OR/17/049 Radon

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Introduction

Radon, ^{222}Rn, a radioactive, colourless and odourless gas with a half-life of 3.82 d is the largest source of radiation exposure for most of the UK population and is the second highest cause of lung cancer after smoking.

Public Health England published a review of the potential public health impact of shale gas extraction in 2014 (PHE-CRCE-009). This included exposure to radon that might be released through a range of pathways. The report recommended the need to determine the baseline concentrations including measurements of radon in air at relevant locations around exploration sites.

The Vale of Pickering has been identified as a potential area for shale gas extraction. The main area of the Vale does not have naturally elevated radon potential, however there are areas of naturally elevated radon potential (radon Affected Areas in which at least 1% of homes are expected to be above the UK Action Level of 200 Bq m^{-3}) at around 5 to 8 km to the north and south of the proposed site (KM8). In these areas homes are likely to have higher radon levels.

Indoor radon concentrations exhibit diurnal, monthly and seasonal variation (Miles and Algar, 1988[1]), thus long term testing gives better estimates of the annual average radon concentration. PHE has recruited householders who have agreed to receive standard packs of passive detectors by post for several consecutive periods of 3 months. Some 151 properties in the Vale of Pickering were included in the study. In addition each home received two passive detectors to carry out monitoring over a longer period of up to a year. Measurements in this study follow the PHE Validation scheme (Howarth, C B, and Miles, J C H, 2008[2]) for handling, placement and reporting of results for homes.

Outdoor radon levels have been assessed using passive radon monitors very similar to those used routinely in homes. The detectors have been placed in small aluminium wrapped weather-proof plastic pots in discreet but open-air locations for several consecutive periods of 3 months or longer in a number of locations in the Vale of Pickering and around Oxfordshire to measure the radon concentrations in the open air.

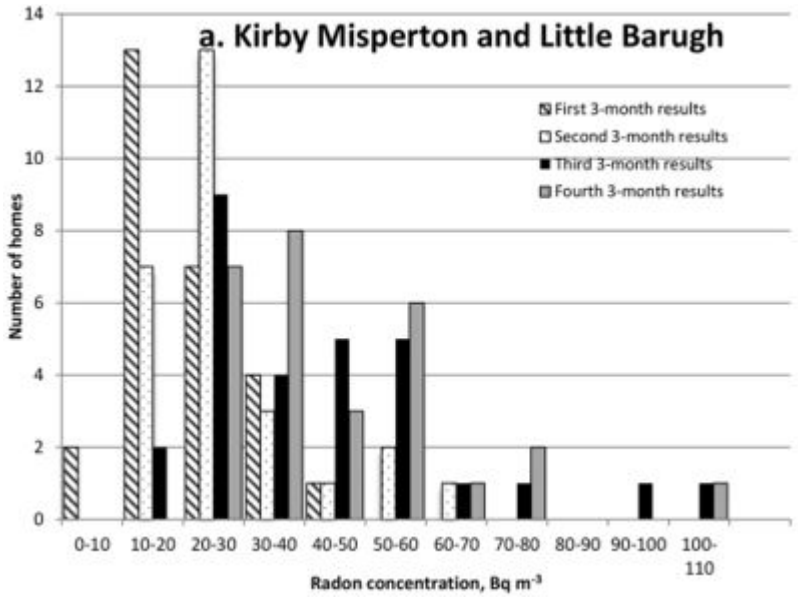
An active radon monitor (AlphaGUARD model P30) was placed in the enclosure at the KM8 site together with several passive detectors to assess the radon outdoor concentration at the site.

