction practice and ensure a higher than normal level of workmanship. For example, in a cavity wall if the damp proof course is to act as a barrier the normal separate damp proof course in each leaf should be replaced with a single stepped damp proof course across the cavity (Figures 2 and 3) having joints lapped and sealed or with a membrane carried through to the outside face (Figure 4). The membrane and damp proof course arrangements shown in the Figures are possible solutions and illustrate the principle of barrier protection: other arrangements may be equally valid. Precautions should be taken to minimise possible differential movement between walls and concrete slabs and to make provision for this in the membrane at wall and floor joints. Many plastic films such as polyethylene, PVC etc. are suitable as membranes provided they are of adequate thickness and any joints are formed with airtight seals. Where possible, service pipes should not penetrate the radon-proof membrane and where this is

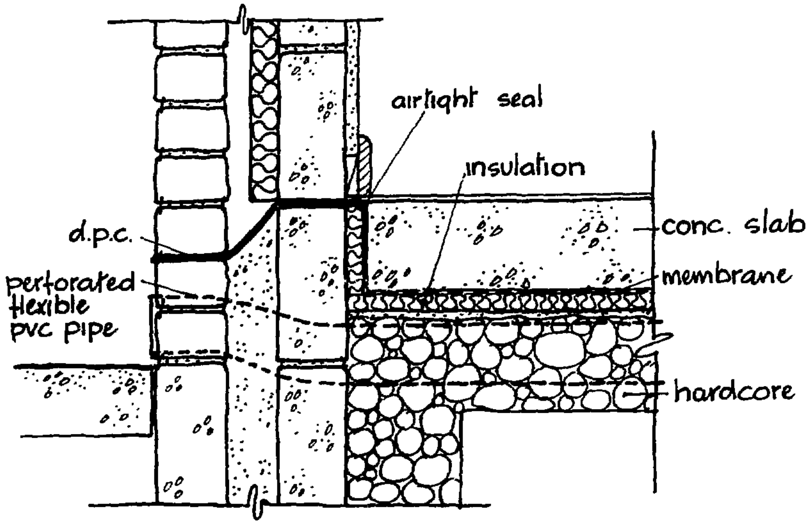

Figure 2: WALL/FLOOR SECTION

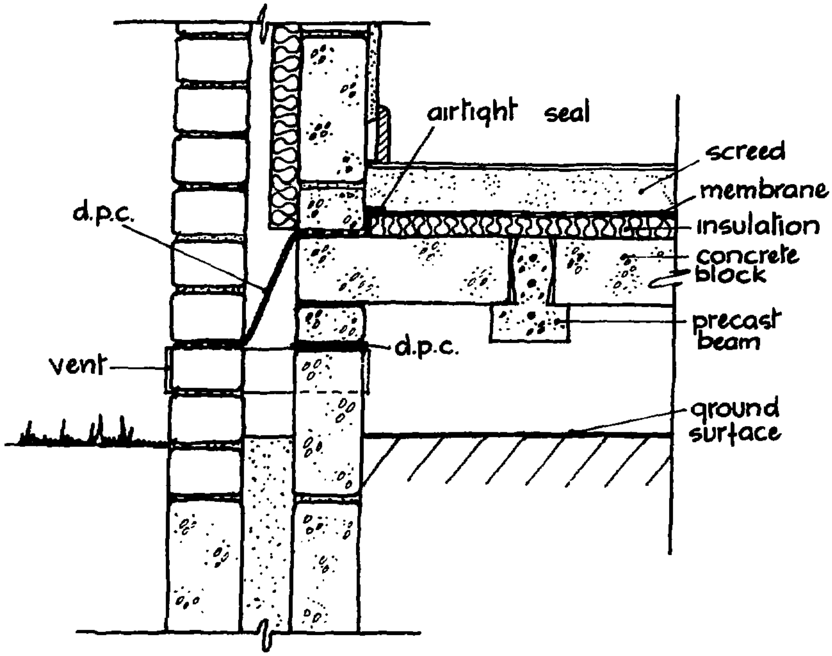

Figure 3: WALL/FLOOR SECTION

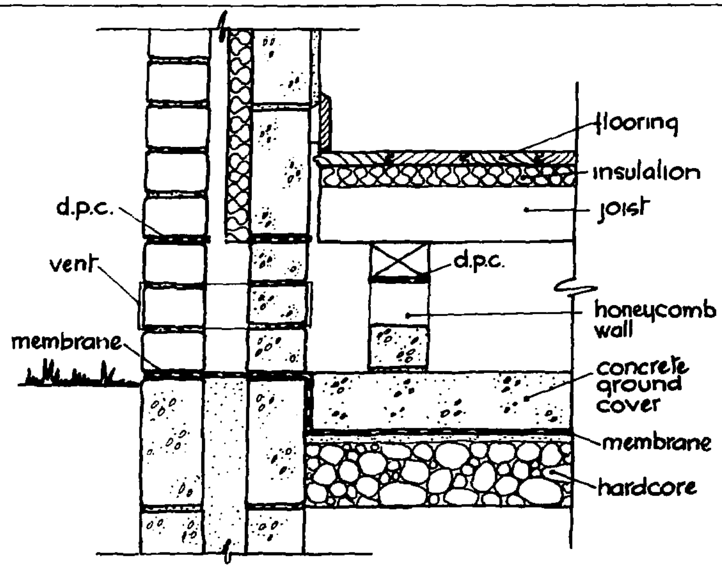

Figure 4 : WALL/FLOOR SECTION

not possible the penetrations should be provided with an airtight seal.

Alternatively, it may be possible to rely on an in-situ concrete ground floor slab on its own to provide a barrier. The Swedish Council for Building Research has indicated that a concrete slab of conventional good quality, provided it is free from cracks and holes, presents sufficient resistance to radon, even where there is a high sub-slab concentration of the gas. In such cases consideration should be given to the use of steel or polypropylene fibres in the concrete mix in order to control the incidence of plastic shrinkage cracking. Suitable airtight seals at slab perimeter to damp proof course etc. would, of course, be necessary.

(b) Depressurization

