## Research Article

# Preliminary Investigation on Radon Levels in Local Dwellings

**Ian Mifsud,[1] Andrew J Amato-Gauci,[1] Lucianne Licari,[1] Michael Sammut.[2]**
1 ***Department of Public Health, 15 Merchants Str., Valletta, Malta.***
2 ***Department of Pathology, University of Malta Medical School, Guardamangia, Malta.***

**Summary** *Ionising radiation due to radon has been measured in local dwellings. The results indicate that radon levels are dependent on various factors including floor location, type of underlying geological formation and ventilation. Short term measurements were carried out in this survey. The measured values were within the safety limits recommended by WHO. The use of etched-track detectors has been recommended in order to assess the overall annual exposure.*

**Keywords:** natural radioactivity, radon, local dwellings

Natural radiation is the principal source of exposure to ionising radiation by the general public. The most important contributing factor to this form of radiation in European dwellings has been identified as radon and its radioactive decay products (NRPB, 1993).

| Organisation | Action level - Existing Dwellings | Action level - Future Dwellings |
|---|---|---|
| US - EPA | 150 | 150 |
| WHO | 200 | 200 |
| EU | 400 | 200 |
| ICRP | 200 - 600 | --- |

Table 1. Recommended intervention levels for radon gas in dwellings (Bq $m^{-3}$)(US - EPA: United States Environmental Protection Agency; WHO: World Health Organisation; EU: European Union; ICRP: International Commission on Radiation Protection).

Radon is a product of the radioactive decay process of uranium and thorium. There are three natural isotopes: radon-219, -220 and -222. Under normal circumstances radon-219 and radon-220 have a limited contribution to human exposure in indoor environments. This study restricts itself to radon-222 exposure.

Lung cancer cases have been attributed to radon's alpha emitting properties. However, there is still considerable scientific controversy over the relationship between radon levels and the risk of lung cancer (Bowie and Bowie, 1991; ICRP,1994; Pershagan et al, 1994). Much of the data gathered to assess the risk from indoor radon has been derived indirectly from studies of underground miners, experimental animal studies and cellular studies. Results of a meta-analysis of eight epidemiological surveys indicate that the risk from indoor radon can be predicted from miners (Lubin and Boice, 1997). Until extensive case-control studies are completed, data from miners remain the best source available.

Some health authorities have stated that the indirect evidence linking low levels of radon exposure to lung cancer is insufficient to warrant a remedial action level of 200 Bq $m^{-3}$ (annual average) accepted by various governments (Bowie and Bowie, 1991).

Estimates given in Table 2 indicate the lifetime risk of lung cancer potentially induced by radon (Bowie and Bowie, 1991). Such estimates suggest that where people are exposed to radon, smokers are more likely to be at risk of lung cancer than non-smokers, with a synergic effect being observed. The numerical estimates of this synergism are still uncertain (IARC, 1988).

| Radon level in Bq $m^{-3}$ | Smokers | Non-smokers |
|---|---|---|
| 20 | 10 in 1000 | 1 in 1000 |
| 100 | 50 in 1000 | 5 in 1000 |
| 200 | 100 in 1000 | 10 in 1000 |
| 400 | 200 in 1000 | 20 in 1000 |

Table 2. Estimated lifetime risk of lung cancer potentially induced by radon.

### Materials and methods

A pilot survey to determine the magnitude of radon levels in confined air spaces was carried out between June 1994 and November 1995. Measurements were carried out in 68 localities throughout Malta and Gozo. Sites were chosen from a list of selected acquaintances through the Health Protection Branch (Department of Public Health). Other than this, no particular bias was used in the selection of sites.

Air sampling was carried out by continuous method using 'alpha guard' - a portable electronic radon monitor. The variable measuring cycle period was set at 10 minutes for the duration of a 24 hour measuring period. At this short cycle setting, diurnal variation in radon levels was logged.

During the survey, besides location, the following parameters were also noted (1) ventilation (good or poor -

arbitrary scale based on the number and size of windows, doors and ventilators); (2) site (basement, ground floor, first floor or higher); and (3) underlying bedrock (based on geological maps - Globigerina or Coralline limestone; no attempt was made to further subdivide bedrock into the various strata).

**Results**

Radon measurements were expressed as time weighted averages (over 24 hour periods) in Bequerels per cubic metre (Bq $m^{-3}$). The arithmetic mean value for all sites was 55 Bq $m^{-3}$. The corresponding median value was 37.5 Bq $m^{-3}$. The lowest mean value was 10 Bq $m^{-3}$ and the highest value was 199 Bq $m^{-3}$. The computed geometric mean was 40 Bq $m^{-3}$ with a corresponding geometric standard deviation of 2.3.