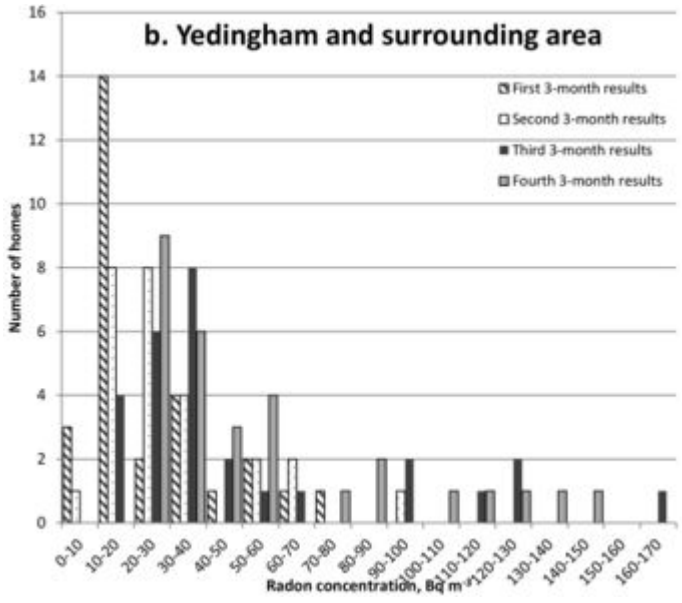
Indoor radon monitoring

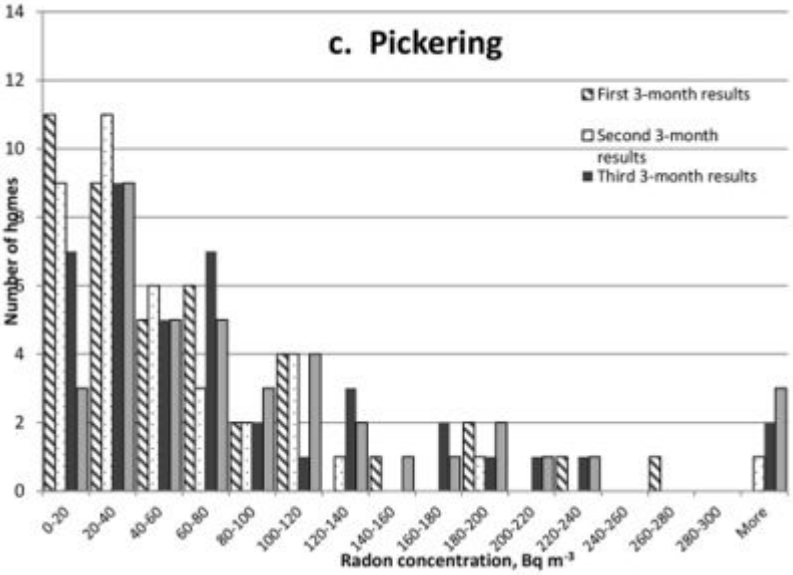
Results from the four three-month periods (December 2015 to December 2016)

Four areas were selected for indoor radon monitoring in the Vale of Pickering: Kirby Misperton and Little Barugh, Yedingham, Pickering and Malton. Pickering and Malton are both areas of established elevated radon potential.

Local radon distributions for the four 3-month tests in homes in Kirby Misperton and Little Barugh, Yedingham and surrounding area, Pickering, and Malton are compared in Figure 100a, b, c and d, respectively.

- 

- 



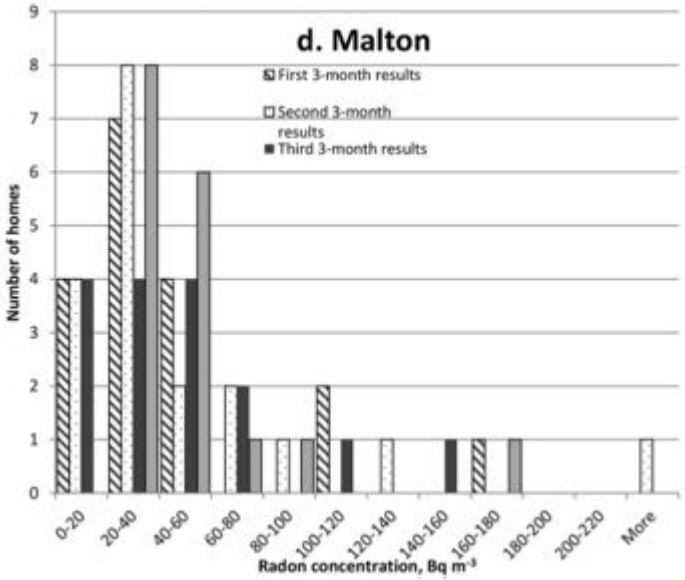


Figure 100a-d Indoor radon concentrations in the area of Kirby Misperton and Little Barugh, Yedingham, Pickering and Malton. © PHE, 2017.

Results from the four 3-month back to back tests in homes are presented in Table 14. The annual average radon concentrations were calculated employing seasonal correction factors as outlined in PHE Validation scheme (Howarth C B and Miles J C H, 2008[2]). Distribution parameters assuming log-normality show that homes in Kirby Misperton and Little Barugh, and Yedingham are situated in areas with low radon potential while Pickering and Malton are situated in areas with higher radon potential known as radon Affected Areas.

Table 14 Range and distribution of indoor radon measurements.