After sealing or providing a barrier, the most common way of attempting to cope with infiltration of radon is to eliminate the pressure gradient between the soil and the building. In a building with a concrete ground floor slab in direct contact with the soil, this will usually mean providing, in the permeable hardcore layer under the slab, a sump or collection chamber into which the radon gas is drawn and from which it is piped to the outside air. An electrically operated fan will normally be necessary to provide the suction, although in certain circumstances the "stack effect" of a pipe taken up through the building may be able to reduce the underfloor pressure sufficiently. A fan operated system is far from being an ideal solution as, apart from the cost of installing and running a fan constantly, the noise and maintenance aspect cannot be ignored. However, despite all its drawbacks it is still the most reliable of current methods when radon levels are very high and may be the only practical option in severe cases.

(i) Existing Buildings

In an existing building this remedy can be both troublesome and expensive. It will involve breaking through the existing slab to form a sump, installing the associated piping, reinstating the slab and any existing damp proof membrane and sealing the junction between the old and new concrete. As a solution for an existing building, this technique should be considered only when other options give little hope of success.

In an existing building with a very permeable hardcore layer under the floor it may be possible to make a pipe connection to this layer at a point outside of and adjoining an exterior wall. This would involve breaking through the rising wall and inserting a pipe to which a fan would be attached to reduce the underfloor pressure and draw the soil gas out into the open air.

Also, where the ground adjoining an existing building is very permeable it may be possible to form a sump outside of and close to the building and have a suitable fan fitted to draw soil gas from the ground which may reduce the pressure in the underfloor area.

(ii) New Buildings

Installing a sump when constructing a new building is relatively easy and inexpensive and a useful precaution even if later found to be unnecessary.

