PYLON ELECTRONICS INC.
APPLICATION BRIEF NUMBER 1 –

LOW LEVEL OUTDOOR RADON MEASUREMENTS

LOW LEVEL RADON - OUTDOOR AIR

Radon is a colourless, odourless, chemically inert, naturally occurring, radioactive gas which is found at varying concentrations in outdoor air. It is formed by the decay of radium and is a member of the uranium - 238 decay series. Uranium and radium are present at low concentrations in many soils, rocks and in materials, including building materials.

Radon being a radioactive gas with a half life of 3.8 days, is able to move from its generation sites to the free atmosphere, where it is transported by various mechanisms such as horizontal winds, convection and diffusion. Outdoor radon can provide valuable information on the movement of continental air masses, the movement of pollutants, and the dispersion or containment of dangerous radioactive materials.

The concentration of radon is normally less than 1 pCi/L outdoors; in fact it is usually about 0.1 pCi/L. There is considerable variability in outdoor levels however; meteorological and geological factors, and the presence of local radon emitting sources all play a role in determining the final equilibrium radon level. Uranium mill tailings, uranium ore stockpiles, nuclear test sites and processing plants, naturally occurring radon in soil, rock and water, are examples of localized sources of radon in the environment. The influence of the localized sources on the surrounding radon levels is often small and careful monitoring and analysis is often required to characterize this influence. Factors such as the strength of the source, the emanation rates, temperature, humidity and moisture, winds and the distance from the source all have an impact on the radon level.

Naturally occurring sources of radon can be distributed over large areas (province wide) and the impact of the sources on the atmospheric radon level can vary considerably location to location and from period to period. There is evidence that moisture is the principle factor affecting the emanation rate and the highest radon levels are encountered during dry periods.

Uranium mining and milling operations can result in anomalous local releases of radon to the atmosphere as a result of the omnipresent high concentrations of radium in uranium ore. Near one uranium tailings pile for example, the radon concentration in the air was 0.8 to 282 pCi/L, while one kilometre away it ranged from near background to 42 pCi/L. In a uranium mining region several mines may operate in relatively close proximity to each other. Among the man made radon sources associated with these operations are open pit mines, ore piles, milling operations and mill tailings piles. Also, it is possible in such an area to have high radium bearing geological formations on or near the earth's surface which could also present locally high natural radon sources.

In a cross Canada survey based on measurements at three meters elevation, large regional differences in the outdoor radon level were noted. Results varied from 11.0 Bq/m^3 to a high of 60.7 Bq/m^3. The mean outdoor concentrations for Manitoba (59 Bq/m^3) and Saskatchewan (61 Bq/m^3) exceeded the average indoor level of 55 Bq/m^3 in the United States. The regional variations showed little correlation with the uranium concentration of the ground as measured by gamma ray spectrometry. A major factor in the regional variations of the summer outdoor radon levels was attributed to the variations in soil moisture and its associated effect on radon flux from the soil. All communities with radon levels above 30 Bq/m^3 were located in regions where the annual precipitation was less than 550 mm per year. The high radon levels found in the prairies in the summer of 1990 may not be typical since measurements were made during a very dry period.

The measurement of the radon concentration is an important step in the maintenance and mitigation of sites contaminated with radium. Levels must be constantly monitored to prevent excessive exposure to workers and those living in the immediate environment, and to identify and spot any airborne movement of materials from the site.

RADON AS A TRACER IN THE ATMOSPHERE

Radon is an ideal tracer being a chemically inert gas, easy to measure, and being a radioactive gas with a half life of 3.8 days, it is able to move from its generation sites to the free atmosphere.

Radon and its progeny have been used to study atmospheric mixing, vertical advection, residence and transit times of atmospheric molecules over land and oceans and to establish the boundaries of continental air masses. It is a useful surrogate to study the movement of chemical pollutants.

Continental and Marine Air Masses

Radon is being continuously emitted from all land masses. It also emanates from the oceans but at a rate two or three orders of magnitude smaller than from land areas, and this enables radon to be used as a tracer. Thus if an air mass passes over land it accumulates radon and when it moves over the ocean where the radon concentration is normally low, its presence is easily identified.