Area (number of homes)	**First 3-month results (Dec 15–March 16), Bq m^{-3}**			**Second 3-month results (Apr–June16), Bq m^{-3}**			**Third 3-month results (July–Sep 16), Bq m^{-3}**			**Fourth 3-month results (Sep–Dec 16), Bq m^{-3}**		
	Range	GM	GSD	Range	GM	GSD	Range	GM	GSD	Range	GM	GSD
Kirby Misperton and Little Barugh (27/27/29/28)	9–41	18	1.5	13–69	25	1.5	16–110	37	1.6	20–104	41	1.5

Yedingham and surrounding (28/26/28/30)	9–72	21	1.9	10–97	26	1.8	17–170	39	1.9	21–143	46	1.8
Pickering (42/38/41)	6–270	40	2.7	9–450	44	2.6	13–460	56	2.6	17–619	71	2.5
Malton (18/19/16/17)	12–170	36	2.1	11–240	39	2.1	8–150	34	2.3	20–171	45	1.7

Seasonality of indoor radon

Seasonality was studied using the four 3 month back-to-back measurements in each home without seasonal correction. This included all homes where results were available for all of the measurement periods.

The first batch of indoor detectors was sent over a two week period between the end of November and the beginning of December 2015. Each of the detector packs that formed the second, third and fourth batches were sent at the same time. The houses from the first two batches sent in November and December were combined for reporting purposes as the difference in send out dates were small (a week or so).

The average radon concentrations were calculated for Kirby Misperton and Little Barugh (KL-LB), Yedingham, Pickering and Malton. The results are presented in Figure 101. From the plot it is evident that there is little variation in the indoor measurement results for Kirby Misperton and Little Barugh, and Yedingham for the period of November/December 2015 to June 2016, the results only appear to increase in the final measurement period from September to December 2016. This variation is different to that observed for the UK as a whole where radon levels tend to be higher in winter and lower in summer. A different pattern was observed in Pickering where the normal seasonal pattern in the UK was seen. A similar but much smaller seasonal variation was observed in homes in the Malton area.

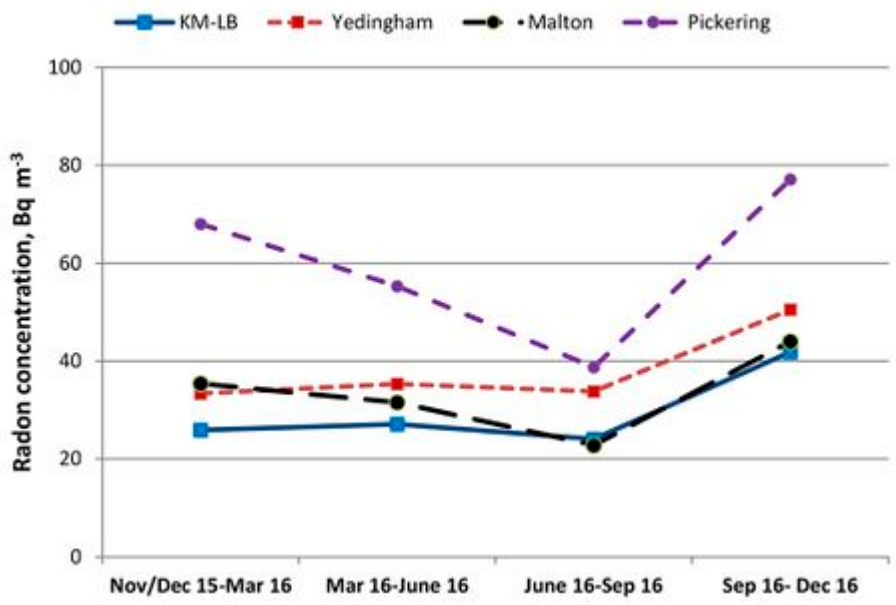


Figure 101 Misperton and Little Barugh, Yedingham, Pickering and Malton. © PHE, 2017.

Outdoor radon monitoring

Four sites were selected for outdoor radon monitoring in the Vale of Pickering around Kirby Misperton (the area closest to the KM8 site), Yedingham (control site), Pickering and Malton (sites in radon Affected Areas). One site in Oxfordshire was selected as an additional control. Five 3-month

and one 1-year passive detector were used to record radon concentrations at each sampling point. The locations of the monitoring points in the Vale of Pickering are shown in Figure 102.