The normal recommended underfloor sump is usually centrally located and consists of a 600x600x50 mm concrete paving slab supported on loose-laid bricks on edge spaced apart around its perimeter (Figure 5 and 6). A 100 mm diameter PVC pipe is inserted into the chamber thus formed and is taken through an exterior wall where it is turned up and capped until it is necessary to extend it and fit an extract fan. Alternatively, the exhaust pipe and fan may be located at a suitable place within the building for soil gas extraction to the outside air at a high level. Depending on the size and layout of the building, more than one sump may be necessary.

(c) Ventilation

Ventilation is the process whereby internal air is gradually replaced by outdoor air. Natural ventilation is driven by pressure differences caused by wind or by differences in air density between indoors and outdoors. As a remedy for radon, ventilation should be considered in two ways - ventilation of the space under the ground floor and ventilation of the internal building space.

(i) Underfloor Ventilation - Existing Buildings

Existing buildings with high radon levels which have a suspended type of ground floor construction are fortunate in having what may be an easily remedied situation. The air space under the floor effectively disconnects it from the ground and offers the opportunity of intercepting the rising soil gas and removing it by ventilation before it can enter the building. The underfloor ventilation normally provided to remove rising ground moisture can usually be increased to allow a

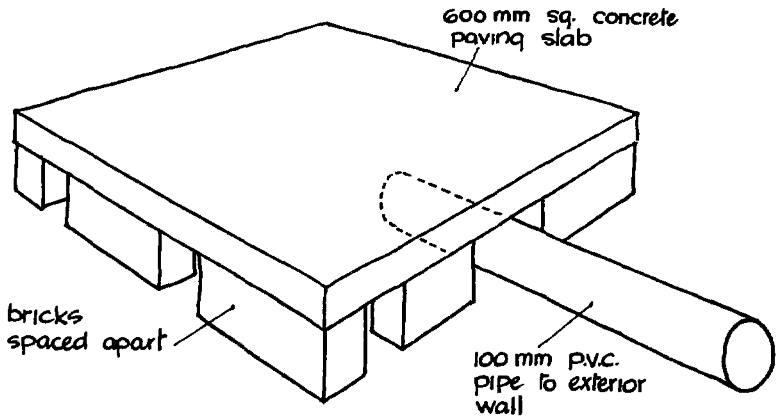

Figure 5: UNDERFLOOR SUMP DETAILS

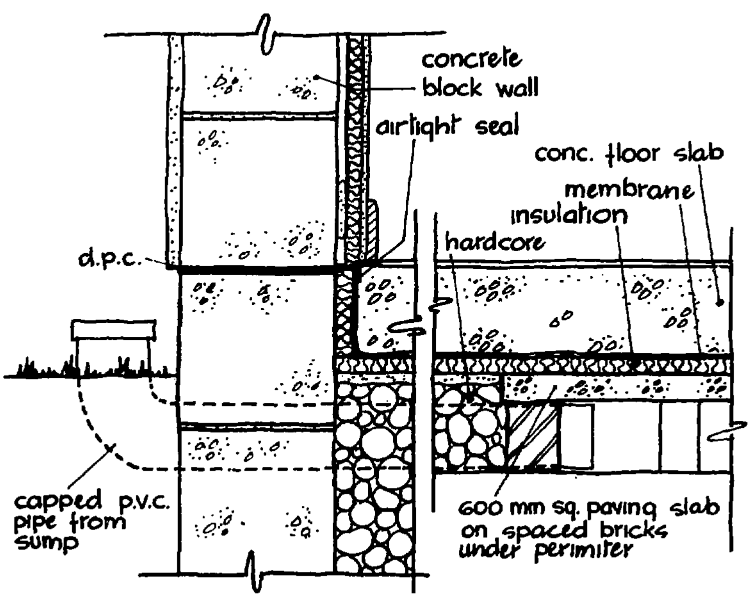

Figure 6: SECTION SHOWING UNDERFLOOR SUMP

sufficiently strong undercurrent of outside air to constantly replace the soil gas as it emerges from the ground. As the increased air movement under the floor would have a cooling effect it may be necessary to install floor insulation to prevent an energy penalty. The ease of adding insulation would depend on the construction details. Should this approach not result in the desired reduction within the building, it would then be possible to resort to "active" depressurization of the sub-floor by sealing all the wall vents and installing an extract fan system to draw air from the space under the floor.

