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Breaking New Ground: Does Radon Present a Health Risk to Nova Scotia Workers?

May 2009

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RS2007-IG17

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- 185 alpha track detectors were used to test for radon in 21 selected NS industries over a three month period between May 2008 and January 2009.
- A workplace was eligible for inclusion in the study if it:
    - contained water treatment plant; was a coal power generator; was located geographically within identified potential radon target areas; had large square footage or was interested and volunteered for the study
- The two workplaces with levels of radon above the Canadian NORM Guidelines (Health Canada 2000) of 150 Bq/m^3 were given advice regarding management and signage and were provided with education sessions for staff. Although they exceeded 150 Bq/m^3, they did not exceed 400 Bq/m^3, and therefore fell into the NORM "management" classification, not requiring any mitigation activity. Both workplaces will include radon in their loss management activity for future monitoring and control.
- Possible reasons for lower than expected radon levels are:
    - Absence of soil or water sources of radon
    - High levels of general dilution ventilation
    - High amount of supplied air into building, creating positive pressure
    - Well designed and maintained building foundations
- Information dissemination of the project results was widespread and included lectures to the following groups:
    - Cape Breton Cancer Symposium, October 2008
    - Canadian Institute of Public Health Inspectors, NS & PEI Branch
    - Safety Services Nova Scotia, Annual Provincial Conference, Halifax
    - NS Cancer Prevention Society; Speaker Series, Wolfville
    - American Industrial Hygiene Conference and Exposition, Toronto, ON.
- The results indicate that workplace radon concentrations in these selected NS workplaces were not significant from an exposure point of view. Future work should be done on smaller or poorly ventilated businesses in targeted geographic locations.
- Of 23 workplaces selected, only 2 chose not to participate.

Breaking New Ground: Does radon present a health risk to Nova Scotia workers?

Executive Summary

Radon is an invisible, odorless, naturally occurring radioactive gas (Chen, 2004; CCOHS, 2005; Health Canada, 2006), that is emitted by the natural breakdown of uranium and can be found in high concentrations where the rocks and soils contain uranium, granite, shale, or phosphate and in soils contaminated with certain types of industrial waste (Kendall, 2002). A systematic assessment carried out in Nova Scotia has shown that many areas in the province are radon prone due to elevated levels of natural radioactivity in soil. In particular, an area from Sheet Harbour going west to just east of Bridgewater, and north to Windsor has been identified as an area with potential radon contamination. There is also an area of high concentration just west of the Town of Canso, and around Cheticamp and Ingonish on Cape Breton Island (Province of NS, 2006). The purpose of conducting the study was to obtain data where very little previous data is available.

This study assessed 21 workplaces in Nova Scotia to determine worker radon exposure, and compared the results to NORM guidelines (2002, p21). Twenty three (23) workplaces were approached, with only two refusing to participate. Workplaces were assessed if they met at least one out of five criteria for inclusion in the study. One hundred and fifty three (153) alpha track detectors were used along with seventeen (17) duplicates (detectors placed at same location for same duration). These were exposed over a minimum sampling time of 90 days, in periods over May 2008 until January 2009. Fifteen (15) blanks were also collected and were not exposed prior to analysis. No outdoor background samples were taken. After collection, the detectors were sent to LEX Scientific for analysis (LEX, 2009). Results were communicated with each workplace party by a letter from the researcher, comparing the results to the standards and providing advice and education where necessary.

The results indicate very low radon concentrations in 19 (nineteen) of the 21 (twenty-one) workplaces, even in potentially radon prone areas of the province and in potentially radon prone type of workplaces such as coal power and water treatment facilities (Harris, 1991; Lewis, 2001). These 19 workplaces had concentrations of radon of less than 50

Bq/m^3, comparable to the average residential indoor radon concentration (American Lung Association, 2009), with some similar to and in some cases less than outdoor radon concentrations of 10 Bq/m^3 (UNSCEAR 2000).

Only two workplaces were found to have radon concentrations above average indoor levels. One had a radon concentration averaged over locations of 94.0 Bq/m^3, with one location at 164 Bq/m^3. This was an office/warehouse complex without mechanical ventilation and with little occupancy and activity. This workplace was in a previously unidentified high radon geographic location. The other workplace had a radon concentration averaged over several locations of 98.4 Bq/m^3, with two results above 150 Bq/m^3. It was also an office/warehouse complex with no mechanical ventilation and little occupancy during the work week. This workplace was also in a previously unidentified high radon geographic location.

Recommendations were given to both these workplaces to sign the rooms where radon was above 150 Bq/m^3, to occupy the rooms for less than 4 hours per day and to educate the workers. Education sessions for both these workplaces took place during 2009. Both workplaces will continue to periodically test for radon as part of their continuing loss management program.

All other workplaces received letters stating their specific results with comparison to the standards, and the fact that no follow up action was necessary. Each workplace was also offered voluntary training sessions at their request. Only one workplace with negligible radon concentrations requested such a training session.

As a follow up to the workplace monitoring, the results have been discussed with several stakeholders who requested seminars or lectures on the topic of radon. These were delivered in October 2008, March 2009, June 2009, with one more session planned for Ottawa in October 2009.

Benefits from the study include overall improvement of the education and awareness level regarding radon in Nova Scotia. A large number of workplace participants were interested in surveying their homes for radon following the study.

Future direction for workplace monitoring of radon would be to encourage businesses to test for radon, even if they do not fall within the priority industries or priority geographic locations. In particular, encouragement to test for radon should be given to small businesses, hospitals, schools and other workplaces that either do not have mechanical ventilation or have limited ventilation.

Limitations of the study include the fact that the study only performed measurement of radon itself and not its short lived decay products. Additionally, a longer term sample of up to 12 months may have picked up variation in the radon concentration attributable to seasonal changes. However, the majority of workplaces were measured during fall or winter conditions, which usually have higher indoor radon concentrations. One limitation is the lack of personal samples taken, all samples were area samples, which does not truly estimate actual worker exposure. Another limitation is the representativeness of the selected workplaces. Although all met at least one of the criteria, there was not a random selection of workplaces, nor was consideration given for a representative geographic study of Nova Scotia. Future studies should consider random selection of study workplaces, as well as geographic representativeness and poorly ventilated workplaces.