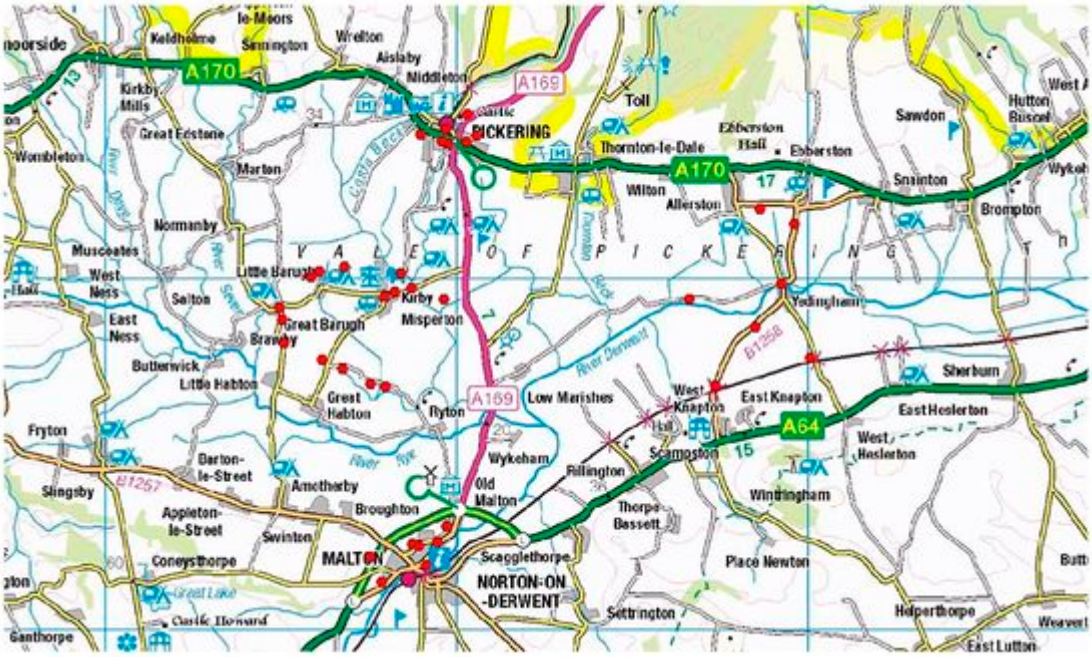


Figure 102 Outdoor radon sampling points in the Vale of Pickering. Includes mapping data licensed from Ordnance Survey. © Crown Copyright and/or database right 2017. Licence number 100021290 EUL.

Results for the five three-month periods (October 2015 to January 2017)

The results from the five 3-month monitoring periods were plotted and compared with each other at each sampling point in the area around Kirby Misperton, Yedingham (control area), Pickering and Malton in Figure 103 to Figure 106. Results from the 1-year test, are included where these are available. It was not possible to obtain results for all sites due to detectors being removed or damaged. Some sites where this damage occurred early on in the monitoring period have been re-located. For these monitoring points the 1-year results are not yet available. The results from the control area around the Vale of White Horse in Oxfordshire are shown in Figure 107.

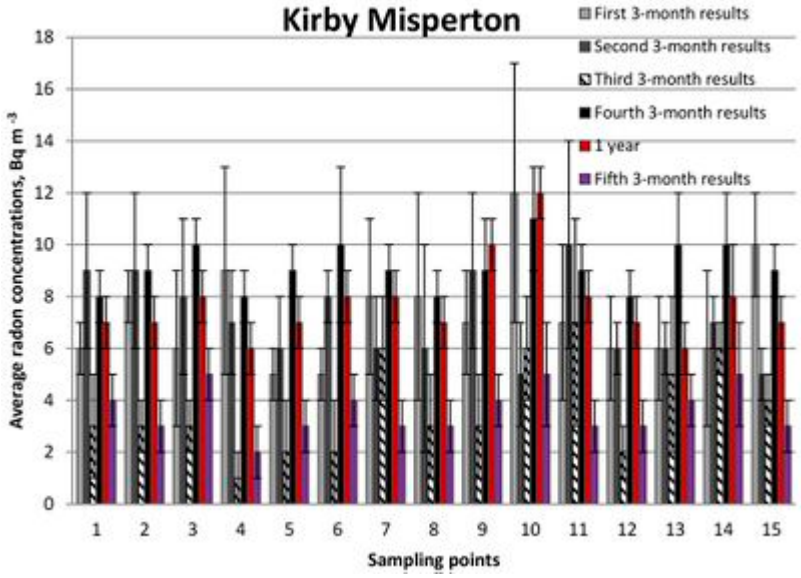


Figure 103 Average radon concentrations at the sampling points around Kirby Misperton. © PHE, 2017.