Comparison of mean levels are shown in Tables 3, 4, and 5 (all values expressed in Bq $m^{-3}$).

| Underlying bedrock | Coral. (Malta) | Coral. (Gozo) | Glob. (Malta) | Glob. (Gozo) |
|---|---|---|---|---|
| Mean* ± SEM | 2.97 ± 0.21 | 3.88 ± 0.29 | 3.75 ± 0.12 | 4.31 ± 0.21 |
| Geomean | 19.49 | 48.42 | 42.52 | 74.44 |
| 95% confidence interval | 13 - 30 | 27 - 87 | 33 - 54 | 49 -113 |
| Number of readings | 13 | 6 | 41 | 8 |

Table 3. Variation in radon levels according to bedrock * values refer to logarithmic transformed data (Coral: Coralline limestone; Glob: Globigerina limestone).

| Floor level | Basement | Ground | First/ higher floors |
|---|---|---|---|
| Mean ± SEM | 4.64 ± 0.25 | 3.63 ± 0.12 | 3.20 ± 0.22 |
| Geomean | 103.54 | 37.71 | 24.53 |
| 95% confidence interval | 63 - 171 | 30 - 48 | 16 - 38 |
| Number of readings | 4 | 42 | 6 |

Table 4. Variation in radon levels according to floor location.

Significant differences ($p < 0.05$) were observed between measurements carried out on Coralline formations in Malta and other types of bedrock in Malta and Gozo.

Significant differences ($p < 0.05$) were observed between measurements taken in basements compared to measurements taken on other floors. No significant difference was observed when comparing ground floor readings to first/higher floor readings.

No significant difference was observed in rooms with poor ventilation when compared to others with good ventilation.

| Ventilation | Poor | Good |
|---|---|---|
| Mean ± SEM | 3.87 ± 0.19 | 3.56 ± 0.11 |
| Geomean | 47.94 | 35.16 |
| 95% confidence interval | 33 - 70 | 28 - 44 |
| Number of readings | 26 | 42 |

Table 5. Variation in radon levels according to degree of ventilation.

**Discussion**

Radon levels appear to depend on local geology as well as floor location. (The degree of ventilation was rated on an arbitrary scale. This may have led to discrepancies in the classification of rooms according to the degree of ventilation.) Measurements based on rate of air exchange would have been a better indicator than arbitrary assessments. However, ventilation does influence radon levels. Figure 1 shows the variation of radon in an office located on the third floor of the Medical School building in G'Mangia. Continuous measurements were taken over a seven day period. Lower radon levels were observed during office hours than after office hours when doors and windows were kept shut, resulting in lower rates of air-exchange. During weekends a further increase in radon levels was observed since windows and doors were kept closed for longer periods of time compared to working days, resulting in a further accumulation of radon.

Figure 2 shows readings carried out throughout the two islands (all measurements in Gozo were carried out on the ground floor). No specific factor was identified as responsible for the higher levels recorded in Gozo. Seasonal variations may be a contributing factor but other factors, such as the characteristics of local geology, may also be important.

During this survey, radon levels approximated a log-normal distribution. This is consistent with findings in surveys carried out in other European countries (EC, 1995). This characteristic can be used to estimate the percentage of housing stock above pre-determined threshold levels (NRPB, 1990).

Radon measurements showed diurnal variations. Although no data analysis was carried out on parameters related to diurnal changes (eg temperature, pressure), maximum radon levels were generally recorded during the early hours of the day. (Night time is normally associated with a decrease in human activity, thus lower rates of air exchange may occur during the night.) Other factors such as changes in atmospheric pressure may also have an effect on the diurnal variation of radon.