Research Problem and Context

This research investigated radon in selected Nova Scotia workplaces, to determine air concentrations within those workplaces. Radon is an invisible, odorless, naturally occurring radioactive gas (Chen, 2004; CCOHS, 2005; Health Canada, 2006), that is emitted by the natural breakdown of uranium and can be found in high concentrations where the rocks and soils contain uranium, granite, shale, or phosphate and in soils contaminated with certain types of industrial waste (Health Canada, 2006). The radon itself then decays into a series of short-lived radioisotopes that can be inhaled, often referred to as radon 'daughters' or 'progeny' (Copes, 2007). These progeny decay rapidly themselves emitting alpha particles that when inhaled, can cause damage to bronchial and lung tissues. Exposure to radon and its progeny has been associated with an increased risk of lung cancer, depending on the level of radon and the length and time of the exposure (Health Canada, 2006).

Radon can move freely through small places in the soil and rock, enabling it to enter the atmosphere or seep into buildings through dirt floors cracks in concrete walls or floors, sumps, joints or basement drains (Colgan et al, 2004; Health Canada, 2006). A systematic assessment carried out in Nova Scotia has shown that many areas in the province are radon prone due to elevated levels of natural radioactivity in soil. In particular, an area from Sheet Harbour going west to just east of Bridgewater, and north to Windsor has been identified as an area with potential radon contamination. There is also an area of high concentrations just west of the Town of Canso, and around Cheticamp and Ingonish on Cape Breton Island (Province of NS, 2006). Very little workplace radon data is currently available.

A joint Federal-Provincial group has produced guidance to manage radiation doses in workplaces with naturally occurring radioactive materials (NORM) including radon. The Canadian NORM Guidelines (Minister of Public Works, 2000) recommend that where the average concentration of radon gas in a work area is more than 150 Bq/m^3, steps should be taken to limit worker doses (NORM 2002). When the concentration is more than 800 Bq/m^3, a Radiation Protection Management program should be implemented, including steps to reduce the radon levels to below 800 Bq/m^3 (NORM, 2002).

This study assessed worker exposure in several Nova Scotia workplaces. The information gained will be communicated to the workplaces as well as Department of Labour, to help formulate guidance for new policy and/or procedures. Results will be shared for use by other employers and employees to assess their workplace environments and for methods to help prevent radon entry and to limit exposure.

In addition to the technical assessment of exposures in priority industries and workplaces, the information gained from the literature search will be provided to the Nova Scotia Department of Environment and Labour for their own use. This guidance will help other employers and employees assess their workplace environments. Every effort will be made to ensure confidentiality of individual workplace results, with the overall attempt to gain useful information for managing radon in NS workplaces.

Occupations assessed within this study that have the potential for high 222Rn exposure included water plant operators and coal power plant workers. These occupations were included due to the fact that radon releases from ground water can give high radon concentrations in treatment facilities (Harris, 1991; Lewis, 2001), and coal and flyash often contains measurable amounts of uranium and radium - the parent of radon (Klassen, 2002). The coal power generators had ash management facilities on site, which may contribute to overall radon. In addition, workplace partners with these workers were willing to participate in the study, and the workplaces were located within Nova Scotia.

Methodology

Workplace Selection

The intent of the study was to identify workplaces with potentially high levels of radon, although all workplaces were of interest due to lack of pre-existing information on overall workplace radon levels. The investigators determined prior to beginning the study that no workplace would be excluded if they were interested and volunteered to become participants. However, the majority of the testing took place in either the targeted activity workplaces (water treatment) or the targeted geographical locations. Two of the 23 contacted workplaces refused to participate. One was a large scale manufacturing organization, while the other was an office complex in a geographically radon prone area. Both stated that they did not want to participate because they were not prepared to deal with high radon concentrations at this time. One felt this way due to economic constraints, the other due to labour/management issues. The end result was a participation rate of 91%.

Workplaces within Nova Scotia were considered for the study if they met the following criteria:

- contained water treatment plants
- were coal power generators
- were located geographically within the identified high potential radon target areas
- had large square footage
- were interested and volunteered for the study

Once a list of workplaces was made, contact was initiated by phone call to safety professionals within that workplace. If interest was expressed, a formal letter was then sent by the investigator to senior management and the safety professional at the workplace. Upon approval to continue, the investigator made phone and email contact with identified personnel at each individual workplace. A schedule was developed for the researcher to visit each site, provide information, and set up the passive radon monitors (PRMs) alpha track detectors. Twenty one workplaces agreed to participate in the study. Thank are expressed to all those who agreed to participate in the study, especially those who made significant efforts to assist in PRM placement and retrieval.

Choice of Passive Monitor

There are two main types of monitors; long term and short term monitors. The short term monitors contain “activated carbon” which absorbs radon from the air. The amount of radon at the end of the exposure time is related to the average concentration over the exposure duration. As radon decays with a four day half life, the exposure duration is normally only 2 to 4 days [Ruano-Ravina 2008]. The long term monitors are known as ‘alpha particle track’ detectors because they have a small square of plastic film inside the monitors that produce “latent tracks” when the alpha particles hit them. [Ruano-Ravina, 2008] In the lab, the squares of plastic are treated chemically to enhance the latent tracks which are then counted using a microscope. The number of tracks detected is proportional to the integral of radon concentration over the exposure duration. These monitors are long-term because they are normally in place for 3 – 12 months. [Ruano-Ravina, 2008].

Radon concentrations vary from month to month, day to day or even hour to hour, so the activated carbon short term monitors cannot capture the longer term variations. The long-term, alpha track monitors however can measure for much longer and so provide a better representation of average concentrations. The alpha track monitor was chosen for this reason.

PRM Placement

Prior to a site visit, the researcher discussed the work site with the contact person at each location to determine square footage, air flow patterns and work activity. The Health Canada guidelines for PRM placement were followed in ensuring appropriate locations for the sampling. These guidelines are:

Preferred device locations were:

- By an interior wall at breathing level, but at least 50 cm from ceiling.
- Where occupants spend much of their time.
- In occupied rooms in basements or the floor with the lowest level occupied rooms in the building.

- In rooms above crawl spaces, over slabs or built into the side of a hill with walls that may be in contact with the earth.
- One PRM per 200 square feet.

Devices were not placed:

- In bathrooms, closets, cupboards, sumps, crawl spaces or nooks because relatively little time is spent there
- Near air currents caused by heating, ventilation, doors, windows or fans.
- Near heat, such as over radiators or in direct sunlight
- Near electrically powered equipment or appliances (Health Canada, 2006)

Prior to a site visit, the researcher discussed the work site with the contact person at each location to determine square footage, air flow patterns and work activity. Upon arrival at each workplace the researcher met with the contact person and determined the sampling locations for each PRM. The contact person or designate accompanied the researcher while setting up the PRMs to ensure appropriate placement and representative locations based on occupancy. Signs were placed with the PRM so that individual workers would be aware of the sampling, understand the nature of the testing and have a number to call if any questions or concerns. An information package and brochures were left with each contact person so that additional information could be provided as needed if questions arose. Additionally, a Powerpoint presentation on radon in the workplace was offered to each workplace for their own use (all workplaces took a copy of the presentation). An offer to perform a training session was also given to each workplace at the time of the visit (one workplace asked for a session).