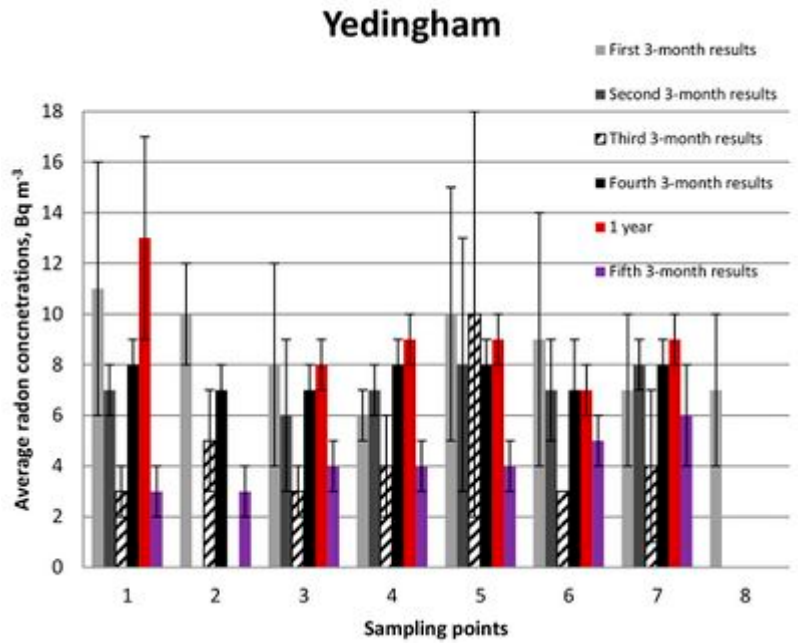


Figure 104 Average radon concentrations at the sampling points around Yedingham. © PHE, 2017.

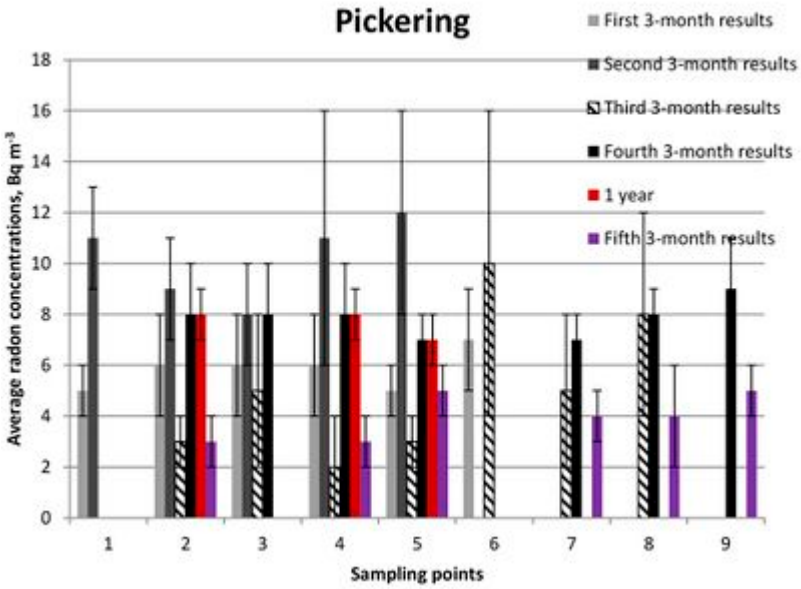


Figure 105 Average radon concentrations at the sampling points around Pickering. © PHE, 2017.

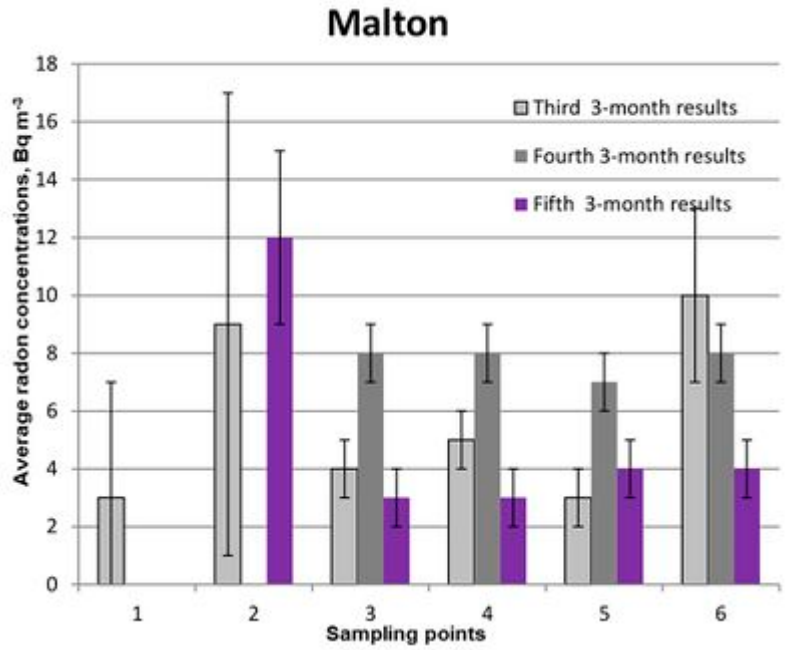


Figure 106 Average radon concentrations at the sampling points around Malton. © PHE, 2017.

