

***Radon in Irish Primary  
and post-Primary Schools  
The Results of a National Survey***

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***May 2004***



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## Summary

*This report presents the results of a survey of radon concentrations in schools in the Republic of Ireland. The survey was carried out by the Radiological Protection Institute of Ireland (RPII) on behalf of the Department of Education and Science. A workplace Reference Level of 400 Bq/m<sup>3</sup> is set down in national legislation. However, in the case of schools the RPII has recommended that, wherever possible, radon concentrations should be reduced to below 200 Bq/m<sup>3</sup>. The objective of the survey was to assess the distribution of radon in Irish schools and to identify those requiring remedial work to reduce radon exposure to children and staff.*

*The survey was carried out on a phased basis from 1998 to 2002. All schools in the Free Education System were invited to participate. Indoor radon concentrations were measured using passive alpha track-etch detectors with a measurement period of one academic year from September to the following June.*

*Measurements were completed in the ground floor classrooms and offices of 3444 schools, representing over 85% of the approximate 4000 primary and post-primary schools in Ireland. Of these, 898 had radon concentrations greater than 200 Bq/m<sup>3</sup> and 307 had radon concentrations in excess of the national Reference Level for workplaces of 400 Bq/m<sup>3</sup> in one or more ground floor rooms. The average radon concentration in the schools surveyed was 93 Bq/m<sup>3</sup>.*

*Different remediation strategies have been adopted for schools with maximum radon concentrations between 200 and 400 Bq/m<sup>3</sup> and for schools with radon concentrations in excess of 400 Bq/m<sup>3</sup>. In schools with radon concentrations below 400 Bq/m<sup>3</sup>, passive remediation through increased background ventilation is, where practicable, being used to reduce the radon concentrations. Where the initial radon concentration exceeded 400 Bq/m<sup>3</sup>, a remediation consultant assessed the school and remedial measures specific to each school have been designed. In the majority of these cases active remediation in the form of sumps is being used to remediate schools with radon concentrations in excess of 400 Bq/m<sup>3</sup>.*

*Following the completion of remedial work, further radon measurements were carried out by the RPII to determine if the remediation had been effective. In schools with additional background ventilation, a nine-month radon measurement from September to the following June was made in each room that had been remediated. Where sumps or other active systems had been installed, three-month radon measurements were repeated in every ground floor office and classroom in the school.*

*To date post-remediation measurements have been completed in 208 schools; 108 of these had undergone passive remediation by means of additional background ventilation while 100 had a radon sump or other active system installed. Ventilation was found to reduce radon concentrations by an average factor of 1.9 (47%) while active systems resulted in an average reduction factor of 5.5 (82%). Twelve of the 208 schools still have radon concentrations in excess of 400 Bq/m<sup>3</sup> and require additional remediation work.*

## 1. INTRODUCTION

It is well established that long-term exposure to elevated levels of radon gas increases an individual's risk of developing lung cancer in later life [NRC, 1999]. Surveys conducted in Ireland during the late 1980s and early 1990s indicated that high indoor radon concentrations were common in homes in certain parts of the country [McLaughlin and Wasiolek, 1988; Madden *et al.*, 1994]. In 1990 the Irish Government adopted an annual average indoor radon concentration of 200 becquerels per cubic metre (Bq/m<sup>3</sup>) as the national Reference Level for homes above which remedial measures to reduce indoor radon should be considered. This Reference Level is advisory and has no legal standing.

Between 1992 and 1999 the Radiological Protection Institute of Ireland (RPII) conducted a nationwide geographically-based survey of radon in Irish homes using the 10 x 10 km<sup>2</sup> grid squares of the Irish National Grid as sampling units [Fennell *et al.*, 2002]. This survey quantifies comprehensively the distribution of radon in the Irish housing stock and identifies those parts of the country where high indoor radon concentrations are more likely to be found. Indoor radon concentrations were determined using passive alpha track-etch detectors installed for a continuous twelve-month period. Measurements were completed in 11,319 homes and concentrations in the range 10 to 1924 Bq/m<sup>3</sup> were found with an average value of 89 Bq/m<sup>3</sup>. This survey estimated that approximately 91,000 homes, representing 7% of total housing stock, have average indoor radon concentrations in excess of 200 Bq/m<sup>3</sup>.

The results of the survey were used to predict the percentage of homes in each grid square with radon concentrations in excess of the 200 Bq/m<sup>3</sup> Reference Level. Maps showing these predictions have been produced and published (see [www.rpii.ie](http://www.rpii.ie)). A grid square with 10% or more of homes predicted to exceed the Reference Level is designated a High Radon Area. Preliminary surveys of radon concentrations in schools indicated that high concentrations of radon gas were found in individual classrooms within schools and that there can be considerable variability in the radon concentration from room to room [McGarry, 1996]. These results, together with results from the National Radon Survey, suggest that schools in many areas throughout the country are likely to have radon concentrations in excess of 200 Bq/m<sup>3</sup>.