(ii) Underfloor Ventilation - New Buildings

For new buildings, whether there is evidence of high ground radon or not, the use of a suspended type ground floor in either timber or precast concrete makes provision for a remedy if one is needed in the future. Normal underfloor ventilation may be installed initially and, if indoor radon measurements taken after construction show acceptable levels, then no further action is necessary. Should the indoor measurements be high, the steps previously described for existing buildings could be taken to the extent necessary. Since the provision of floor insulation would be normal in most new buildings, there would be no need for further insulation work.

In a new building where the preferred form of ground floor construction is a concrete slab on ground there is an alternative method to the type of under slab depressurization sump previously described. This alternative, while still at experimental stage, would permit a "passive" ventilation approach as a first option and, subject to indoor measurement levels, a second option of using an "active" fan assisted depressurization system if that became necessary.

The construction detail would provide for a number of 100 mm UPVC perforated land drainage flexible pipes embedded in the hardcore layer immediately below the floor slab. (Figure 2). These pipes would penetrate through, and finish flush with, the outer faces of the external walls at a level just above the finished exterior ground, forming a connecting conduit through which a current of air could flow. Such cross ventilation could, with sufficient air movement in the conduit, draw into it the rising radon gas and transfer it to the outside air. The number and arrangement of pipes necessary would depend on the house exposure to the prevailing winds, the construction details and the general layout. Interconnection of the main pipe runs within the floor plan area would be an advantage. It may be necessary in some cases to adjust the ground levels adjoining the exterior walls and also the hardcore layer to permit the pipe end openings to be located above the exterior ground or paving levels. Should this natural ventilation system not produce the required reduction, the ends of the pipe conduits at the exterior walls could be sealed where necessary and an "active" fan system installed to depressurize the underfloor layer. In this case the perforated pipe would become an elongated sump performing in the same way as the brick and concrete slab collection chamber previously described, but arguably in a more effective shape. It should be easier to install than the normal sump and offer flexibility where more than one sump may be necessary. The principal advantage of this system is that it offers the prospect of a passive ventilation solution which can be converted in a "fall back" situation to a mechanically operated system.

(iii) Ventilation of Internal Space - Existing and New Buildings

Increasing the ventilation of living areas, whenever possible, by opening windows on two or more sides of a building is the simplest method of reducing high radon concentrations. This will not always be possible for security reasons and in cold weather would be impractical due to discomfort and the increase in heating costs. This additional heating cost could be significantly reduced by installing a mechanically balanced supply/exhaust ventilation system with heat recovery. This would introduce and extract air at approximately the same rates, resulting in a neutral pressure within the building. To operate successfully, a balanced system requires a reasonably well sealed building in order to control air movement, and for radon reduction, it is essential that there are properly designed and located air inlets and outlets to allow incoming air to mix with room air. Mechanical ventilation of this type may not on its own be able to remedy a high level of radon but, as well as generally improving the quality of indoor air, it could be a useful supplementary tool with other systems. However, these systems are relatively expensive to install and it is unlikely that they would find wide-scale application in this country.

(d) Pressurization - Existing and New Buildings

It is generally accepted that the use of extract fans within a house to improve ventilation is counterproductive in dealing with high levels of radon. The net effect is to reduce the pressure in the house and thereby induce more radon from the soil through any available openings in the ground floor. It should be noted also that the effect of open fires and other combustion appliances is to reduce air pressure within a house and for this reason should ideally be provided with a dedicated source of outdoor air. An alternative approach is to use a fan system to provide a positive pressure throughout the house and in that way reverse the normal inflow of soil gas from under the floor.