At the end of the three month (90 day) sampling period, the researcher contacted each workplace to arrange a mutually acceptable pick up date for the PRMs. All workplaces complied with the sampling term, and so none were sampled for under the 90 day limit. Two PRMs were could not be found at pick up, at two different sites.

PRM Analysis

The PRMs were picked up and sent to LEX Scientific in Guelph, Ontario for analysis. LEX was contacted with regard to shipping and they stated that there was no need for any special handling or shipping procedures, as a short term shipping process would not affect the detectors in a significant way. Analysis was performed in accordance with the Alpha Track method identified by the United States Environmental Protection Agency (US EPA). This method provides accurate and reproducible measurements of indoor radon concentrations. This analysis represents the average radon concentration in the air only during the measurement period indicated.

Limitations of the study include the fact that the study only performed measurement of radon itself and not its short lived decay products. Additionally, a longer term sample of up to 12 months may have picked up variation in the radon concentration attributable to seasonal changes. One limitation is the lack of personal samples taken, all samples were area samples, which does not truly estimate actual worker exposure. Another limitation is the representativeness of the selected workplaces. Although all met at least one of the criteria, there was not a random selection of workplaces, nor was consideration given for a representative geographic study of Nova Scotia. Future studies should consider random selection of study workplaces, as well as geographic representativeness.

Blanks and Duplicates

One blank was used for each ten (10) PRMs. A blank was defined as a sealed, unexposed alpha track detector. Fifteen blanks were used in total. As the detectors actually measure exposure = $Bq.d/m^3$, which is then converted to average concentration by dividing by exposure time, the blank correction is best done in terms of exposure. The apparent exposure of each blank was calculated by multiplying the reported concentration by the exposure time to give exposure. The values followed a log-normal distribution, and the median value 660 $Bq.d/m^3$ selected as the blank correction. See Appendix A for details.

The apparent exposure of each PRM was calculated by multiplying the reported concentration by the exposure time, and the blank correction subtracted to give the corrected exposure. This was converted to corrected concentration by dividing by the exposure time.

One duplicate was set up for each ten (10) PRMs, in close proximity (within 10 cm) to its partner and exposed for the same duration as the original sample (Health Canada, 2006). Seventeen (17) duplicates were used in total. Results for the duplicates were compared for quality analysis.

Reporting

Each workplace was provided a letter report summarizing the results and providing comparison to available standards. In the case of results falling below 150 Bq/m^3, the letter communicated no need for further action, however, the ALARA principle was introduced. In the case of results falling above 150 Bq/m^3, follow-up action was recommended, and a phone number was provided for additional contact as necessary. The follow up action complied with the NORM guidelines for workplaces. Additionally, an offer was made to provide a training session for staff regarding the levels found, or radon in general.

Radon Limits

The NORM guidelines (2002) suggest that levels of less than 150 Bq/m^3 are unrestricted from both worker and public access (p20). Radon concentrations between 150 and 800 Bq/m^3 fall into the "NORM Management" classification and require different levels of action depending on where the concentrations fall (p21). The principle of ALARA (as low as reasonably achievable) should be applied and may involve restriction of access, change in work practices and periodic review to ensure the levels have not changed.

Radon concentrations above 800 Bq/m^3 require the institution of a radiation protection management program (NORM 2002, p20).

Research Findings

Table 1 provides the results seen for the different types of workplaces where monitoring was performed. No workplace identifiers are in place other than their workplace activity description. As can be seen from Table 1, the range of results was from -2.0 to 202.1 Bq/m^3, with an overall average of 25.7 Bq/m^3 for all workplaces (the negative value is due to blank correction). In each workplace, the average radon exposure was below 150 Bq/m^3 in all cases. After duplicate analysis, all but two of the workplaces had negligible radon concentrations (less than background levels). Only two workplaces contained individual radon readings above 150 Bq/m^3, although their average radon concentration was less than 150 Bq/m^3. One of these workplaces was a hydro facility office complex, which did not have mechanical ventilation, and had relatively low occupancy and activity (storage area). The other workplace was an office/warehouse complex, also without mechanical ventilation and relatively low occupancy and daily activity. Both of these workplaces were located in geographic areas that were not identified as potentially high radon locations. There are several public buildings nearby one of the workplaces (one school and one sports complex) which are targeted for radon monitoring within the next several years. It will be interesting to see if their results are similar to the levels seen at workplaces assessed in this study.

Coal power generating stations have been identified as potentially problematic with respect to radon concentrations (Colgan, 2006). Table 1 indicates that the four coal powered generating stations monitored had extremely low levels of radon, so much so that they are less than typical background levels of 50 Bq/m^3. This may be due to the absence of radon impacted soils, high levels of natural and mechanical ventilation, coal sources that do not contain significant amounts of radium or uranium and absence of radon impacted cooling water supply.

Water treatment plants have been identified as potentially problematic with respect to radon concentrations (Colgan, 2006). Table 1 indicates that the four waste water treatment facilities had negligible levels of radon. This is probably due to the fact that the water was not well or ground water treatment but either surface water or waste water. Another possible reason is the presence of large mechanical ventilation systems and naturally good ventilation in the site buildings (Orlando, 2003).

The two hydro stations fit the criteria for potentially high levels of radon, as they both handle large amounts of water. One hydro station had negligible levels of radon in their water handling area, even though it was in a previously identified potentially high radon geographic location. Possible reasons for the low radon concentrations in the water handling area may be due to high levels of aeration prior to the water's arrival at the hydro station, predominantly surface water usage or high levels of natural dilution ventilation.

The other hydro station had one room in the office complex that was poorly ventilated and had low occupancy (storage area) had a radon concentration of 169.1 Bq/m^3. It was also located in a potentially higher radon area due to its geography.

Table 1: Type of Workplace, range and average radon concentrations in Becquerels per cubic meter of air, Nova Scotia (blank corrected).