In 1998 the RPII was commissioned by the Department of Education and Science (DES) to survey radon in all primary and post-primary schools in the Republic of Ireland. The objective of the study was to identify schools with radon concentrations greater than 200 Bq/m<sup>3</sup> in any ground floor office or classroom so that remedial work to reduce concentrations could be undertaken. Following completion of the first set of measurements in June 1999, the DES commenced an on-going programme to remediate all affected schools as they were identified.

In May 2000 new legislation was introduced in Ireland covering exposure to radon and other natural radiation sources in the workplace. These Regulations are included in Statutory Instrument No. 125 of 2000 which sets down a national Reference Level for workplaces of 400 Bq/m<sup>3</sup> averaged over any three-month period [Stationery Office, 2000]. Where the workplace radon concentration exceeds this Reference Level, the employer must carry out an evaluation to determine if measures should be taken to reduce workers' exposure to radon. In September 2003, the Health and Safety Authority stated that, in order to comply with the Safety, Health and Welfare at Work Act, 1989, [Stationery Office, 1989] all indoor workplaces in High Radon Areas must be measured for radon [HSA, 2003].

Schools are workplaces and therefore come under the scope of Statutory Instrument No. 125 of 2000 should radon concentrations exceed 400 Bq/m<sup>3</sup>. In order to provide additional protection to children while in school, the RPII has advised that remedial work should be undertaken to reduce exposure to radon where an occupied classroom was found to have radon concentrations above 200 Bq/m<sup>3</sup>. The annual radiation dose resulting from exposure to an average radon concentration of 200 Bq/m<sup>3</sup> during a typical school year is approximately 1 millisievert (mSv).

## 2. SURVEY METHODOLOGY

At the commencement of the survey contact details of all schools in the Free Education System were supplied by the DES to the RPII. There are approximately 4000 such schools throughout the country, ranging in size from small rural two teacher primary schools to large post-primary schools catering for more than one thousand students. The survey was carried out on a phased basis from 1998 to 2002. Throughout the second and third year of the survey, schools that did not complete the survey in years one and two were given a further opportunity to participate.

A small number of additional schools that did not complete, or were not included in, the original survey were tested from September 2001 to June 2002. The reasons for failure to participate in the original survey included failure to respond to the invitation letter, loss of detectors during the measurement period or inability to participate due to structural repairs being carried out in the school at the time. The results of radon measurements made in these schools have also been included in this report.

During the first year of the survey schools in the East of the country excluding Dublin were tested. The following year schools in Dublin, the midlands and the Northwest were tested, while schools in the South and West of the country were tested during the final year.

School radon surveys were carried out over a nine-month period coinciding with the academic year i.e. from September to May/June of the following year. In April preceding the start of the survey, schools were sent details of the survey, a radon information leaflet and an application form. Schools were informed at this stage that, in the event of high radon concentrations being detected, the DES would fund remedial work. Schools were requested to send back completed application forms before the end of June in order to be included in the survey commencing the following September. The information sought from the schools included the number of ground floor classrooms and ground floor offices/assembly areas to be tested, a contact person in the school who would take responsibility to place and remove the detectors and details of whether any previous measurements or remedial work had ever been carried out at the school. A copy of the application form is given in Appendix 1.

In early September participating schools were issued with one detector for each room in which a radon measurement was to be made. The radon detectors used in this survey are passive alpha track-etch detectors consisting of a two part polypropylene holder and a CR-39 (polyallyl diglycol carbonate) detection plastic. Full instructions on the placement of detectors were given to each school. Instructions for the return of the detectors were sent to schools towards the end of the academic year. Further details of the detector type used in this survey, its processing and the quality control procedures used are given in Fennell *et al.* [2002]. All analyses were carried out by the radon measurement service of the RPII which is accredited by the Irish National Accreditation Board to ISO 17025 standard.

Results were issued to each school only when all detectors from the relevant phase were processed. Schools with results below 200 Bq/m<sup>3</sup> were advised that no further action was necessary. Schools with results greater than 200 Bq/m<sup>3</sup> were advised that remedial work would be arranged by the DES. Copies of individual results for all schools were sent to the DES.

### 3. RESULTS

The RPII issued an invitation to participate to 4072 schools in the Free Education System. Of these, 3798 schools responded positively and were sent detectors and radon measurements were subsequently completed in 3444 schools.