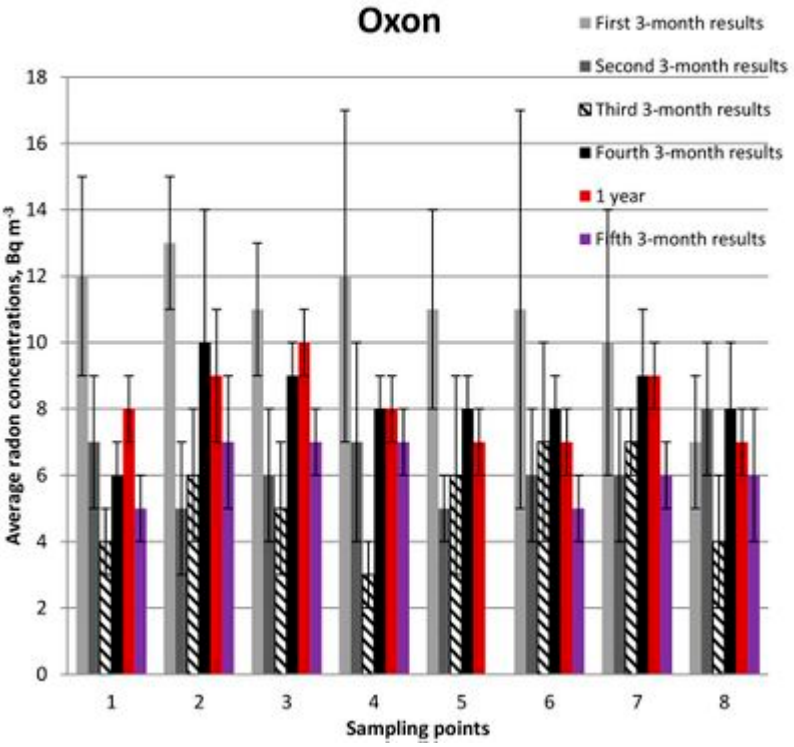


Figure 107 Average radon concentrations at the sampling points in the Vale of White Horse, Oxfordshire. © PHE, 2017.

Table 15 Analysis of outdoor radon results.

Area	First 3-month (Oct 15–Jan 16) Bq m^{-3}	Second 3-month (Jan–April 16) Bq m^{-3}	Third 3-month (April–July 16) Bq m^{-3}	Fourth 3-month (July–Oct 16) Bq m^{-3}	Fifth 3-month (Oct 16–Jan 17), Bq m^{-3}
Kirby Misperton	7 ± 2	7 ± 2	4 ± 2	9 ± 1	4 ± 1
Yedingham	9 ± 4	7 ± 2	5 ± 2	7 ± 1	4 ± 1
Pickering	6 ± 2	10 ± 3	5 ± 2	8 ± 1	4 ± 1
Oxon	11 ± 3	6 ± 2	5 ± 2	8 ± 2	6 ± 1
Malton	--	--	6 ± 3	8 ± 1	5 ±

Aggregated results for outdoor monitoring from the five measurement periods are given in Table 15. There is an indication of some variability in the results for all areas with results for July-October 2016 being slightly higher than results for the previous two periods Although the above results are similar to those measured in previous studies (Wrixon et al 1988[3]) there is an indication that the outdoor radon levels are slightly higher than previously measured in UK. Although the 3-month results are close to the detection limit for the technique they are consistent with the results for the 1-year period (Figure 103 to Figure 107). Results from the additional 6-months detectors, which were placed in areas around Kirby Misperton and Oxfordshire in July are consistent with the above results yet showing smaller measurement uncertainties. We plan to change the detection period for outdoor monitoring from 3 to 6 months as this gives consistent results but with smaller measurement uncertainties.