Type of workplace	Range of radon concentrations Bq/m^3	Average radon concentrations Bq/m^3	# of Detectors
Sports facility	10.5 – 91.4	33.2	7
Manufacturing	9.6 – 33.6	19.3	14
Hydro facility	3.1 – 31.2	13.1	6
Hydro facility	**39.1 – 169.1**	**94.0**	5
Hospital	3.1 – 9.5	6.6	5
Hospital	1.6 – 13.8	8.6	5
Hospital	1.2 – 6.8	4.5	7
Coal power	0.1 – 11.2	4.9	10
Coal power	-1.9 – 12	3.4	10
Coal power	-2.0 – 7.7	1.0	10
Coal power	10.6 – 43.7	22.3	20
Oil/natural gas	0.3 – 6.8	3.4	9

Type of workplace	Range of radon concentrations Bq/m^3	Average radon concentrations Bq/m^3	# of Detectors
power			
Oil turbine power	21.3 – 40.7	34.1	3
Warehouse/office	12.9 – 13.8	13.4	3
Warehouse/office	-0.7 – 75.8	22.7	20
Warehouse/office	**58.5 – 202.1**	**98.6**	14
Water treatment	11.8 – 41.0	24.5	4
Water treatment	53.5 – 70.3	57.0	5
Water treatment	5.8 – 18.8	10.8	4
Water treatment	15.2 – 53.8	28.8	5
Public works	7.6 – 88.1	35.0	4
Summary	-2.0 – 202.1	25.7	170

Table 2 gives the workplace results based on their geographic distribution. The geographic areas where previous studies had suggested the geology might produce higher than background radon levels did not demonstrate this (Province of Nova Scotia, 2006). In fact, some of those potentially impacted areas were lower than other areas. For example, due to geography, Neil's Harbour, Cheticamp, Wreck Cove and Lakeside were expected to be higher than background, but this was not found to be true from this current survey. This may be due to good ventilation, good building design or absence of radon impacted soils or water. The opposite is true of the results found in Coxheath and St. Margaret's Bay. These were not identified as geographic areas where radon was expected to be higher than background, when they were the highest levels within this study set. This may have been due to the fact that both of these workplaces had poor or no ventilation.

Table 2: Radon range and average per geographic location, NS. (blank corrected)

Location (Nova Scotia)	**Range of Results (Bq/m^3)**	**Average Result (Bq/m^3)**	**# of Detectors**
Sydney	10.5 – 91.4	28.9	11
Lingan	0.1 – 11.2	4.9	10
Wreck Cove	3.1 – 31.2	13.1	6
Neil's Harbour	3.1 – 9.5	6.6	5

Location (Nova Scotia)	**Range of Results (Bq/m^3)**	**Average Result (Bq/m^3)**	**# of Detectors**
Cheticamp	1.6 – 13.8	8.6	5
Inverness	1.2 – 6.8	4.5	7
Port Hawkesbury	-1.9 – 12.0	3.4	10
Pt. Aconi	10.6 – 43.7	22.3	20
Trenton	-2.0 – 7.7	1.0	10
Lakeside	-0.7 – 75.8	22.7	20
Dartmouth	0.3 – 40.7	12.1	11
St. Margaret's Bay	**39.1 – 169.1**	**94.0**	5
Glace Bay	53.5 – 70.3	57	9
Louisbourg	5.8 – 18.8	10.8	4
North Sydney	9.6 – 53.8	21.8	19
Bedford	12.9 – 13.8	13.4	4
Coxheath	**58.5 – 202.1**	**98.6**	14
		Total # of Detectors	170

In the two workplaces where some sample results were above 150 Bq/m^3, advice was given to sign the areas and limit access to no more than 4 hours per day. Both workplaces requested education sessions, and both workplaces will be provided these by the researcher (planned for April 28, 2009). Fortunately both locations did not normally have occupancy more than 2 hours per day, so no real change had to take place other than posting signs and educating staff. For the most part, the staff took the information well, and showed signs of being interested in monitoring their own homes, which are located nearby. Their health and safety committees and safety officers were included in the education session, and they are planning to make radon an item for their annual OHS program review.

Data Management

Appendix 1 shows the blank corrected results for all the samples taken, excluding blanks. Appendix 2 shows the blank data and analysis. The geometric average exposure of the blanks from Appendix 1, Figure 2 is 660 $Bq.d/m^3$. (The distribution approximated a log-normal, so the arithmetic mean is high). The blank bias is removed from each measurement by multiplying the reported concentration by the exposure time (days) to give the exposure in $Bq.d/m^3$, subtracting 660 $Bq.d/m^3$, and then dividing the corrected exposure by the exposure time (days) to give average concentration Bq/m^3.

Appendix 3 shows the data for the duplicates and analysis. At low radon concentrations the measurement precision is low, which is a function of the alpha track technology. Only one pair of detectors was exposed to concentrations over 42.8 Bq/m^3. The exposure difference corrected for blank between the two detectors against the mean exposure for that pair was 7%. Excluding that pair, Figure 2 plots the exposure difference corrected for blank between the two detectors against the mean exposure for the pair. There is a large scatter, but the mean difference in reported exposure between pairs of dosimeters is ~30% of average reading plus 180 $Bq.d/m^3$; equivalent to 30% +2 Bq/m^3 in concentration terms. This equation applies up to 40 Bq/m^3, but 80% of the measurements are less than that value, and this may be used as an estimate of the uncertainty for those measurements. Although the percentage uncertainty may seem high, at these low concentrations, comparable to outside air, it is without practical significance from an occupational health point of view. The uncertainty at 200 Bq/m^3 is probably less than 10%, based on the single pair at that level.

Implications for future research

Key objectives were met during this research activity. We obtained relevant information on a relatively uncharacterized hazard in NS workplaces, performed workplace assessments for individual workplaces, increased awareness of worker potential health risks from radon in NS, and recommended changes to help lower health risk to workers.

Based on the results being very low for the targeted workplaces, it is possible that ventilation on an industrial level has reduced the amount of radon being present in the workplace air. The majority of workplaces had very large square footage, with good natural ventilation. The two readings that were closer to the lower limit were in workplaces with little or no ventilation in the measurement locations. Both workplaces had low levels of occupancy throughout the day, which means little activity and air dispersion. These factors could have contributed to the radon concentrations seen.

The results indicate that workplace radon concentrations in these selected NS workplaces were not significant from an exposure point of view. Future work should be done on smaller or poorly ventilated businesses in targeted geographic locations. In addition, if low exposures are likely, a longer exposure time of up to 12 months would improve the precision.