**Figure 1**

**Distribution of Maximum Radon Concentrations in Irish Schools**

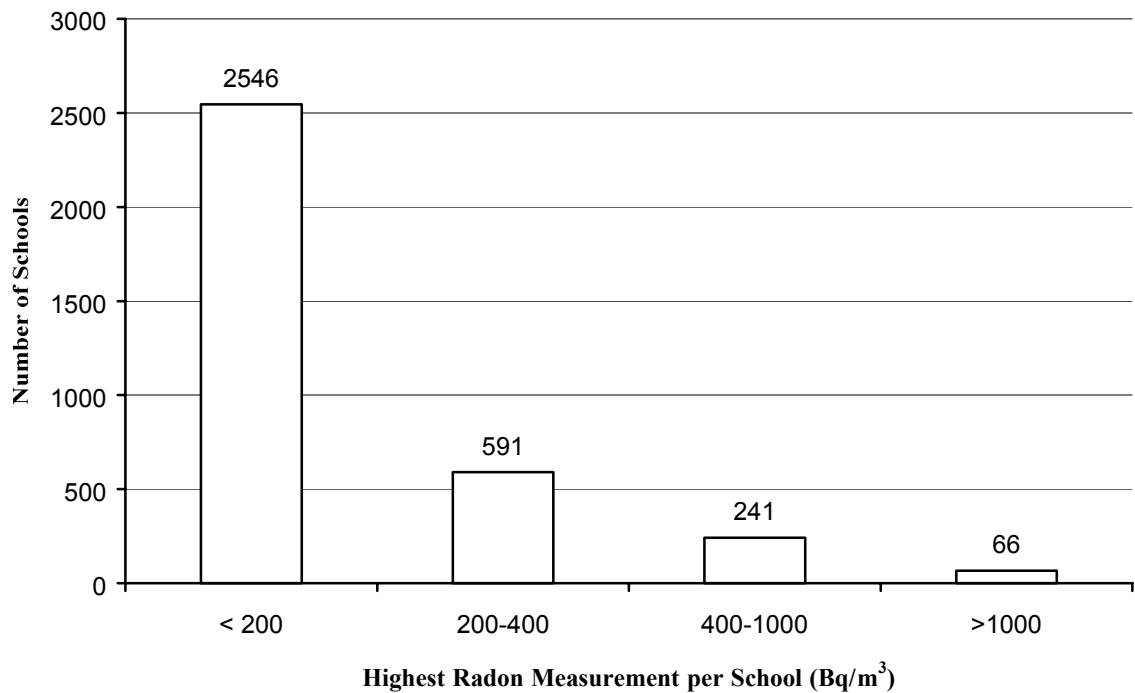


Figure 1 shows the distribution of maximum radon concentration in all schools while Table 1 summarises the results obtained by school type. There were 898 schools in which one or more rooms had radon concentrations above 200 Bq/m<sup>3</sup>. Of these, 591 had maximum radon concentrations between 200 and 400 Bq/m<sup>3</sup>, 241 had maximum radon concentrations between 400 and 1000 Bq/m<sup>3</sup> while 66 had radon concentrations greater than 1000 Bq/m<sup>3</sup> in one or more rooms. A total of 307 schools, or 9% of those measured, had radon concentrations in one or more rooms above the workplace Reference Level of 400 Bq/m<sup>3</sup>. The average radon concentration of 93 Bq/m<sup>3</sup> calculated from the survey data is not dissimilar to the mean concentration of 89 Bq/m<sup>3</sup> for Irish homes [Fennell *et al.*, 2002].

**Table 1**  
**Summary of School Radon Results**

| School Type  | Number of Schools | Bq/m <sup>3</sup> |                    |                |                              |            |
|--------------|-------------------|-------------------|--------------------|----------------|------------------------------|------------|
|              |                   | Arithmetic Mean   | Standard Deviation | Geometric Mean | Geometric Standard Deviation | Max. Conc. |
| Primary      | 2842              | 97                | 125                | 65             | 2.2                          | 2748       |
| Post-Primary | 602               | 86                | 162                | 54             | 2.4                          | 4948       |
| All schools  | 3444              | 93                | 140                | 62             | 2.3                          | 4948       |

The shape of the distribution of *radon concentration* versus *number of schools* follows a lognormal distribution. A lognormal distribution is one that has many more lower values than higher values i.e. the values of the parameter being measured, in this case radon concentration, are not evenly distributed around a central value. The ‘geometric mean’ provides a measure of the average value of this type of distribution, whereas, the ‘arithmetic mean’ is the average value of the individual measurements. The ‘geometric standard deviation’ and ‘standard deviation’ measure the spread of values around the geometric and arithmetic means respectively.

The results of the survey, summarised by county, are presented in Table 2. The mean radon concentration in occupied ground floor rooms varied from 52 Bq/m<sup>3</sup> in Laois schools to 153 Bq/m<sup>3</sup> in schools in Kerry. The county with the highest proportion of schools with radon concentrations above 200 Bq/m<sup>3</sup> is Galway, with 110 schools, or 43% of those measured. By comparison, in Leitrim only two schools out of a total of 42 measured have radon concentrations above 200 Bq/m<sup>3</sup>. In 18 counties schools were identified with radon concentrations in excess of 1000 Bq/m<sup>3</sup>.