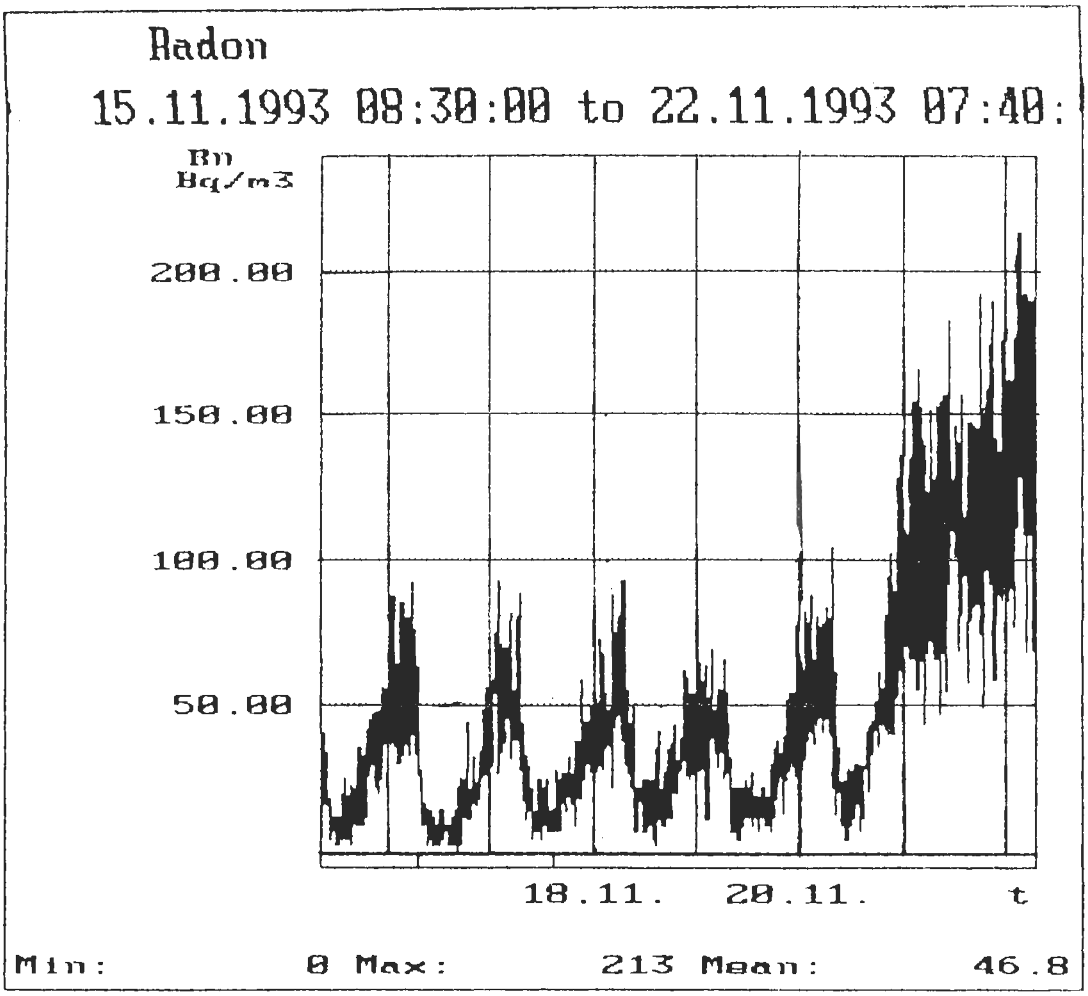
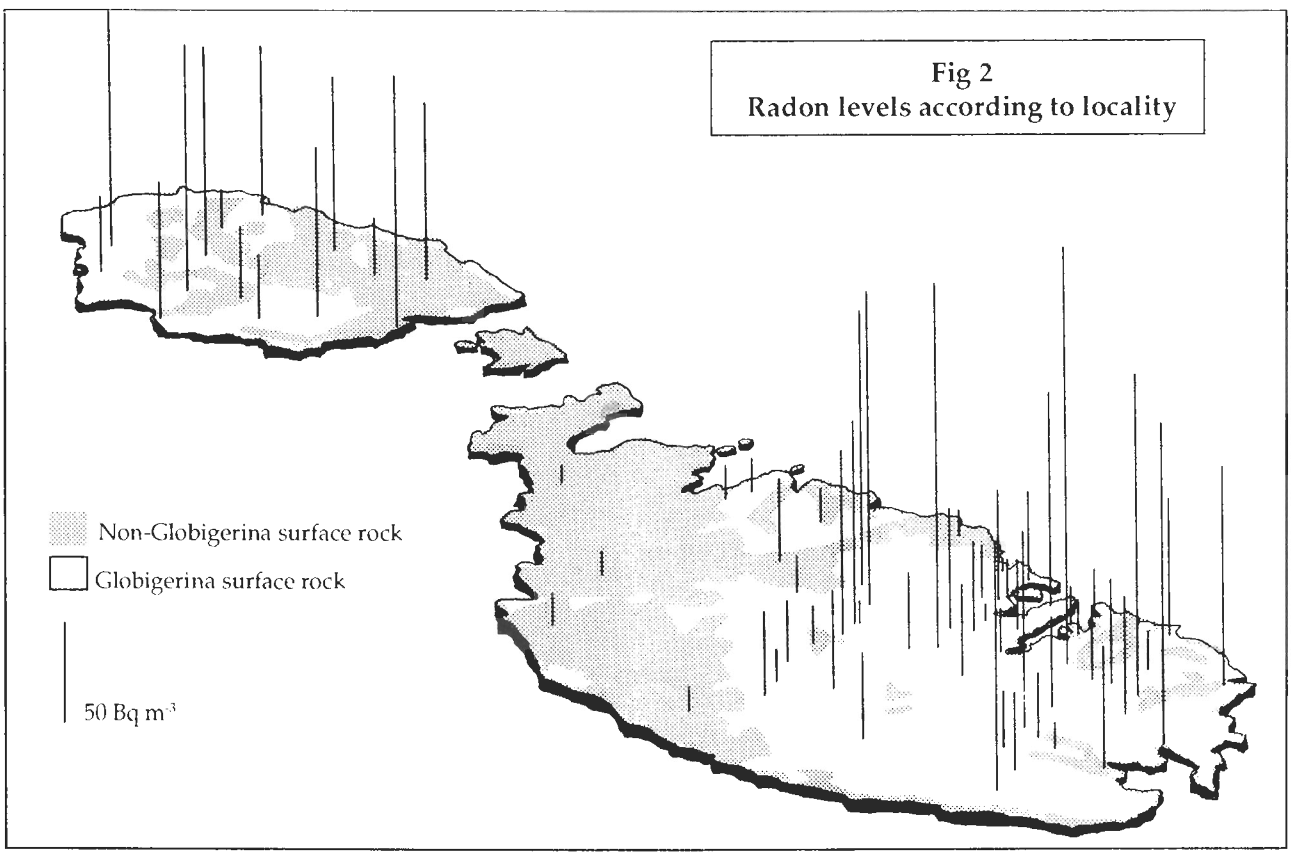