The relative amounts of radon and its progeny are indicative of the residence and transit times over land and oceans. It is also indicative of the exchange or mixing of air masses between the stratosphere and the troposphere.

Shipboard measurements have shown that pulses of radon called radonic storms are often encountered over ocean areas and are often associated with high concentrations of continental dust. A history of the air, addressing such features as time since departure from continental areas, general area of origin, and possible intermediate brief excursions over land, can be established by combining radon concentration data with weather chart analysis.

As early as 1951, Israel pointed out the potential of using radon as an atmospheric tracer, particularly for diffusion studies in the troposphere and as a marker of continental air masses.

Many of the studies have been concerned with the horizontal transport of air masses in the lower atmosphere. The large difference between continental and marine radon concentrations has been used to determine precisely the origin of air masses studied in remote areas, even though meteorological data was unavailable. Larson found correlation’s between fog and continental air mass advection characteristics by high level radon concentrations in the arctic areas. Andreae et al used radon to determine the time of trans pacific transit of air masses from the Asian continent to the United States. Gaudry et al used radon to calibrate emissions of CO_2 from South Africa.

In one 15 year study radon measurements at remote stations in the arctic and subarctic areas gave radon concentrations of 0.1 - 2.0 pCi/m^3. However, sharp increases generally give concentrations reaching 3 - 20 pCi/m^3. Because of the negligible degassing of radon over the sea surfaces, such peaks are accounted for by long range transport from remote continents (mainly South Africa) over southern Indian and Antarctic oceans, with transit times of 1.5 to 7 days and very low dilution factors of 3 to 7. This air mass transport is related to warm sectors of cyclonic systems passing over South Africa and around the Antarctic continent.

Nocturnal Air Drainage

The trapping of atmospheric trace gases and pollutants by inversion at or near ground level is a well known phenomenon. This is especially noticeable in the case of radon originating from the soil. During the night the radon concentration in the atmosphere increases when it is stable, reaching a maximum near dawn.

Cumulus Convection

Thermal updrafts associated with cumulus cloud development carry radon up into the atmosphere. Radon has been used as a tracer in the study of entrainment, mixing and outflow patterns during the growth of cumulus cloud systems.

Pollutants

The lifetime and source characteristics of radon are the same order as those of many air pollutants such as NO_2, CO and methane and many of the moderately active hydrocarbons. Thus radon is a good surrogate for studying the transport of atmospheric pollutants.

Radon has been used to study the vertical transport of pollutants between the regions near urban centers and the free troposphere. It has been shown that the concentration of radon decreases less with height in the troposphere in the summer and the upward mixing in the mid troposphere is efficient.

MEASUREMENT OF RADON GAS IN THE OUTDOOR ENVIRONMENT

Since radon and its daughter products are radioactive, their concentration can be determined by detecting the alpha, beta and gamma radiation which they emit. Alpha particle detection by means of a silver activated zinc sulphide scintillator coupled to a photomultiplier tube is by far the most sensitive active technique for both the gases and the radon daughter progeny. Thus a sample of gas or progeny is collected and as the sample decays it emits alpha particles which produce a light pulse upon impact with the scintillator. This light pulse is detected and amplified by a photomultiplier tube, then counted by a scalar. Various algorithms are employed to relate the count measured to the concentration of radon and its progeny.

Continuous and Quasi Continuous Measurements

In many of the field measurement objectives mentioned, there is a need for continuous measurements at a number of sampling sites. By means of continuous measurements the radon concentration is determined at regular intervals (hourly, daily) and any patterns established (diurnal variations etc.) at each site. The concentration of radon can be logged and the information regularly stored electronically or a hard copy printed on some regular basis.

In general, measurements should be made over as long a period as possible to include diurnal (day and night fluctuations), seasonal, and moisture influences. Moisture in particular plays a major influence in the radon emanation rate from soils. Continuous measurements can warn of excessively high radon levels or the dispersion of hazardous materials.