**Table 2**  
**Summary of School Radon Results by County**

|                  |                               |   |  | <b>No of Schools with Radon Levels in One or More Rooms in Excess of the Stated Value</b> |                               |                                |   |
|------------------|-------------------------------|---|--|---|-------------------------------|--------------------------------|---|
| <b>County</b>    | <b>No of Schools Measured</b> | <b>Arithmetic Mean (Bq/m<sup>3</sup>)</b> | <b>Geometric Mean (Bq/m<sup>3</sup>)</b> | <b>200 (Bq/m<sup>3</sup>)</b>   | <b>400 (Bq/m<sup>3</sup>)</b> | <b>1000 (Bq/m<sup>3</sup>)</b> | <b>Maximum Concentration (Bq/m<sup>3</sup>)</b> |
| <b>Carlow</b>    | 51                            | 91  | 71                                       | 18  | 4                             | 0                              | 696   |
| <b>Cavan</b>     | 87                            | 86  | 43                                       | 5   | 2                             | 1                              | 2689  |
| <b>Clare</b>     | 116                           | 88  | 58                                       | 21  | 9                             | 1                              | 1722  |
| <b>Cork</b>      | 390                           | 122                                       | 82                                       | 147   | 64                            | 14                             | 1921  |
| <b>Donegal</b>   | 166                           | 89  | 64                                       | 38  | 9                             | 2                              | 1673  |
| <b>Dublin</b>    | 499                           | 64  | 48                                       | 108   | 20                            | 4                              | 1390  |
| <b>Galway</b>    | 253                           | 152                                       | 98                                       | 110   | 44                            | 11                             | 2227  |
| <b>Kerry</b>     | 161                           | 153                                       | 82                                       | 36  | 16                            | 7                              | 3848  |
| <b>Kildare</b>   | 115                           | 65  | 49                                       | 21  | 6                             | 2                              | 1155  |
| <b>Kilkenny</b>  | 91                            | 100                                       | 72                                       | 28  | 12                            | 1                              | 1512  |
| <b>Laois</b>     | 62                            | 52  | 44                                       | 6   | 0                             | 0                              | 399   |
| <b>Leitrim</b>   | 42                            | 69  | 50                                       | 2   | 2                             | 1                              | 1688  |
| <b>Limerick</b>  | 148                           | 73  | 53                                       | 29  | 6                             | 0                              | 820   |
| <b>Longford</b>  | 49                            | 84  | 62                                       | 10  | 1                             | 0                              | 456   |
| <b>Louth</b>     | 83                            | 84  | 58                                       | 18  | 8                             | 1                              | 1121  |
| <b>Mayo</b>      | 178                           | 140                                       | 86                                       | 52  | 24                            | 8                              | 1952  |
| <b>Meath</b>     | 113                           | 87  | 62                                       | 27  | 9                             | 1                              | 1262  |
| <b>Monaghan</b>  | 67                            | 54  | 40                                       | 7   | 1                             | 0                              | 493   |
| <b>Offaly</b>    | 67                            | 67  | 54                                       | 16  | 1                             | 0                              | 460   |
| <b>Roscommon</b> | 84                            | 104                                       | 70                                       | 23  | 6                             | 2                              | 1690  |
| <b>Sligo</b>     | 73                            | 77  | 50                                       | 14  | 5                             | 1                              | 2002  |
| <b>Tipperary</b> | 168                           | 94  | 68                                       | 33  | 14                            | 4                              | 2748  |
| <b>Waterford</b> | 88                            | 134                                       | 87                                       | 33  | 13                            | 3                              | 4948  |
| <b>Westmeath</b> | 82                            | 68  | 50                                       | 16  | 2                             | 0                              | 452   |
| <b>Wexford</b>   | 111                           | 115                                       | 79                                       | 41  | 17                            | 2                              | 2628  |
| <b>Wicklow</b>   | 100                           | 97  | 73                                       | 39  | 12                            | 0                              | 900   |

In all surveys of this type it is inevitable that a certain percentage of detectors issued to schools will not be returned for processing. The main reasons given for the non-return of detectors are failure to receive the detectors, failure to place the detectors at the start of the survey and loss of the detectors during the course of the survey. Figure 2 shows the number of detectors issued during each phase of the survey. The detector return rate was greater than 70% for all three phases. In total, 75% of all detectors issued to schools were returned to the RPII for processing. Radon measurements were carried out in 85% of schools that were invited to participate and 91% of schools that responded to the invitation to participate in the survey.

