Radon Soil Gas in the Halifax Regional Municipality: Progress Report on the 2009 Sampling Program

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Introduction

Radon is a very mobile and naturally occurring, odourless, and colorless radioactive gas. Human exposure to radon has been linked to increased incidences of lung cancer. Radon is produced during the natural radioactive decay of uranium. Uranium is found in varying concentrations in all soil and rock (and other sample media including lake bottom sediments, stream sediments, lake water, stream water, vegetation, etc.) throughout Nova Scotia.

During the 2009 field season, radon soil gas samples were collected from locations in the Halifax Regional Municipality (HRM). The samples were collected as a continuation of the 2008 HRM radon soil gas study, which is part of the larger 2007 – 2008 North American Soil Geochemical Landscapes Project (NASGLP). The NASGLP is a tri-national initiative to produce a continuous, comprehensive soil geochemical map of North America, and involves human and financial resources from the federal, provincial and state geological surveys of Canada, the United States of America and Mexico. One add-on component restricted to the Canadian sampling protocols is the acquisition of radon soil gas concentrations, *in situ* gamma ray spectrometric readings and soil permeability determinations at each soil sample site.

The radon soil gas sampling component of the NASGLP evolved into a more detailed survey in the HRM late in the 2008 field season (Goodwin *et al*., 2009a). The sampling and instrumental methods used in this study are consistent with previous sampling programs described by Goodwin (2008) and Goodwin *et al*. (2009a, 2009b), except that radon sampling sites used during the 2009 field season were generally located in mature forest, whereas the 2008 HRM sample sites were typically located in municipal parks.

Sampling Methods

At each sampling site, 150 mL of soil gas were extracted and collected into a syringe from a closed system at each one of five hollow probes driven to a consistent 60 cm depth. The 150 mL of soil gas collected from each probe was transferred to an IK-250 Sampling Ionization Chamber (IC), held in the IC for 15 minutes, and subsequently connected to an ERM-3 electrometer. The ERM-3 determines the radon concentration (in kBq/m^3) of the soil gas after two minutes of processing time. *In situ* permeability measurements of the soil were also determined using Radon-JOK portable sampling equipment at each of the five probes. Similarly, an Exploranium GR-320 spectrometer was used to acquire *in situ* radiometric determinations for Total Count, eU, eTh and K using a five minute counting time. Detailed descriptions of the field sampling protocols and methodologies have been previously described in Goodwin *et al*. (2009a, 2009b).

Objectives

One of the primary objectives of this program is to determine radon soil gas concentrations, soil permeability and the soil radon potential (SRP) index within HRM, which encompasses an area where approximately 40% of the province's

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population resides. In 2008, 20 radon soil gas sites were sampled from various bedrock/soil types and the radon soil concentrations were reported by Goodwin *et al.* (2009a) for each unit sampled. Several bedrock/soil types remained untested, however, while others had relatively few data points from which to make an interpretation. The focus of the 2009 sampling program was to have a minimum of ten sample points in each of the six defined till units. As a result, 40 additional sample sites were tested in 2009 (Fig. 1).

Surficial Geology - Till Units Sampled

Two glacially derived till units dominate the surficial geology in HRM, the distally derived Lawrencetown Till and the overlying, locally derived Beaver River Till (Stea and Finck, 2001). The Beaver River Till can be formally subdivided into three mapable units based on criteria including dominant clast type, matrix composition/texture and geochemistry: (1) slate facies, (2) metasandstone facies and (3) granite facies. A brief description of each of these units has been previously reported by Goodwin *et al*. (2009a) and from references contained therein.

For the purpose of this study, the granite facies was further subdivided into three additional (but informal) units based on the underlying bedrock granite (MacDonald and Horne, 1987): (1) early granite till, derived from relatively primitive granite including granodiorite and monzogranite, (2) middle granite till, derived dominantly from a relatively moderately evolved coarse-grained leucomonzogranite, and (3) late granite till, which is dominantly derived from a relatively highly evolved fine-grained leucomonzogranite. It is further assumed, again for the purpose of this study, that the granite till is representative of the underlying granite bedrock composition. Renewal distances for the granite facies of the Beaver River Till are short, typically in the order of 400 m (Finck and Stea, 1995).