Identification of immediate and long term benefits of the findings

Immediate Benefits:

- Provision of education to Nova Scotia employees working in the participating industries. >1000 employees at the 21 monitored workplaces in NS, became more aware of radon by virtue of participating in the study.
- General improvement in the radon knowledge level of participating workplaces, occupational health and safety committees, safety officers and employees.
- Anecdotally reported increase in home radon testing by employees in the target workplaces.
- Increased knowledge by attendees at seminars, lectures and conferences put on by the researchers including:
    - 51 attendees at CIPHI session on March 13, 2009 (Attendees included inspectors from NS Agriculture and fisheries, NS Environment, NS Health Promotion, Health Canada)
    - 20 attendees at SSNS safety conference on March 26, 2009 (attendees included employee and health and safety representatives from Nova Scotia industry)
    - 180 attendees at the Cape Breton Cancer Symposium, October 2008
    - Attendees at Prevent Cancer Now Speakers Series, April 28, Halifax.

- Attendees at Prevent Cancer Now Speakers Series, April 29, Wolfville.
- Attendees at AIHCE in Toronto, planned for June 1, 2009.
- 67 students in the Public Health Degree, Cape Breton University

Long term benefits

The long term benefits would be the inclusion of radon as a routine occupational health and safety issue to consider in future planning for impacted industries. The two workplaces where radon was determined to be present at more than 150 bq/m^3 will revisit the issue each year as a standing item on their OHS committee. This will ensure long term commitment to the issue, and an increase in the level of interest in radon overall.

Identification of relevant user groups for the project results

Department of Labour
Department of Environment
Department of Agriculture and Fisheries
Health Canada
Health Canada, First Nations and Inuit Branch
WCB of Nova Scotia (Workers' Compensation Board)
Cape Breton District Health Authority
Cape Breton Cancer Centre

Dissemination/knowledge transfer

The major effort of this project was to disseminate information during seminars and conferences. This effort will continue over the next six months.

Formal dissemination of information will also take place in a report format to the stakeholders listed above.

In addition, a research paper will be written to submit to journals which may have relevant target groups as readers, such as:

Environmental Health Review (CIPHI journal)

Health Physics

Radiation Protection Dosimetry

Radioprotection

Journal of the Society for Radiological Protection

Canadian Journal of Public Health

Journal of Occupational and Environmental Hygiene

Acknowledgements

The author would like to thank all the workplaces for their participation. In particular, thanks is given to Milton Howley, Milton Cooke, Karen Butterworth, Angelina Polegato and Harris McNamara for their assistance. Appreciation is expressed to Workers' Compensation Board of Nova Scotia and WorkSafeBC for their support and funding.

References

American Lung Association: What is Radon? Accessed on July 8, 2009 from http://www.lungusa.org/site/pp.asp?c=dvLUK9O0E&b=35395.

Annanmäki M.K, Oksanen F, Markkanen, M (1996). Radon at workplaces other than mines and underground excavations. *Environment International 22*(1): 769-772. Retrieved June 23, 2008 from Science Direct database.doi:10.1016/S0160-4120(96)00181-X

CCOHS, Radon in buildings (2005). Canadian Center for Occupational Health and Safety. Retrieved June 30, 2008 from http://www.ccohs.ca/oshanswers/phys_agents/radon.html

Chen, J. (2005). Lung Cancer Risk due to Radon Exposure for 10-20 Years. International Congress Series. 1276, 442-443. Retrieved on May 14, 2006 from Science Direct.

Colgan, P.A., Madden, J.S., Synnott, H., Fennell, S., Pollard, D., Fenton, D. (2004). Current status of programs to measure and reduce radon exposure in Irish workplaces. Journal of Radiological Protection. 24, 121-129. Retrieved May 19, 2006 from Institute of Physics Publishing Database.

Copes, R., & Scott, J. (2007). Radon exposure: Can we make a difference? Canadian Medical Association. doi:10.1503/cmaj.070559

Radon around the world (2005, autumn). Environmental Radon Newsletter, Issue 5. Retrieved June 29, 2008 from http://www.hpa.org.uk/web/HPAwebFile/HPAweb_C/1194947378773.

Harris, D.B., and Craig, A.B. Control of Radon Releases in Indoor Commercial Water Treatment. USEPA Office of Air and Energy Engineering Research Laboratory, 1991.

Health Canada. (2006). It's Your Health-Radon. Retrieved on May 30, 2006 from http://www.hc-sc.gc.ca/iyh-vsv/environ/radon_e.html

Health Canada. (2006). Report of the Radon Working Group on a new Radon Guideline for Canada.

Kendall, G.M., Smith, T.J. (2002). Doses to Organs and tissues from Radon and its Decay Products. Journal of Radiological Protection. 22, 389-406. Retrieved May 12, 2006 from Institute of Physics Publishing Database.

Klassen, R.A., Garrett, R.G., DiLabio, R.N.W. (2002). Natural Sources of Trace Element Contaminants. Environment Canada. Retrieved May 10 from http://www.nwri.ca/threatsfull/ch14-1-e.html

Lewis, R. An Investigation of Radon Occurrence in Pennsylvania Fish and Boat Commission Fish Culture Stations. Proceedings of the International Radon Conference, Daytona Beach, Fl. October 21-26, 2001.

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Minister of Public Works and Government Services Canada, Canadian Guidelines for the Management of Naturally Occurring Radioactive Materials (NORM), 2000, ISBN: 0-662-29448-3, Cat. No.: H46-1/30-2000E .

Orlando, P., Trenta, R., Bruno, M., Orlando, C., Ratti, A., Ferrari, S., Piardi, S. (2003). A study about remedial measures to reduce ^{222}Rn concentration in an experimental building. Journal of Environmental Radioactivity. 73, 257-266. Retrieved on May 10, 2006 from Science Direct.

Province of Nova Scotia. (2006). Potential Occurrence-Radon Gas-Nova Scotia (Map). Retrieved on May 5, 2006 from http://www.gov.ns.ca/enla/water/radonmap.asp

Radon in workplaces. Radiological Protection Institute of Ireland. Retrieved June 13, 2008 from http://www.rpii.ie/radon/workplcs.html.

Ruano-Ravina, A., Castro-Bernárdez, M., Sande-Meijide, M., Vargas, A., & Barros-Dios, J. M. (2008). Short- versus long-term radon detectors: A comparative study in Galicia, NW Spain. *Journal of Environmental Radioactivity, 99*(7), 1121-1126.

UNSCEAR 2000, Annex B, Paragraph 121, accessed July 8, 2009 from http://www.unscear.org/unscear/en/publications.html.