**Figure 2**  
**Detectors Issued and Measurements Completed**

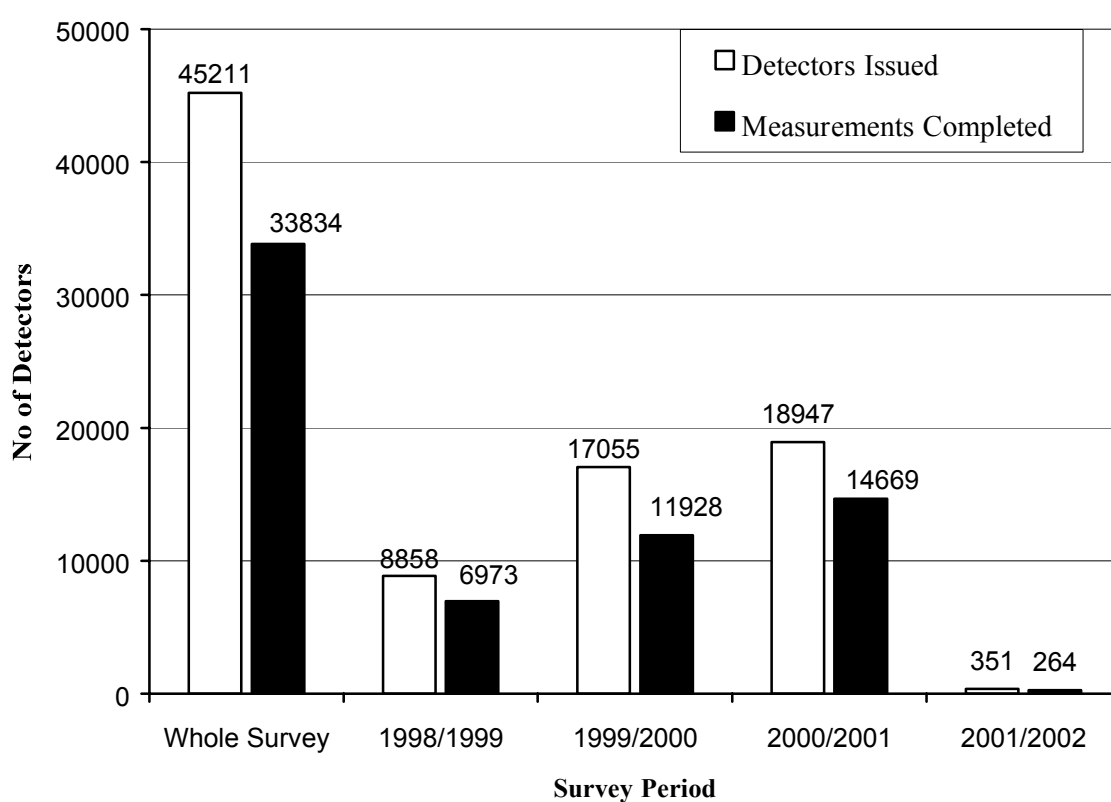


Figure 3 shows the distribution of schools with radon concentrations in excess of 400 and 1000 Bq/m<sup>3</sup>. It can be seen that certain parts of the country, most notably Dublin, Cork and Galway cities, have the highest numbers of schools with radon concentrations above 400 Bq/m<sup>3</sup> whereas only a small number of schools with radon concentrations above 400 Bq/m<sup>3</sup> are found in the midlands. This survey is essentially a population weighted survey and one would expect to find schools with high radon concentrations in the larger population centres such as Cork and Dublin, even though these cities are not classified as High Radon Areas in the National Radon Survey. However, a large percentage of schools with high radon concentrations have been identified in the Northwest and Southeast of the country, an observation that is consistent with the classification of these areas as High Radon Areas.

**Figure 3**

**Distribution of Schools with Radon Concentrations above 400 Bq/m<sup>3</sup>**



#### 4. REMEDIATION STRATEGY

In 2000 soon after the results from the first year of the survey became available, remedial work commenced in schools with radon concentrations above 200 Bq/m<sup>3</sup>. Where practicable, schools with the highest radon concentrations were remediated first.

Two different remediation strategies were adopted depending on the radon concentrations measured in the school. Passive systems, primarily in the form of wall vents designed to provide increased permanent background ventilation were installed in schools with maximum radon concentrations in the range 200 to 400 Bq/m<sup>3</sup>. This approach was adopted following a DES-commissioned study by the UK Building Research Establishment of ventilation rates in 10 Irish schools with radon concentrations in this range [BRE, 2001]. In all 10 schools, the existing ventilation rates were found to be below accepted standards and the study concluded that increasing the ventilation rate by installing vents could help to reduce the accumulation of radon. A DES circular [DES, 2001] giving technical details of the work to be carried out was circulated to all 591 schools in this category. Schools were paid a grant of €191 (£150) towards the cost of installing a vent in each room in which the radon concentration needed to be reduced.

Schools with radon concentrations in excess of 400 Bq/m<sup>3</sup> were remediated by the installation of active systems, normally in the form of a sump. Where this was not practical, mechanically assisted under-floor ventilation was installed. Site visits by a remediation consultant were made to each affected school and a remedial system specific to each was designed. The Board of Management of the school then secured the services of suitably qualified personnel to carry out the remedial works specified by the consultant. A small number of schools in this category with radon concentrations marginally in excess of 400 Bq/m<sup>3</sup> had extra permanent background ventilation systems installed as described earlier.

Following the completion of remedial works, further radon measurements were carried out to determine if the remediation had been effective. In circumstances where additional ventilation was the specified remediation strategy, schools were requested to directly contact the RPII for a post remediation measurement. In schools where sumps or under-floor ventilation were installed, the DES, on receipt of documentation that remedial work had been completed, contacted the RPII requesting post remediation measurements.