Remapping of the surficial geology in HRM using LiDAR imagery is currently in progress (Utting, 2009).

Results

Radon soil gas was detected and measured at all sample sites tested during the 2009 field season. The 2009 sites represent natural background concentrations and are not related to uranium mineralization.

The mean radon soil gas concentration representing each site sampled in 2009 was calculated using the same methodology as was employed in the 2008 sampling program (Goodwin *et al.*, 2009a). Mean radon soil gas concentrations for each of the till units sampled in 2009 and combined with the 2008 are summarized in Table 1 and presented in Figure 1.

The 2009 results closely mirror the 2008 results reported by Goodwin *et al.* (2009a). The highest mean radon soil gas concentration of 51.0 kBq/m^3 is associated with the granite facies till derived from the late stage, highly evolved, fine-grained Tantallon Leucomonzogranite located at the easternmost end of the South Mountain Batholith (MacDonald and Horne, 1987). The middle granite facies till, derived from coarse-grained Halifax Peninsula Leucomonzogranite, had a mean radon soil gas concentration of 50.2 $kBq/m^{3.}$ The primitive granite facies till, derived from Harrietsfield Monzogranite and the Sandy Lake Monzogranite, yielded the next highest mean radon soil gas concentration of 44.3 kBq/m^3.

The highest non-granite, mean radon soil gas concentration of 36.1 kBq/m^3 was associated with the slate facies till, followed by metasandstone facies till with an average radon soil gas concentration of 22.4 kBq/m^3. Consistent with the 2008 sampling, Lawrencetown Till returned the lowest mean radon soil gas concentration of 19.3 kBq/m^3.

The permeability of each of the different (formal) till units was also determined at each site using the same methodology described by Goodwin *et al*. (2009a) and results are summarized in Table 2. The most permeable till tested is the metasandstone facies of the Beaver River Till, followed by the slate facies and the granite facies of the Beaver

