THE COST-EFFECTIVENESS OF RADON REMEDIATION IN SCHOOLS

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INTRODUCTION

Radon remediation in schools was identified early on as a potential priority for governments. The exposure reduction attributable to schools remediation can be substantial (1). Epidemiological and technical radon research has produced information which has enabled attention to be turned to specific effectiveness questions regarding radon identification and remediation programmes in buildings, including schools. Decision making about policy implementation has been an integral part of these programmes and questions have been raised about the economic implications of the regulations (2-5). Very few attempts to answer the economic questions related to proposed and adopted policies for schools remediation have been made, though several authors have suggested possible hypotheses (6).

Radon as a health hazard in schools has been explored in previous studies in Jordan, Israel, Italy, the Slovak Republic and the United Kingdom (1,6). Only the study by Denman and Phillips attempts to answer some of the economic questions posed by decision makers. However, no study to date has estimated the cost-effectiveness of a radon remediation programme for schools using the methodological framework now considered appropriate in the economic evaluation of health interventions (7,8). It is imperative that this should be done, in order that the resources required to obtain health gain from radon remediation in schools can be systematically compared with equivalent data for other health interventions and radon remediation programmes.

In this study a cost-effectiveness analysis of radon remediation in schools was undertaken, using the best available national data and information from Northamptonshire on the costs and effectiveness of radon identification and remediation in schools, and the costs and health impact of lung cancer cases. The overall model presented in this study is generalisable to any collection of schools within a radon affected area, by applying the appropriate regional parameters. These results should help to inform further discussion of policies towards radon remediation in various settings. (For a more detailed discussion see (11)).

METHODS

The goal of the remediation programme was a reduction in radon exposure and corresponding decrease in the number of radon-induced lung cancer cases. Radon exposure was translated into lung cancer cases using lifetime risk estimates derived from relative risk estimates in published epidemiological data (12,13). Outcomes were defined in terms of the survival gain from averting radon-induced lung cancer cases, and expressed in life-years gained. The survival gain was estimated using life expectancy data from cancer registries (1992) and national life tables from the Office of National Statistics (1997). The incremental cost-effectiveness of a remediation programme versus no programme was then calculated as the ratio of net change in cost to net change in outcome.

The net cost of radon remediation was calculated by obtaining information on the cost of identifying rooms over the action level, the capital, maintenance and running costs of remedial work, and the treatment costs of lung cancer cases. The initial programme costs, including all measurement and remediation costs were assumed to have been incurred between 1993 and 1996, with corrections made for inflation as appropriate. No value added tax (VAT) was charged on the remediation work.

Uncertainty surrounding the main parameters used in the study was handled by reporting standard deviations around treatment costs, and by varying key parameters within plausible bounds in sensitivity analyses. A one-way sensitivity analysis was undertaken. Probabilities surrounding uncertain parameters were not available to carry out probabilistic sensitivity analysis (14).
All costs and outcomes were expressed in present values by applying a 6% annual discount rate to future costs and outcomes, as currently recommended in the UK (15). Costs are expressed in 1997£'s UK prices. The time horizon for the valuation of costs and outcomes was 40 years, based on the anticipated life expectancy of the remediation and the mean manifestation period (full expression of pulmonary malignancy after initial exposure to Rn decay products is expected at 40 years (see (11) for reference details).

Data
In 1992 the Northamptonshire County Council began a radon survey of all schools in its care and subsequently identified and remediated affected rooms, most of which were above the Action Level of 400 Bqm$^{-1}$ (for a more detailed description of the programme see (1,11)).

Radon Identification Costs
The unit cost of measuring radon levels per room is estimated as £15, based on the delivery, removal, reading and reporting from one track etch detector in each room for three months (10). Detailed information was available on the 2371 rooms which were measured in 348 schools, of which 81 rooms were subsequently remediated. The total cost of identification was £35,565. Follow-up detectors for remediated rooms, to assess the effectiveness of the remedial action, increases the total cost to £36,780.

Remedial Work
The total capital cost of installing fans or other remedial work in the identified rooms was £44,358. Maintenance and running costs, including electricity to run fans, spare parts and repairs and fan replacements every 10 years, were £34,183 (discounted at 6%). The total cost of remedial work was therefore £78,541. The total cost figure was £115,321.