The measurement protocol for schools with active systems was to measure radon in all occupied ground floor rooms for a continuous three-month period. In schools with vents a longer measurement period of nine months (one full academic year) was decided upon; however only the room in which the vent was installed was surveyed. The differences in the measurement protocol were deemed necessary as active and passive systems operate differently in the way they reduce indoor radon concentrations.

A three-month measurement period was considered sufficient for schools with active systems as under such controlled conditions radon concentrations are unlikely to show any significant seasonal variations. Because the initial radon concentrations were often very high, it was also desirable to obtain a measurement as quickly as possible in order to assess the effectiveness of the measures taken and if necessary to carry out further remediation. It was anticipated that a sump system could affect the radon concentration not only in the room(s) in which the radon concentration needed to be reduced but also in a number of adjacent rooms. While one would anticipate that the effect of a sump would be to reduce radon concentrations in adjoining

rooms, it cannot be ruled out that in a small number of cases radon concentrations may be increased. For this reason it was decided to re-measure radon in all occupied ground floor rooms in schools where active systems were installed.

In schools where the remedial action taken was increased ventilation, a nine-month measurement period was adopted because radon concentrations would be expected to exhibit a greater seasonal variability than in the case of active systems. Furthermore, prior to remediation the radon concentrations were, in most cases, less than 400 Bq/m<sup>3</sup> so that there was less urgency in quickly assessing the effectiveness of the remedial measures. It was not necessary to measure radon in all occupied ground floor rooms as vents would only be expected to affect the radon concentration in the room in which they were installed.

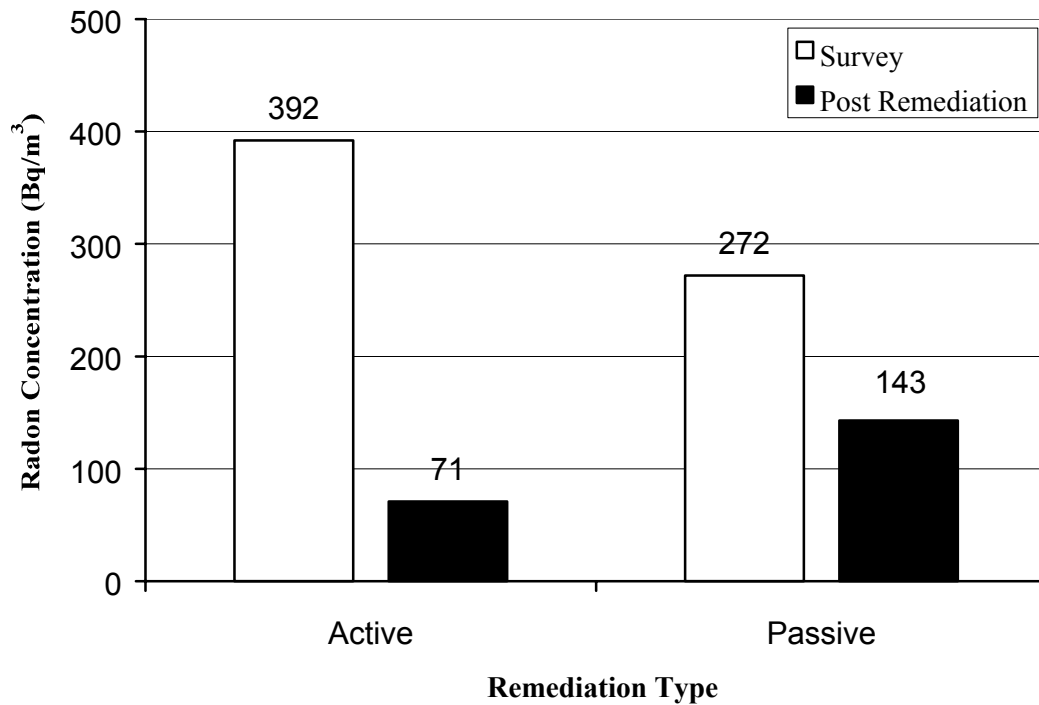
As in the initial survey, passive diffusion track-etch CR-39 detectors were used for all post-remediation measurements and individual results were sent to both the school and to the DES.

To date the RPII has completed post-remediation measurements in 208 schools (Figure 4 and Table 3). In most cases, post-remediation test results indicate that the remedial measures taken are effective in reducing the concentrations of indoor radon as shown in Figure 4 where the average post-remediation radon concentrations in rooms where remedial work was undertaken was significantly lower compared to corresponding levels in the original survey. The average reduction in radon concentrations for active systems is 5.5 (82%) and the corresponding figure for passive systems is 1.9 (47%). These reductions were verified statistically ( $p < 0.001$ ) by performing a one tailed paired t-test on the reductions exhibited by both remediation systems.

Active mitigation systems, principally radon sumps, have been installed in a further 93 schools and post-remediation measurements will be completed during the 2003-2004 school year.