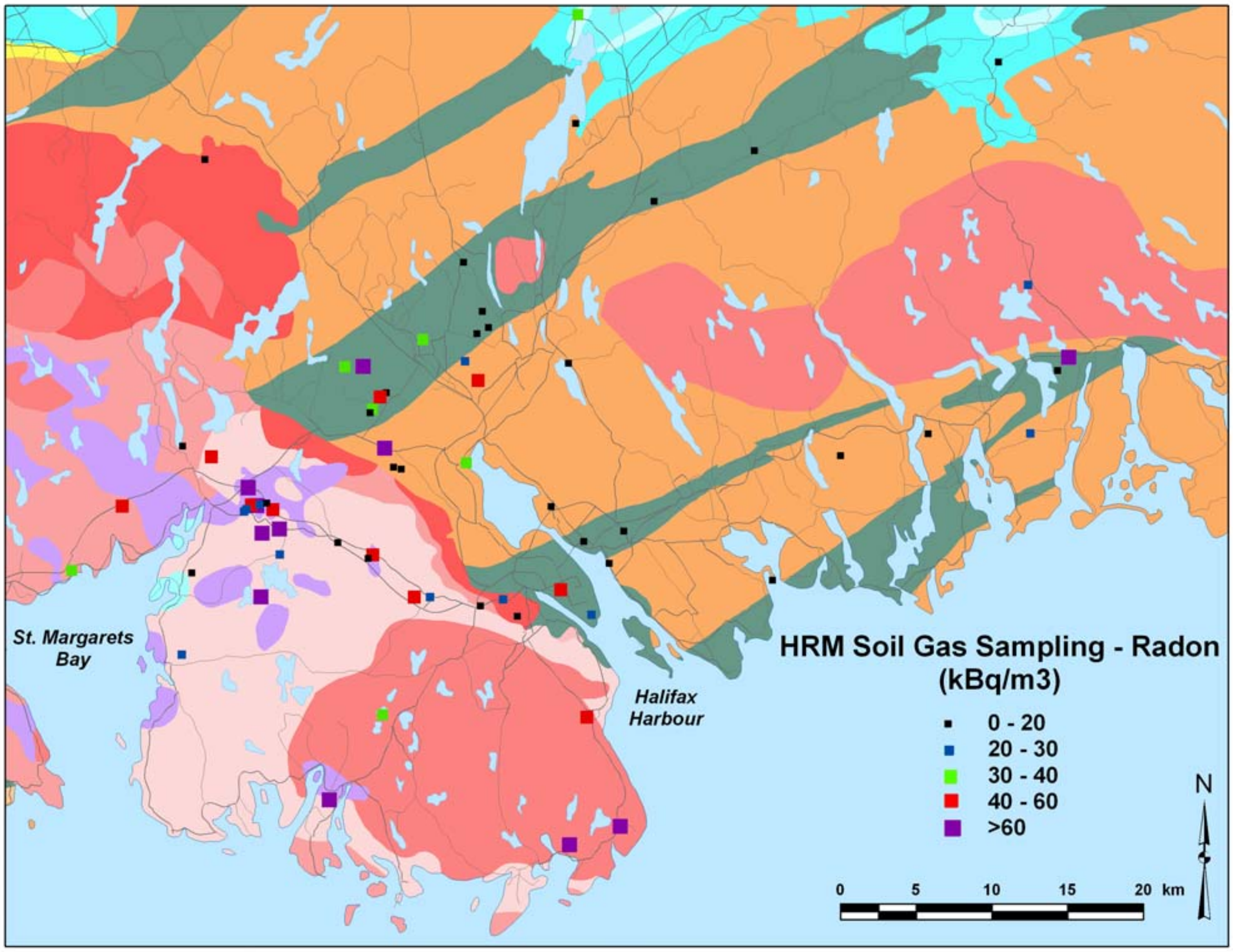

Figure 1. Sample locations and results for radon soil gas concentrations from sample sites tested during the 2008 and 2009 field seasons. Bedrock geology simplified after Keppie (2000).

River Till. The least permeable surficial material tested was the Lawrencetown Till, which is generally clay-rich.

The soil radon potential (SRP) index (Neznal *et al*., 2006) for HRM was first calculated by Goodwin *et al*. (2009a). The SRP index was recalculated for this study using the samples collected in 2008 and 2009 and results are summarized for each till unit in Table 3. Although the absolute mean SRP indexes vary slightly from data presented by Goodwin *et al*. (2009a), the order remained the same with the granite facies of the Beaver River Till yielding the highest SRP index followed by the slate facies, the metasandstone facies and the Lawrencetown Till.

Combined 2008 and 2009 summary results for *in situ* gamma ray spectrometric readings for equivalent uranium (eU), equivalent thorium (eTh) and potassium (K) are presented in Tables 4, 5 and 6, respectively. The maximum mean eU concentrations are highest in the granite facies of the Beaver River Till followed by the slate facies and metasandstone facies. Concentrations of eU are lowest in the Lawrencetown Till (Table 4). These results are nearly identical to eU results presented by Goodwin *et al*. (2009a).

The eTh concentrations, however, are highest in the slate facies of the Beaver River Till followed by metasandstone facies and the granite facies (Table 5). The lowest mean eTh concentration is associated with the Lawrencetown Till.

Table 1. Radon soil gas concentrations for the various till units sampled in 2008 and 2009.

Till Unit	n =	Mean Radon Soil Gas (kBq/m^3)
Granite Facies (evolved)	10	51.0
Granite Facies (middle)	10	50.2
Granite Facies (primitive)	10	44.3
Slate Facies	10	36.1
Metasandstone Facies	10	22.4
Lawrencetown Till	10	19.3

Table 2. Soil gas permeability results for the various till units sampled in 2008 and 2009.