Appendix 1

Blank Corrected Average Radon Concentrations

Detector Number	**Date Out.**	**Date In**		Bq/m3
J22584	7-May	6-Aug		misssing
J32120	7-May	6-Aug		21.1
J32223	7-May	6-Aug		25.4
J32273	7-May	6-Aug		91.4
J32292	7-May	6-Aug		20.4
J32322	7-May	6-Aug		30.1
J32327	7-May	6-Aug		10.5
J32339	7-May	8-Aug		33.2
			ave	33.2
J32350	22-May	23-Aug		13.4
J32355	9-May	8-Aug		20.4
J32359	9-May	8-Aug		11.8
J32360	9-May	8-Aug		41.0
J32391	9-May	8-Aug		24.6
J32414	9-May	8-Aug		24.5
			ave	24.5
J32487	13-May	12-Aug		7.2
J32566	13-May	12-Aug		3.1
J32577	13-May	12-Aug		5.4
J32637	13-May	12-Aug		31.2
J32676	13-May	12-Aug		15.7
J32678	13-May	12-Aug		15.6
J32415	13-May	12-Aug		13.1
			ave	13.1
J32721	13-May	12-Aug		4.3
J32722	13-May	12-Aug		8.0
J32731	13-May	12-Aug		3.1
J32739	13-May	12-Aug		9.5
J32740	13-May	12-Aug		7.7
			ave	6.6
J32779	14-May	13-Aug		13.8
J32783	14-May	13-Aug		6.3
J32789	14-May	13-Aug		10.8
J32791	14-May	13-Aug		10.3
J32807	14-May	13-Aug		1.6
			ave	8.6

J32908	14-May	13-Aug		6.1
J32919	14-May	13-Aug		5.2
J32922	14-May	13-Aug		6.8
J32925	14-May	13-Aug		5.1
J32940	14-May	13-Aug		3.5
J32946	14-May	13-Aug		3.6
J32960	14-May	13-Aug		1.2
J32434	14-May	13-Aug		4.5
			ave	4.5
J32980	15-May	14-Aug		5.1
J32985	15-May	14-Aug		0.6
J32989	15-May	14-Aug		3.7
J32995	15-May	14-Aug		5.8
J33005	15-May	14-Aug		11.2
J33014	15-May	14-Aug		1.0
J33018	15-May	14-Aug		2.3
J33020	15-May	14-Aug		10.6
J33021	15-May	14-Aug		0.1
J33025	15-May	14-Aug		8.5
J32341	15-May	14-Aug		4.9
			ave	4.9
J33033	21-May	20-Aug		2.7
J33048	21-May	20-Aug		0.1
J33050	21-May	20-Aug		12.0
J33052	21-May	20-Aug		1.5
J33067	21-May	20-Aug		-0.4
J33071	21-May	20-Aug		1.5
J33072	21-May	20-Aug		-1.9
J33086	21-May	20-Aug		9.3
J33088	21-May	20-Aug		2.1
J33089	21-May	25-Aug		6.6
J32445	21-May	20-Aug		3.4
			ave	3.4
J33095	26-May	25-Aug		-1.3
J33098	26-May	25-Aug		0.7
J33104	26-May	25-Aug		1.9
J33117	26-May	25-Aug		-1.1
J33119	26-May	25-Aug		-0.3
J33134	26-May	25-Aug		2.2
J33135	26-May	25-Aug		7.7
J33148	26-May	25-Aug		-2.0
J33149	26-May	25-Aug		-1.9
J33157	26-May	25-Aug		3.9
J32448	26-May	25-Aug		1.0
			ave	1.0
J33174	26-May	25-Aug		13.8

J33181	26-May	25-Aug		12.9
			ave	13.4
J33215	27-May	26-Aug		14.9
J34392	27-May	26-Aug		23.1
J34397	27-May	26-Aug		19.4
J34399	27-May	26-Aug		27.8
J34402	27-May	26-Aug		23.4
J34408	27-May	26-Aug		26.9
J34410	27-May	26-Aug		26.3
J34416	27-May	26-Aug		30.1
J34417	27-May	26-Aug		75.8
J34429	27-May	26-Aug		59.4
J32459	27-May	26-Aug		21.7
J34433	27-May	26-Aug		22.3
J34435	27-May	26-Aug		15.0
J34437	27-May	26-Aug		16.4
J34438	27-May	26-Aug		28.7
J34452	27-May	26-Aug		33.9
J34454	27-May	26-Aug		4.3
J34456	27-May	26-Aug		-0.7
J34466	27-May	26-Aug		0.2
J34475	27-May	26-Aug		-0.4
J34480	27-May	26-Aug		7.9
			ave	22.7
J34481	27-May	26-Aug		6.8
J34497	27-May	26-Aug		6.8
J34507	27-May	26-Aug		0.3
J34509	27-May	26-Aug		3.1
J34511	27-May	26-Aug		0.6
J34521	27-May	26-Aug		5.2
J34531	27-May	26-Aug		2.6
J34539	27-May	26-Aug		4.0
J34540	27-May	26-Aug		0.5
J34544	27-May	26-Aug		3.4
			ave	3.4
J34546	27-May	26-Aug		40.3
J34549	27-May	26-Aug		40.7
J34557	27-May	26-Aug		21.3
J34604	27-May	26-Aug		159.0
J34610	27-May	29-Sep		169.1
J34612	27-May	29-Sep		62.3
J34621	27-May	29-Sep		40.2
J34629	27-May	29-Sep		39.1
			ave	94.0
J34667	5-Jun	9-Sep		55.1

J34669	5-Jun	9-Sep		55.2
J34671	5-Jun	9-Sep		70.3
J34673	5-Jun	9-Sep		53.5
J34675	5-Jun	9-Sep		50.8
J34761	5-Jun	9-Sep		57.0
				57.0
J34699	27-Jun	8-Oct		12.3
J34708	27-Jun	8-Oct		6.5
J34710	27-Jun	8-Oct		5.8
J34712	27-Jun	8-Oct		18.8
			ave	10.8
J34714	27-Jun	25-Sep		53.8
J34715	27-Jun	25-Sep		15.4
J34716	27-Jun	25-Sep		17.1
J34718	27-Jun	25-Sep		42.8
J34723	27-Jun	25-Sep		15.2
J34755	27-Jun	25-Sep		28.8
			ave	28.8
J34725	3-Jul	8-Oct		21.4
J34730	3-Jul	8-Oct		23.1
J34732	3-Jul	8-Oct		7.6
J34736	3-Jul	8-Oct		88.1
			ave	35.0
J34773	19-Sep	8-Jan-09		66.7
J34775	19-Sep	8-Jan-09		58.5
J34781	19-Sep	8-Jan-09		62.5
J34783	19-Sep	8-Jan-09		77.0
J34787	19-Sep	8-Jan-09		66.6
J34788	19-Sep	8-Jan-09		75.0
J34790	19-Sep	8-Jan-09		111.1
J34792	19-Sep	8-Jan-09		106.1
J34794	19-Sep	8-Jan-09		90.2
J34809	19-Sep	8-Jan-09		73.6
J34818	19-Sep	8-Jan-09		202.1
J34826	19-Sep	8-Jan-09		186.6
J34830	19-Sep	8-Jan-09		84.8
J34833	19-Sep	8-Jan-09		120.2
J34834	19-Sep	8-Jan-09		98.6
			ave	98.6
J34838	24-Sep	6-Jan-09		33.6
J34841	24-Sep	6-Jan-09		33.2
J34842	24-Sep	6-Jan-09		36.4
J34860	24-Sep	6-Jan-09		31.1
J32690	24-Sep	6-Jan-09		15.6
J32691	24-Sep	6-Jan-09		11.0