For both active and passive remediation, instances have arisen where the desired reduction in radon concentrations has not been achieved. Data from Table 3 show that, following remediation, 64 of the 208 schools still have radon concentrations above 200 Bq/m<sup>3</sup> and 12 of these schools have concentrations above 400 Bq/m<sup>3</sup> in one or more classrooms. In instances where, following remediation, the radon concentration is in the range 200 to 400 Bq/m<sup>3</sup>, there is no legal requirement to further reduce the radon concentration. Consequently, additional remediation work is not recommended unless a further reduction in radon concentration can be achieved at minimal cost. The radon concentration must always be reduced below the workplace Reference Level of 400 Bq/m<sup>3</sup>.

**Figure 4**  
**Average pre- and post-Remediation Radon Concentrations**  
**in Remediated Schools**



**Table 3**  
**Status Summary of Post-Remediation Survey**

| Proposed remedial system | Number of Schools |   |   |   |
|--------------------------|-------------------|---|---|---|
|                          | Total             | Completed post-remediation measurements | One or more rooms 200 - 400 Bq/m <sup>3</sup> | One or more rooms > 400 Bq/m <sup>3</sup> |
| Active                   | 307               | 100                                     | 18  | 10  |
| Passive                  | 591               | 108                                     | 34  | 2   |
| <b>Total</b>             | 898               | 208                                     | 52  | 12  |

## 5. CONCLUSIONS AND RECOMMENDATIONS

- Radon measurements have been carried out in approximately 33,834 ground floor classrooms and offices in 3444 schools. This represents approximately 85% of all Irish primary and post-primary schools. Work to remediate schools with radon concentrations above 200 Bq/m<sup>3</sup> is on-going or has been successfully completed.
- This survey identified 898 schools with radon concentrations in one or more ground floor classrooms or offices above 200 Bq/m<sup>3</sup> and 66 of these had radon concentrations in excess of 1000 Bq/m<sup>3</sup>. Schools with radon concentrations above 200 Bq/m<sup>3</sup> were found in every county in Ireland and schools with radon concentrations exceeding 1000 Bq/m<sup>3</sup> were found in 18 counties. The average radon concentration in schools prior to any remedial works being carried out was 93 Bq/m<sup>3</sup>.
- The post-remediation test results available to date indicate that remedial measures undertaken are effective in reducing indoor radon concentrations. Post-remediation measurements have been completed in 208 schools. The average reduction factors in indoor radon concentrations for active (sumps and mechanically assisted under-floor ventilation) and passive (additional ventilation) systems are 5.5 (82%) and 1.9 (47%) respectively.
- Remedial measures carried out in 208 schools have successfully reduced the radon concentration to less than 400 Bq/m<sup>3</sup> in 196 schools and to less than 200 Bq/m<sup>3</sup> in 144 schools. In the 52 schools where, following remediation, the radon concentration is in the range 200 to 400 Bq/m<sup>3</sup>, there is no legal requirement to further reduce the radon concentrations. Consequently, additional remediation work is not recommended unless a further reduction in radon concentration can be achieved at minimal cost. Radon concentrations in all rooms should always be reduced to below 400 Bq/m<sup>3</sup>.
- There are approximately 500 schools which to date have not had radon measurements carried out. At the request of the Department of Education and Science, the Radiological Protection Institute of Ireland has again contacted these schools and the importance of measuring the radon concentration in all occupied classrooms and offices has been stressed to their Principals. For those schools located in a High Radon Area, radon measurements are necessary in order to comply with health and safety legislation.
- A total of 591 schools have received grants from the Department of Education and Science to have passive mitigation systems in the form of additional ventilation installed. At the end of November 2003, post-remediation measurements had been completed in 108 schools, leaving a further 483 schools for which the effectiveness of the measures taken to reduce radon concentrations had not yet been evaluated. It is important that such measurements are carried out so that the effectiveness of increased ventilation in reducing indoor radon concentrations in each of these schools can be assessed.
- Active remediation systems in the form of sumps or mechanically assisted sub-floor ventilation have been installed in 193 schools and in 100 of these post-remediation measurements have been completed. The results of post-remediation measurements in the 93 schools in which remediation work has only recently been completed will be available by the end of the 2003-2004 school year.

- Remediation work to reduce radon concentrations is underway in the remaining 114 schools with radon concentrations above 400 Bq/m<sup>3</sup>. This work should be completed as quickly as possible so that the risks to staff and pupils can be reduced.
- In commissioning and funding the programme, the Department of Education and Science has invested significant amounts of money in its radon measurement and remediation programme. It is vital, therefore, that the sumps and ventilation systems that have been installed continue to operate effectively. A comprehensive maintenance and testing programme needs to be put in place for all mechanical components of the remediation systems. In addition, the Board of Management should ensure that adequate records of all remedial work, maintenance and testing are maintained.
- For those schools in which remedial works have been successfully completed, regular measurement of radon concentrations should be carried out in order to confirm the long-term efficacy of the remediation systems. It is recommended that retesting of active systems take place at intervals of three to five years. More frequent testing may be justified in situations where very high radon concentrations were initially present. Passive systems would only require retesting in the event of some material change to the room in question. The same measurement protocols as in the first round of post-remediation measurements should be applied.