In a house with a pitched roof this fan unit could be housed in the attic space and an air stream introduced into the house through a diffuser in the ceiling. Each room would be slightly pressurized and air forced out through crevices in windows, doors and other openings, reversing the normal inflow. Compared with outside conditions, the air in the attic would be warmed by solar gain for most of the year during daytime, but during nighttime use in very cold weather some pre-warming of the air would be necessary. A temperature controlled small electric heater could remove the chill but would add to the running cost. There is available commercially an attic mounted unit which was designed primarily for condensation control but which could in some cases provide the desired pressurization to control radon entry. This system would likely have most success in a reasonably well sealed house where a constant positive pressure could be maintained with a relatively low powered fan.

Some sources have dismissed this approach on the assumption that warm and moist indoor air would be forced into the building fabric giving rise to rot and condensation staining. This result is unlikely except in an extremely "tight" structure with few openings to allow the air to escape - a situation which is difficult to achieve in practice. For existing houses without other easy alternatives, this system of pressurization may provide a solution and would be less disruptive than many of the alternative remedies.

(e) Air Cleaning - Existing and New Buildings

Another way of removing radon progeny from the indoor air space is by various air treatments. Since radon decay products are solid particles they can be removed by continuously circulating the air through a device which removes them when they are attached to atomized or larger dust particles which are suspended in the air. This method has advantages over other techniques in that equipment for solid particle removal from air is available commercially at low cost and there is the added benefit of the removal at the same time of other air pollutants such as dust and pollen. Several devices are available for removing particulates from indoor air. They can be categorized according to their principles of operation into mechanical filters and electrostatic filters. Mechanised filters collect particles through mechanical forces exerted on them by the air flow and a fibrous filter medium. Electrostatic filters collect particles primarily as a result of electrical forces exerted on them when suspended in an air stream. It is important to note that these systems remove only particles from the air and do not remove any radon gas, which means that the production of progeny through the decay of radon is not affected. While these systems are "active" rather than "passive" the capital and running costs are substantially lower than for advanced mechanical ventilation systems.

The main problem with these devices is that, despite their success in removing particles with attached progeny, this does not necessarily reduce the radiation dose to the lungs and may even make matters worse. By removing the particles with the attached decay products, the newly created progeny then find fewer dust particles to adhere to and remain in the more hazardous unattached state. Radon decay products attached to particles deposit upon respiratory surfaces with only a few percent probability, whereas unattached progeny deposit with nearly 100% probability. As the mix of unattached and attached radon progeny is an important consideration in assessing lung dosimetry it is understandable why air cleaning devices on their own are not recommended at present as a solution to a radon problem. They can nevertheless effect some reduction in the radiation dose when used in combination with other more efficient systems and may contribute a positive side effect when filters are installed to remedy some other indoor air problem.

11. Conclusion

If elevated levels of radon have been identified or are anticipated and it has been decided to take some action, the first step may be to seek advice. Unless the appropriate measures can be chosen with confidence, professional advice should be sought from an architect, engineer or radiation scientist who is properly qualified to make the decisions.

In existing buildings with a radon problem, the options available to prevent the entry of soil gas are few and tend to be difficult to introduce with a high degree of success. Existing construction details and local conditions will often indicate the most appropriate remedy. Sealing alone may work well where the levels are not very high and the workmanship is thorough, but in many cases it may require a combination of two or more methods, e.g. sealing and ventilation, to achieve the necessary reduction. "Active" methods, such as fan assisted depressurization, need only be introduced when other simpler methods have failed and there is an urgency to reduce dangerously high levels.

In new buildings it is relatively easy and inexpensive to take precautions against the problem. Building Regulations require that measures be taken to avoid danger to the health of occupants of new buildings caused by radioactive substances in the ground under buildings. Even in areas where the prospect of trouble from radon would not be considered great, it may be a worthwhile exercise to take some preventive action. The provision of membrane barriers would in many cases be merely an extension of the precautions already necessary for the prevention of rising moisture and the addition of a sub-floor sump, even if never used, would be cheaply bought insurance.

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