Lung cancer treatment
Published costings for treating lung cancer cases are rare and the costs used in this study were generated using the method outlined in (17). As current epidemiology is inadequate to discriminate between radon-induced small cell and non small cell lung cancers, a combined cost estimate is calculated. The Northamptonshire combined estimate was chosen as it relates to the same geographical area as the remediation programme.

Lung cancer risk from radon exposure
The magnitude of the risk of lung cancer from residential radon exposure is currently debated, especially that for childhood exposure. The NRPB currently estimates the lifetime risk of lung cancer for a person per working level month (WLM) as 3.5x10$^{-4}$ for each year of exposure (12,13), where 1.26x10$^6$ Bq m$^{-3}$ h = 1 WLM (10). This conversion figure is used in the current study. (Studies are currently underway to pool European and North American indoor radon risk estimates for lung cancer, which will provide potentially more precise and robust estimates (18)).

The NRPB lifetime risk estimate is derived by applying UK population lung cancer and life tables figures to the relative risks of radon-induced lung cancer reported in the International Commission on Radiological Protection (ICRP) report (12). The report highlights the many uncertainties surrounding the estimates, particularly concerning the effect of age at exposure. For children under the age of 20 years, the relative risk may be a factor of two or three times higher than that of adults (ICRP 1987). (See (11) for a more detailed discussion).

Benefits Stream Profile over Time
There are several different ways of loading the life years into the model and three of these are explored in this study. For the baseline, the life years gained are assumed to be equally distributed over the last fifteen years of the 40-year time horizon of the analysis (Y25 to Y40). This figure is then discounted at a 6% rate.

Life Years Gained per lung cancer case
The number of life years lost per lung cancer death was then calculated using the Office of National Statistics 1991 life tables to estimate remaining years of life expectancy in the general population. The average number of life years lost due to premature mortality from lung cancer was estimated as 13.51 years per case. This is very close to an estimate of 13.5 years by the ICRP (19) and is used elsewhere (17,19).
RESULTS

Costs

The net cost of the radon programme consists of initial and follow-up detectors at a cost of £36,780; remedial work and discounted running and replacement costs totalling £78,541 minus discounted averted costs of the 6.62 lung cancer cases of £6,973 per case, which equals £7,280. The net cost (where appropriate figures are discounted at 6% per annum over 40 years), is therefore £108,041.

Outcomes

The total number of people exposed in the affected school rooms was 1990, with 170 staff and 1820 pupils. The annual total per person reduction in radon achieved by the remediation work was $3.0 \times 10^5$ Bq m$^{-3}$ h (or 0.23 WLM), as the occupants spend an average of 4.84 hours per day in the rooms, for 190 days per year (a daytime equivalence factor of 0.64 was chosen (see(1))). This total dose reduction translates into 0.1656 cases of lung cancer averted per year, equivalent to 6.62 cases over 40 years. A total of 90 life years were gained from these averted lung cancer cases. This figure, discounted at a 6% rate and where the life years are evenly distributed over the last 15 years of the horizon, equals 14.31 life-years.

Cost-effectiveness

Combining the cost and outcome results reported above, the incremental cost per life-year gained of a residential radon remediation programme compared to no programme is £7,550 (rounded from £7551.36).

Sensitivity Analysis

A one-way sensitivity analysis was undertaken with the data. This involved varying each uncertain component of the evaluation individually, while keeping the baseline parameter values for all the other components the same. See (11) for the results from the one-way sensitivity analysis of eight parameters and assumptions, showing the resulting cost-effectiveness ratio as the parameter values are reset at plausible maxima and minima.

It is clear that the cost-effectiveness ratio is most sensitive to changes in the average capital cost of remediation, the discount rate chosen for the life years, and the lifetime risk of lung cancer. The cost-effectiveness ratio is also sensitive to changes in the assumptions concerning life years benefit streams (the time over which the life years are gained). Varying the discount rate applied to averted costs has little effect on the results. The ratio is more sensitive to the choice of discount rate for running and replacement costs. Varying the estimated average cost of treating lung cancer or percent of rooms remediated have little effect on the cost-effectiveness results.

The uncertainty surrounding the lifetime risks for childhood exposure are also dealt with in the sensitivity analysis. The minimum value of parameter chosen is half the current risk estimate and the maximum value of parameter chosen reflects a trebling in the current risk estimate to reflect the largest estimate increase for childhood exposure hypothesised in the literature (12).