Continuous measurements must be made with an electronic recorder-logger equipped with a very sensitive radon sensor capable of measuring to less than 0.01 pCi/L (trace level). A sensitivity to 1.0 pCi/m^3 is sometimes required. The system must be reliable and rugged since it is often located remotely in the outdoor environment. It must operate with minimum servicing over prolonged periods.

A sensitive, active measurement system such as the Pylon Trace Level Radon Gas Detector (TEL) in conjunction with the AB-5 data logger is needed for this type of measurement. Data can be logged over prolonged periods and a hard copy provided. In fact the Pylon TEL-AB-5 detector system is the only commercially available active radon measurement system capable of measurements at the trace level.

The TEL-AB-5 detector system can be readily adapted with a minimum of peripheral equipment to meet many of the measurement objectives mentioned above. This detector achieves high sensitivity by electrically focusing a 20 liter volume of air onto a scintillator-photomultiplier based sensor. The AB-5 monitor is equipped with a pump which draws an air sample into the TEL on a continuous or intermittent basis. Once inside the radon decays into its alpha emitting radioactive daughters, the first of which (RaA) is positively charged. The charged daughter is attracted to the negatively charged center electrode of the TEL. The center electrode is coated with a silver activated zinc sulphide phosphor which produces a strong light emission when impacted with an alpha particle from the radon daughter. The light pulse is detected by a photomultiplier tube, is counted, and the event logged by the AB-5 detector system. A series of measurements can then be dumped to a computer for analysis.

The high sensitivity of the TEL is due to its large sensitive volume (20 L) and low background noise level. In fact, the sensitivity can be readily varied by changing the volume to meet specialized measurement objectives.

In a typical measurement setup the recorder-logger is set to record hourly radon levels. Other measurements of importance such as air and soil temperature, air and soil humidity, wind speed and direction, particulate levels, and soil evapotranspiration rates are often made in association with the radon measurements since these data will assist in the interpretation of the radon levels.

The equipment is normally housed in a weather and tamperproof enclosure and a number of monitoring sites are established, enclosing the area to be monitored. In addition to the measuring equipment at the site, the nature of the surrounding terrain is often noted. Thus, the soil and rock type, vegetation, surface water, local geography, water table etc. are characterized since they all contribute to the radon level being measured.

The TEL-AB-5 system can also be used to test the level of radon at preprogrammed times (quasi continuous or grab sampling) or over extended periods. Grab samples may be taken twice daily, for example, where the interest is in measuring radon levels that change slowly with time i.e. daily fluctuations are small. With the TEL-AB-5 system up to 99 repetitions can be logged.

Integrated Measurements

In some situations an average radon concentration over a prolonged period is all that is needed. Integrating monitors based on cellulose films or TLDs are often employed for this purpose.

Alpha particles from the radon gas and the daughters present in the vicinity of the film melt small tracks upon impact and penetration of the cellulose film, the number of tracks being proportional to the concentration of radon gas and the length of the monitoring period. The tracks are enlarged chemically or electrically and counted manually or by means of a computer scanning program.

With TLDs (thermoluminescent dosimeters) the alpha energy is stored in a small chip, to be released at a later time upon heating. The amount of energy stored in a given experiment is a measure of the alpha energy per incident and the total number of incidents.

Cellulose film monitors and TLDs do not provide information on radon peaks. They are termed integrating monitors and the average radon level for the monitoring period is determined. They are useful where there is a need to monitor a large number of sites and an inexpensive procedure is needed. They cannot be analyzed on site, and must be sent to a laboratory for analysis.

The sensors are small and readily deployed by mounting in an elevated enclosure. The elevation is determined by the nature of the study, the nature of the surrounding terrain and vegetation, the local and prevailing wind currents and normally must be high enough to escape the influence of the radon escaping from the local soil and rock.

The minimum level detectable is very much related to the period of exposure and a monitoring period up to a year is often required to determine outdoor radon levels.

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