Seasonality of outdoor radon

Seasonal variation of outdoor radon was studied using five 3 month back-to-back measurement results, with periods 1 and 5 measured over the same three month period over successive years. The average radon concentrations were calculated for the areas around Kirby Misperton and Little Barugh (15 sampling points) and Oxfordshire (8 sampling points) and plotted in Figure 108. The data for the other areas were not used because various sampling points were moved or lost due to vandalism and a consistent set was not available. Looking at Figure 108 is evident that the patterns of outdoor radon in the two areas which are situated in different parts of England are very similar. There are also indications that the seasonal pattern of outdoor radon is different to that observed for the indoor radon results for the same periods, with results in the summer (April 16 to July 16) being higher than the results in spring (April 16 to July 16). This observation will be studied further when more data are available.

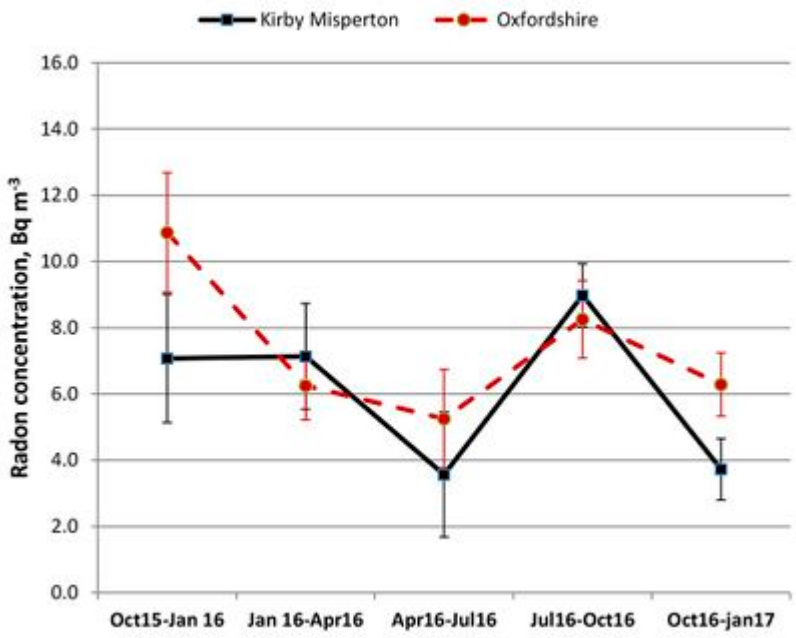


Figure 108 Seasonal variation of outdoor radon concentrations in the area of Kirby Misperton and Oxfordshire. © PHE, 2017.

Monitoring at the KM8 site

The data from the AlphaGUARD continual radon monitoring instrument, placed in an enclosure of the KM8 site for periods April-July 2016, July-October 2016 and October 2016-January 2017 are

plotted in Figure 109. The background of the instrument was taken into account when data were processed. The radon data, taken at 1 hour intervals, are log-normally distributed. The distribution parameters for the above monitoring periods are given in Table 16. The average radon concentrations measured over the three monitoring periods were in the range 5 to 6 Bq m^{-3}. In order for a comparison to be made between the outdoor radon concentrations measured with the instrument and the other outdoor results, passive monitors were also placed in the enclosure at the KM8 site. The average radon concentration measured with the passive detectors in the same enclosure was 4 ± 1 Bq m^{-3}, 8 ± 1 Bq m^{-3} and 7 ± 1 Bq m^{-3} for April 16–July 16, July 16–October 16 and October16-January 17, respectively. These values are similar to the arithmetic means of the distributions for these periods in Table 16, showing a good agreement between the two different measurement techniques.

A graph showing the raw data obtained from the AlphaGUARD is shown in Figure 110. This shows the time series of the radon, without background correction. The data identified some isolated peaks in radon concentrations on certain days, usually during the night.