DISCUSSION

To date no study has estimated the cost-effectiveness of a radon remediation programme in schools using an appropriate methodological framework for evaluating health interventions. In this study, the cost-effectiveness of radon remediation programmes in schools was calculated.

General information on the average costs of remediation and potential savings to the health care system will be helpful as increasing numbers of local authorities around Europe start planning remediation programmes for the schools under their care. The model used in this analysis of Northamptonshire data can be generalised to any other area, and alternative regional parameter estimates can be substituted if these are available. As the sensitivity analysis indicates, however, remediation is likely to prove cost-effective even if these parameter estimates are substantially different.

This study highlights the need for the evaluation of other schools' remediation-based radon-induced lung cancer prevention programmes in other countries using similar methodological techniques.

By evaluating the radon remediation programme in similar terms to other health interventions,
comparisons can be made based on outcomes and costs per life year gained. If the same methodology is adopted for schools as in another study of residential homes, the cost-effectiveness ratio of £2,710 per life year gained observed in this study of schools (assuming that the life years are equally distributed over the 40 year horizon), remediation is much lower than that observed for a residential programme to remediate existing residential properties in the same area, at £13,250 (17). Even the ratio of £7,550 per life year gained reported in this study (assuming life years are evenly distributed over the last 15 years of the 40 year time horizon) compares favourably to many other cost-effectiveness ratios reported in published studies of health care interventions in the United Kingdom up to 1996 by falling between the fifth and sixth deciles of all published results (20).

Although the technical and epidemiological research surrounding radon remediation has progressed steadily in the last two decades, its recognition as an environmental and public health issue has lagged. Potential health gains from exposure reduction have not yet been achieved. One way for this to be remedied is to describe radon remediation interventions in a context which allows them to be compared in terms of health outcomes/effectiveness and resource requirements to other public health interventions. It is imperative that this should be done in order that the resources required to obtain health gain from radon remediation in schools can be systematically compared with equivalent data for other health interventions and radon remediation programmes. This forms a part of the wider goal of evaluating health and safety and environmental health interventions in the same way as other public health interventions are now routinely evaluated.

When compared to other lung cancer prevention programmes such as smoking cessation programmes, the cost-effectiveness ratio of schools remediation appears less impressive. The most recent cost-effectiveness ratios published for smoking cessation programmes in the United Kingdom ranged from £212 to £873 per discounted life year gained in £1997 (21). (And these studies did not compute averted treatment costs, which will reduce the ratios even farther). It will be important to compare the cost-effectiveness ratios from school-based anti-smoking programmes with schools-based radon remediation when figures become available.

Future advances in the area of childhood exposure and radon risk estimates will allow more precision in the evaluation of such programmes.

Two other types of economic evaluation are available to examine the resource allocation issues present in radon remediation policy. They are cost-utility analysis (CUA) and cost-benefit analysis (CBA). Most economic analyses of health interventions in the last 30 years have been either CEAs or CUAs. CUA is an economic evaluation tool similar to CEA, however, the outcomes are measured in two dimensions: quantity and quality of life years gained (8). The application of CUA to radon remediation is rendered difficult at present due to the lack of radon-induced lung cancer quality of life estimates.

CBA is recognised throughout the literature as the ‘gold standard’ for economic evaluations (7). However, most practitioners have shied away from undertaking CBAs because of their very strict data requirements and implicit assumptions, including the valuation of outcomes in the same terms as the numerator (money). Nevertheless, techniques for the valuation of outcomes have been strengthened more recently in consequence of their application to environmental health problems. CBA could in principle be applied to radon remediation evaluations and two valuation studies are currently underway by the author that will provide the outcome valuations needed to undertake CBAs of radon remediation policy alternatives. This will provide an opportunity to compare cost-benefit results with the cost-effectiveness results reported here.

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REFERENCES

2. Wrixon, A. D., Green, B. M. R., Lomas, P. R., Miles, J. C. H., Cliff, K. D., Francis, E. A., Driscoll, C. M. H., James, A. C., and O’Riordan, M. Natural Radiation Exposure in UK Dwellings. NRPB-R190. London,
HMSO. (1988).