J32692	24-Sep	6-Jan-09		10.4
J32695	24-Sep	6-Jan-09		15.2
J32743	24-Sep	6-Jan-09		15.6
J32746	24-Sep	6-Jan-09		13.3
J32759	24-Sep	6-Jan-09		17.8
J32787	24-Sep	6-Jan-09		9.6
J32769	24-Sep	6-Jan-09		16.1
J32854	24-Sep	6-Jan-09		12.3
J34748	24-Sep	6-Jan-09		19.3
			ave	19.3
J32863	6-Oct	6-Jan-09		19.7
J32867	6-Oct	6-Jan-09		25.5
J32872	6-Oct	6-Jan-09		28.4
J32890	6-Oct	6-Jan-09		29.0
J32970	6-Oct	6-Jan-09		27.3
J32975	6-Oct	6-Jan-09		43.7
J32976	6-Oct	6-Jan-09		33.9
J33183	6-Oct	6-Jan-09		25.4
J33184	6-Oct	6-Jan-09		10.6
J33187	6-Oct	6-Jan-09		17.6
J33189	6-Oct	6-Jan-09		18.3
J33193	6-Oct	6-Jan-09		18.6
J33195	6-Oct	6-Jan-09		23.6
J33202	6-Oct	6-Jan-09		16.5
J33207	6-Oct	6-Jan-09		12.4
J34559	6-Oct	6-Jan-09		11.5
J34564	6-Oct	6-Jan-09		14.4
J34567	6-Oct	6-Jan-09		15.1
J34584	6-Oct	6-Jan-09		31.0
J34593	6-Oct	6-Jan-09		22.5
J34765	6-Oct	6-Jan-09		22.3
			ave	22.3
J34724	MISSING	MISSING		
J34770	5-May	8-Sep-08		20.3

Appendix 2 Blank Analysis

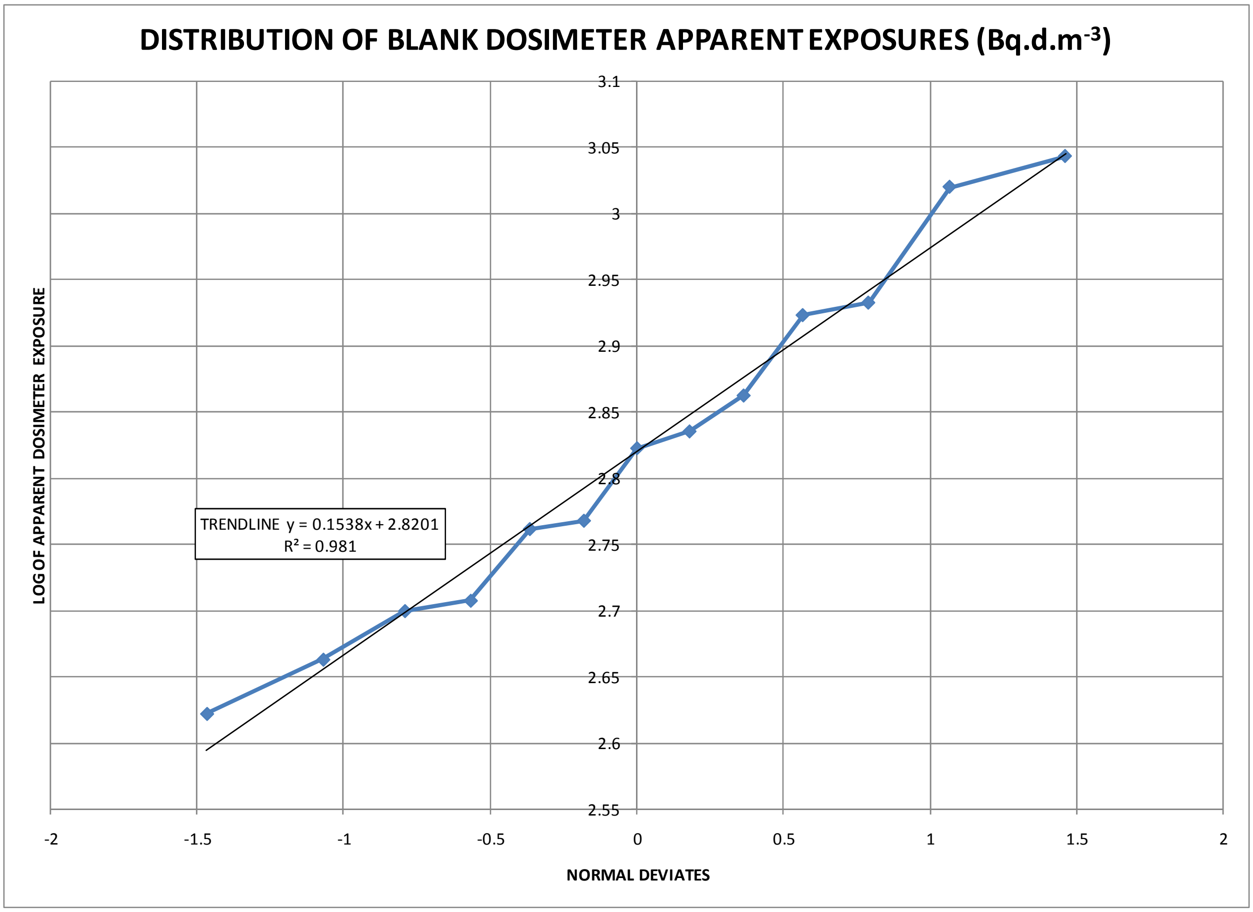

Figure 1 Blank Dosimeter Analysis

Blank Dosimeter Data

Nominal Exposure Dates		Reported average Bq.m^{-3}	Apparent Exposure (Bias) Bq.d.m^{-3}
07-May	08-Aug	9.2	855.60
09-May	08-Aug	4.6	418.60
13-May	12-Aug	4.2	382.20
14-May	13-Aug	5.5	500.50
15-May	14-Aug	11.5	1046.50
21-May	20-Aug	19.2	1747.20
26-May	25-Aug	8	728.00
27-May	26-Aug	7.3	664.30
27-May	26-Aug	9.2	837.20
05-Jun	09-Sep	6.1	585.60
27-Jun	25-Sep	7.6	684.00
19-Sep	08-Jan-09	5.2	577.20
24-Sep	06-Jan-09	4.9	509.60
06-Oct	06-Jan-09	5	460.00
06-Oct	06-Jan-09	12	1104.00