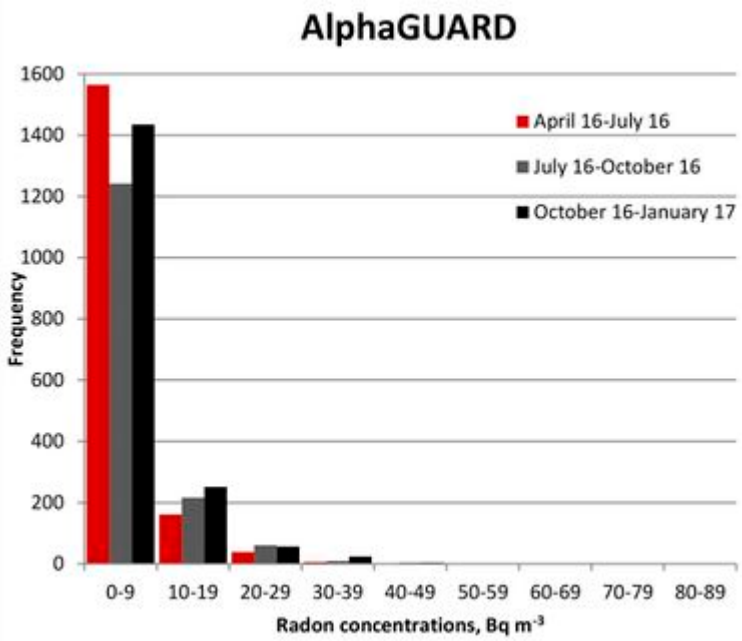


Figure 109 AlphaGUARD data from the enclosure at KM8 site. © PHE, 2017.

Table 16 Range and distribution of AlphaGUARD radon measurements.

Period of monitoring	Bq m^{-3}			
	Range	AM	GM	GSD
April 16–July 16	1–46	5	5	2.0
July 16–October 16	1–81	6	4	2.4
October 16–January 17	1–50	6	4	2.5

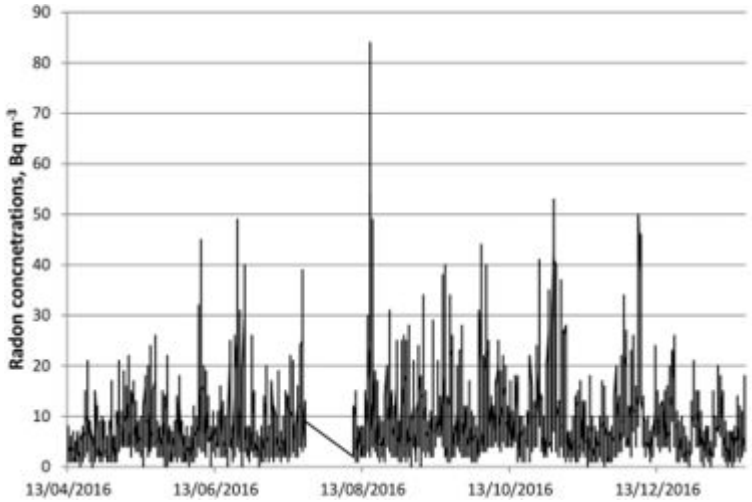


Figure 110 Time series of radon concentrations recorded by AlphaGUARD between April 2016 and January 2017. © PHE, 2017.

Conclusions

Indoor radon

The analysis of the results for around 120 homes measured in the Vale of Pickering showed distributions of indoor radon concentrations consistent with the usual log-normal distribution for indoor radon.

The results for Kirby Misperton and Little Barugh and Yedingham areas are consistent with their non-radon Affected Area status, with all results below the Action Level of 200 Bq m^{-3}.

The results for both Pickering and Malton confirm our assessment as being radon Affected Areas with radon concentrations spread over a wider range from about 10 to 460 Bq m^{-3} and where predicted numbers of homes exceeding the Action Level were observed.

Seasonal variation of indoor radon was also studied for all areas. Results indicatedthat there is little seasonal variation in the areas of Kirby Misperton and Little Barugh, and Yedingham. However, normal UK seasonal variation was observed in Pickering which follows the normal seasonal pattern in UK with the highest radon concentrations in winter and lowest radon concentrations in summer.

Outdoor radon

The results from the five 3-month back to back measurements of outdoor air are consistent with but a little higher than the radon concentrations observed in previously in the UK, 4 Bq m^{-3}. There is no indication of elevated radon concentrations in Pickering or Malton, radon Affected Areas. The analysis of results for another control site in Oxfordshire showed that the radon concentrations were similar to those for the Vale of Pickering.

Seasonal variation of outdoor radon was studied for areas around Kirby Misperton and Oxfordshire. Results showed similar patterns in these geographically distant areas.

Monitoring at the KM8 site

Results from an active monitor AlphaGUARD and passive detectors, placed in the KM8 enclosure are in good agreement with the average outdoor radon in the area of Kirby Misperton.

References

1. ↑ Miles, J C H, and Algar, R A. 1988. Variations in radon-222 concentrations. Journal of Radiological Protection 8 (2), 103–106.
2. ↑ [2.0] [2.1] Howarth, C B, and Miles, J C H. 2008. Validation scheme for organisations making measurements of radon in dwellings: 2008 revision. Chilton, HPA-RPD-047
3. ↑ 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 C. 1988. Natural Radiation Exposure in UK Dwellings. Chilton, NRPB-R190.

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