## **6. ACKNOWLEDGEMENTS**

The authors acknowledge the assistance received from the officials of the Department of Education and Science and from the staff of the participating schools in carrying out this survey.

## 7. REFERENCES

BRE, 2001. **Ventilation Assessment for Schools in Southern Ireland with Moderate Radon Levels.** Report No: 210121, A Report Prepared for the Office of the Minister for Education and Science, Dublin Ireland. Building Research Establishment. Environment Division, Bucknalls Lane, Garston, Watford WD25 9XX.

DES, 2001. **Radon Mitigation for Schools with a Maximum Average Level of between 200 and 400 becquerels per cubic metre (Bq/m<sup>3</sup>) in One or More Rooms.** Circular letter M46/01. Department of Education and Science, Tullamore, Co Offaly.

Fennell, S.G, Mackin, G.M., Madden, J.S., McGarry, A.T., Duffy, J.T., O'Colmáin, M., Colgan, P.A. and Pollard, D. 2002. **Radon in Dwellings. The Irish National Radon Survey.** RPII-02/1, Dublin: Radiological Protection Institute of Ireland.

HSA, 2003. Personal Communication from Health and Safety Authority to Radiological Protection Institute of Ireland. 30<sup>th</sup> September 2003.

Madden, J.S., Duffy, J.T., Mackin, G.M., Colgan, P.A. and McGarry, A.T. 1994. **Radon in Selected Areas of Ireland.** RPII-94/3, Dublin: Radiological Protection Institute of Ireland.

McGarry, A.G., 1996. Practical Implications of Radon Regulation in Ireland. **Annales de l'Association Belge de Radioprotection**, 21, p. 29-37.

McLaughlin, J.P. and Wasiolek, P. 1988. Radon Levels in Irish Dwellings. **Radiation Protection Dosimetry**, 24, p. 383-386.

NRC 1999. **Health Effects of Exposure to Radon.** National Research Council Report, BEIR 6. National Academy Press, Washington, DC.

Stationery Office, 1989. **Safety, Health and Welfare at Work Act (No. 7 of 1989).** Department of Labour. Published by Government Publications Office, Molesworth St., Dublin 2.

Stationery Office, 2000. **Radiological Protection Act, 1991 (Ionising Radiation) Order. Statutory Instrument 125 of 2000.** Department of Public Enterprise. Published by Government Publications Office, Molesworth St., Dublin 2.

## Appendix 1

### Application Form for Schools Radon Measurement



**Radiological Protection Institute of Ireland**  
An Institiúid Éireannach um Chosaint Raideolaíoch

## School Radon Measurement

### Application Form

**Note:** a separate application form must be completed for primary and secondary schools.

|  |  |
|--|--|
| Roll Number:   | <input type="text"/>   |
| School Name:   | <input type="text"/>   |
| School Address:  | <input type="text"/><br><input type="text"/>   |
| School type:<br>(tick box as applicable)   | <input type="checkbox"/> Primary <input type="checkbox"/> Secondary <input type="checkbox"/> Vocational <input type="checkbox"/> Community <input type="text"/> Other (please specify) |
| Contact Name:  | <input type="text"/><br><small>The contact person will take responsibility for placing and retrieving detectors, record keeping etc.</small>   |
| Contact Address:<br>(if different from the school address)   | <input type="text"/><br><input type="text"/>   |
| Telephone Number: (include area code)  | <input type="text"/> <input type="text"/>  |
| Fax Number: (include area code)  | <input type="text"/> <input type="text"/>  |
| Email Address: (if applicable)   | <input type="text"/>   |
| Number of Ground Floor Classrooms:<br>(include science and language laboratories, craft rooms etc.)  | <input type="text"/>   |
| Number of Ground Floor Offices:<br>(include staff room, career guidance rooms, libraries etc.)   | <input type="text"/>   |
| <b>Note:</b> Areas such as toilets, hallways, stairwells, storage rooms etc. do not need to be tested. Also, prefabs do not need to be measured as they are raised above ground level. |  |
| Have you ever had radon measurements carried out in your school?   | <input type="checkbox"/> Yes <input type="checkbox"/> No   |
| If yes, when were they carried out (Year):   | <input type="text" value="19"/> <input type="text"/>   |
| Have you ever had remediation work carried out in your school to reduce radon levels?  | <input type="checkbox"/> Yes <input type="checkbox"/> No   |
| Signature:   | <input type="text"/>   |
| Position:  | <input type="text"/>   |
| Date:  | <input type="text"/> / <input type="text"/> / <input type="text"/>   |

If you have any queries regarding the completion of this form, or if you require further information, please contact the Radon Department, Radiological Protection Institute of Ireland on FREEPHONE RADON 1800 300 600.

This application form should be completed and returned to the RPII as soon as possible to ensure that detectors will be issued at the beginning of September.

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