Till Unit	n =	Min. (m^2)	Max. (m^2)	Mean (m^2)
Beaver River Till (BRT) (metasandstone facies)	10	1.455E-12	1.788E-11	8.61E-12
BRT (slate facies)	10	5.906E-13	1.561E-11	7.374E-12
BRT (granite facies)	30	4.490E-13	1.551E-11	5.770E-12
Lawrencetown Till	10	2.000E-14	1.1562E-11	3.729E-12

Table 3. SRP indexes for the various till units sampled in 2008 and 2009.

Till Unit	n =	Min. SRP	Max. SRP	Mean SRP
Beaver River Till (BRT) (metasandstone facies)	10	5.0	37.7	15.1
BRT (slate facies)	10	8.4	45.9	27.2
BRT (granite facies)	30	7.9	101.4	34.5
Lawrencetown Till	10	-0.1	19.2	9.6

Table 4. *In situ* gamma ray results (eU) for the various till units sampled in 2008 and 2009.

Till Unit	n =	eU Min. (ppm)	eU Max. (ppm)	eU Mean (ppm)
Beaver River Till (BRT) (metasandstone facies)	10	1.0	1.8	1.3
BRT (slate facies)	10	1.0	2.5	1.6
BRT (granite facies)	30	1.0	3.9	2.0
Lawrencetown Till	10	0.8	1.4	1.0

Table 5. *In situ* gamma ray results (eTh) for the various till units sampled in 2008 and 2009.

Till Unit	n =	eTh Min. (ppm)	eTh Max. (ppm)	eTh Mean (ppm)
Beaver River Till (BRT) (metasandstone facies)	10	3.9	5.8	5.0
BRT (slate facies)	10	1.1	9.2	5.6
BRT (granite facies)	30	2.3	6.0	4.1
Lawrencetown Till	10	2.8	5.5	4.0

Table 6. *In situ* gamma ray results (K) for the various till units sampled in 2008 and 2009.

Till Unit	n =	K Min. (%)	K Max. (%)	K Mean (%)
Beaver River Till (BRT) (metasandstone facies)	10	0.8	1.4	1.1
BRT (slate facies)	10	0.6	1.6	1.1
BRT (granite facies)	30	0.7	2.3	1.4
Lawrencetown Till	10	0.6	1.4	1.0

Mean *in situ* K concentrations follow a pattern similar to eU. The highest mean K concentrations are associated with the granite facies of the Beaver River Till followed by identical mean concentrations for the slate and metasandstone facies (Table 6). The lowest K concentrations are associated with the Lawrencetown Till. The mean *in situ* K concentrations follow a similar trend reported by Goodwin *et al*. (2009a).

Conclusions

Sampling of radon in soil gas indicates that radon is present everywhere across Nova Scotia and throughout the Halifax Regional Municipality (Goodwin *et al*., 2009a, 2009b). Additional radon in soil gas samples were collected from within the municipality during 2009, and results confirm that radon is present at all sample sites. The highest radon in soil gas concentrations are associated with locally derived granite facies of the Beaver River Till, followed by its slate facies and metasandstone facies, and the distally derived Lawrencetown Till. Soil gas permeability determinations were also acquired at each sample site. The most permeable unit tested was the metasandstone facies of the Beaver River Till, followed by its slate facies and granite facies, whereas least permeable was the commonly clay-rich Lawrencetown Till. The soil radon potential (SRP) index, a measure of the soil gas radon level and permeability, was calculated for each till unit sample. The highest SRP index was associated with the granite facies of the Beaver River Till followed by its slate facies and metasandstone facies, and the lowest SRP index was associated with Lawrencetown Till.

In situ gamma ray spectrometric readings for equivalent uranium (eU), equivalent thorium (eTh) and potassium (K) were also measured at each sample site. Granite facies of the Beaver River Till had the highest readings for eU and K, whereas Lawrencetown Till had the lowest levels for eU, eTh and K.

It is anticipated that the data on radon soil gas concentrations (as it applies to a particular bedrock or soil type unit) from this study will assist health officials and municipal planners to determine if there is a correlation between homes with a high concentration of radon in indoor air with areas of naturally elevated radon in soil gas. A radon potential map for the province of Nova Scotia is currently in preparation (O'Reilly, 2009; O'Reilly *et al*., 2010).

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