Figure 1. Variation in Radon levels over seven days.



| Country (population size in millions) | Number of houses sampled | Period and duration of exposure | Sample characteristics | Radon conc [$Bqm^{-3}$] Geom. Aver.Mean | | Geom Std. Dev. |
|---|---|---|---|---|---|---|
| Belgium (10.0) | 300 | 1984-1990 3 months to 1 year | selected acquaintances | 48 | 37 | 1.9 |
| Czechoslovakia (15.6) | 1200 | 1982 grab sampling | ---- | 140 | --- | --- |
| Denmark (5.2) | 496 | 1985-1986 6 months | random | 47 | 29 | 2.2 |
| Finland (5.0) | 3074 | 1990-1991 1 year | random | 123 | 84 | 2.1 |
| France (56.9) | 1548 | 1982-1991 3 months | biased | 85 | 52 | 2.3 |
| Germany (77.4) | 1500 | 1991-1993 1 year | random | 50 | 40 | --- |
| Greece (10.2) | 571 | 1987-1994 6 months | selected acquaintances | 92 | 68 | 2.9 |
| Hungary (10.6) | 122 | 1985-1987 -2.5 years | --- | 56 | --- | --- |
| Ireland (3.5) | 1259 | 1985-1989 6 months | random | 60 | 34 | 2.5 |
| Italy (56.8) | 4800 | 1989-1993 1 year | stratified random | 77 | --- | --- |
| Luxembourg (0.4) | 2500 | 1991 | --- | --- | 65 | --- |
| Norway (4.2) | 7525 | 1987-1989 6 months | random | 60 | 32 | --- |
| Portugal (10.3) | 4200 | 1989-1990 1-3 months | volunteers in a selected group | 81 | 37 | --- |
| Spain (39.0) | 2000 | 1988-1989 grab sampling | random | 86 | 41-43 | 2.6 - 3.7 |
| Sweden (8.4) | 1360 | 1991-1992 3 months | random | 108 | 56 | --- |
| Switzerland (6.6) | 1540 | 1982-1990 3 months | biased (not stratified) | 80 | --- | --- |
| UK (57.0) | 2093 | 1986-1987 1 year | random | 20.5 | 15 | 2.2 |
| Malta (0.4) | 68 | 1994-1995 24 hour | selected acquaintances | 55 | 40 | 2.3 |

Table 6. Summary of radon surveys in European dwellings.

The range of average radon levels measured in European dwellings varies greatly, from about 7 Bq $m^{-3}$ to 140 Bq $m^{-3}$ (Christodoulides and Christofides, 1994; EC, 1995). Table 6 gives values for indoor radon concentrations in various European countries (EC, 1995).

**Conclusion**

It is difficult to predict with certainty the concentration of radon inside dwellings. Local geological characteristics, housing design, construction material as well as the social behaviour of individuals living inside the dwelling influence radon concentrations. Seasonal changes have a profound affect on radon concentrations (NRPB, 1992). This aspect of seasonal variation could not be evaluated by short-term sampling techniques, as was undertaken in this study. Short term measurements are particularly useful for screening purposes and in assessing the diurnal variations in the concentration of radon. This study was carried out using a sample based on selected acquaintances. This may introduce a bias. Thus, further studies need to be carried out on a random sample representative of the housing stock. Furthermore, such studies need to be directed at taking extended measurements in rooms where people spend a considerable time. These measurements give better estimates than short-term radon measurements. In particular, one-year measurements are the most appropriate, except for cases in which dwellings are not inhabited for a long period of the year. Long term integrated measurements can be conveniently carried out using etched-track detectors. Such detectors are inexpensive, reliable and easy to use. The main disadvantage being that they do not give a measurement in the field and must be sent to a laboratory for processing.

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