Apppendix 3 Duplicate Analysis

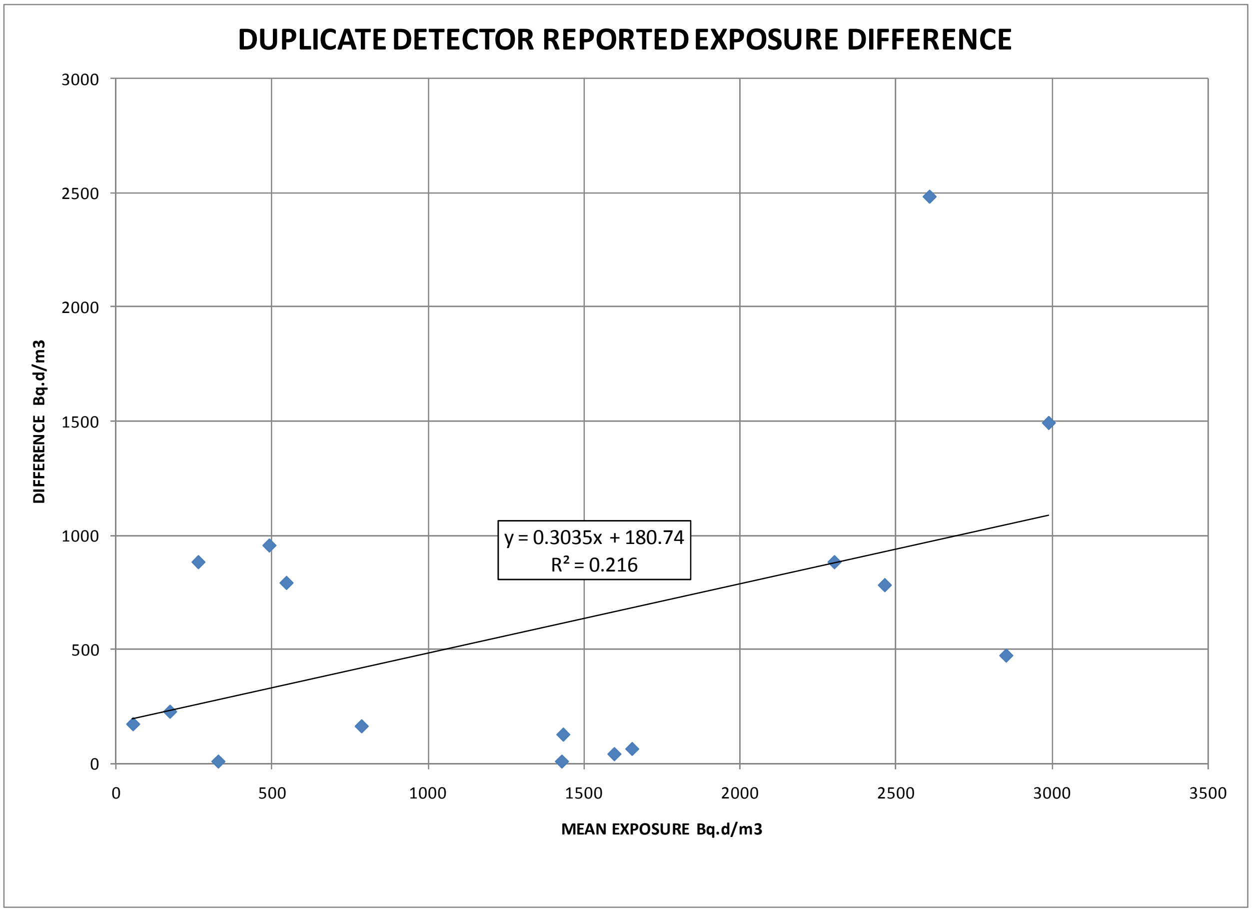

Figure 2 Duplicate Detector Difference versus Exposure

Duplicate Detector Data

Exposure Dates		Corrected Average Bq.m^{-3}	Exposure Bq.d.m^{-3}	Difference Bq.d.m^{-3}	Mean Exposure Bq.d.m^{-3}
07-May	06-Aug	20.4	1861	883	2302.05
07-May	06-Aug	30.1	2743		
09-May	08-Aug	41.0	3735	1492	2989.1
09-May	08-Aug	24.6	2243		
13-May	12-Aug	15.7	1433	9	1428.45
13-May	12-Aug	15.6	1424		
13-May	12-Aug	9.5	869	164	786.9
13-May	12-Aug	7.7	705		
14-May	13-Aug	10.3	942	792	545.75

14-May	13-Aug	1.6	150		
14-May	13-Aug	3.5	323	9	327.35
14-May	13-Aug	3.6	332		
15-May	14-Aug	10.6	969	956	491.15
15-May	14-Aug	0.1	13		
21-May	20-Aug	-0.4	-32	173	54.35
21-May	20-Aug	1.5	141		
26-May	25-Aug	7.7	705	883	263.65
26-May	25-Aug	-2.0	-178		
27-May	26-Aug	15.0	1369	127	1433
27-May	26-Aug	16.4	1497		
27-May	26-Aug	28.7	2616	473	2852.6
27-May	26-Aug	33.9	3089		
27-May	26-Aug	3.1	286	228	172.65
27-May	26-Aug	0.6	59		
27-Jun	25-Sep	42.8	3849	2484	2607
27-Jun	25-Sep	15.2	1365		
19-Sep	08-Jan-09	202.1	22428	1721	21567.75
19-Sep	08-Jan-09	186.6	20708		
24-Sep	06-Jan-09	15.2	1576	42	1596.8
24-Sep	06-Jan-09	15.6	1618		
06-Oct	06-Jan-09	17.6	1622	64	1653.8
06-Oct	06-Jan-09	18.3	1686		
06-Oct	06-Jan-09	31.0	2854	782	2463.4
06-Oct	06-Jan-09	22.5	2072		