The object of this study is to measure radon concentrations, both in the soil and buildings of the JRC Ispra, in order to compile a radon map indicating areas with low, medium and high concentrations. The monitoring is being performed following the recommendations for the implementation of Title VII of the European Basic Safety Standards Directive (BSS) concerning significant increase in exposure due to natural radiation sources. For measuring radon both passive and active methods are being used. The passive method is a passive track detector in Karlsruhe beakers. The active instrument used for indoor measurements is a portable radon monitor “Alphaguard PQ2000”. The study is divided into two parts: soil air measurements and indoor measurements. For soil air measurements a geological study of the area was performed in order to identify measurement sites and understand the relationship between radon emission and soil type. A thick layer of alluvial and glacial deposits covers the JRC area with more than 100 meters thickness in some sites. 38 measurement sites were chosen to cover the whole area. The measurements commenced in August 1998 and will be completed after one year to take into account seasonal variations, which are critical especially for outdoor measurements.

The mean concentration measured so far for every site is less than 10000 Bq/m³. For indoor measurements monitoring in many buildings is being performed both with active and with passive methods. The mean concentration measured, with the active monitor, for all buildings is less than 50 Bq/m³ in both old and new constructions.

The results so far obtained indicate that the JRC territory is not a radon prone area. The thickness, composition and low permeability of superficial deposits may be the reason for low radon concentrations in this area.

INTRODUCTION

The object of this study is to measure the radon concentration, in both the soil air and buildings of the Joint Research Centre (JRC) Ispra. The object is to compile a radon map indicating areas with different concentrations and for the radioprotection of workers. This study was necessary for two main reasons: the first is that in the Angera area, close to Ispra, very high radon concentrations have been measured in many buildings. The second is the “EcoCentre” project that intends to transform the centre’s environmental impact within few years, turning it into a model for other research centres. The aim of the project is to have an ecological and economical centre by transforming the original buildings and services designed for nuclear research.

The radon monitoring in the JRC is being performed following the recommendations for the implementation of Title VII of the European Basic Safety Standards Directive (BSS) (European Commission, 1997, pp. 7-18) concerning significant increase in exposure due to natural radiation sources. This technical guide suggests ways of identifying the types of work activities that should be made subject to control, and the nature of the controls that may then be appropriate. Title VII of the European Union BSS has for the first time set down a framework for controlling exposures to natural radiation sources arising from work activities. With regard to radon in the workplace the guide suggests investigations of the geographical variation of radon exposures in both above ground workplaces like offices and below ground workplaces. Radon surveys should be based on reliable long-term measurements (one year) in workplaces in order to average out short-term variation in radon levels. It will be necessary to take into account differences between concentrations averaged
over 24 hours and those encountered during the working day. Geological information may be a useful general guide to identifying areas where radon levels in buildings are likely to be above average. However, there is a complex relationship between geological parameters and radon levels in buildings. Nevertheless, geological maps can be helpful in interpolating the results of surveys of radon in buildings.

**AREA DESCRIPTION**

The Ispra Research Centre located on the eastern shore of lake Maggiore in Italy, was set up in 1956 as a nuclear research centre but since 1973 has seen a shift towards non-nuclear research. The centre covers a total area of 160 ha, with a built-on area of 37.5 ha, of which buildings represent 7.3%. At present, the total staff is about 1700 people with about 70000 visitors/year.

The territory around the centre has a quite heterogeneous geological situation. In the Ispra-Angera area, several types of rock outcrops exist: rhyolite and tuff (Permian), dolomite and dolomite limestone (Trias), pudding stone (Oligocene) and clay (Pliocene). Alluvial and glacial deposits with a mostly sandy loamy composition cover the bedrock. In the Ispra region, five principal subparallel and subvertical faults exist, with a NNW-SSE direction. In Angera, there are two subparallel faults with a NNE-SSW direction. A geophysical investigation showed that a tectonic valley exists corresponding to the Ispra-Angera alluvial and glacial area. This valley is probably related to the regional fault of Porto Valtravaglia-Arolo-Angera.

A thick layer of alluvial and glacial deposits covers the Joint Research Centre area with more than 100 meter thickness in some sites. Some drill samples were taken at the JRC for foundation studies, which showed the presence of a number of layers such as: fine micaceous sand, fine compact clay, loamy clay, sand pockets and loam and silty sand. The average vertical permeability measured is $10^{-9}$ m/s and the horizontal permeability is $10^{-11}$ m/s in the sandy loam and $10^{-5}$ m/s in the sand.

**MATERIALS AND METHODS**

For measuring radon concentration, both passive and active methods are used.

The passive method is a passive track detector in Karlsruhe beakers. These are used for indoor measurements and have been calibrated both in the Rijksuniversiteit Gent and in Berlin at the Bundesamt für Strahlenschutz (BfS). The beakers are left in the offices for a period of 4-6 weeks. By using this method, the average level over time is obtained. Fluctuations due to opening and closing windows and doors and in particular fluctuations due to changes in radon soil emission rate caused by changes in atmospheric conditions are covered.

For soil measurements, a method was developed with the same Karlsruhe beakers suspended inside a PVC tube. The tube is open at the lower end and buried in the soil to a depth of 70 cm. This depth was chosen in order to measure below the topsoil that is influenced by several factors like rain, frost, and human activities. The active instrument used for indoor measurements is a portable radon monitor “Alphaguard PQ2000” based on a design-optimised pulse ionisation chamber in combination with DSP-technologies (digital signal processing). In normal operation, the gas being measured diffuses via a large-surface area glass fibre filter into the ionisation chamber. This instrument can measure a range of radon-222 concentrations from 2 Bq/m³ to 2000000 Bq/m³ and
gives simultaneous measurement of temperature, pressure and humidity. The Alphaguard PQ2000 has various calibrations referenced to accepted radon standards.

Most buildings are being monitored with particular attention given to the ground floor and underground work areas. Measurements are being performed both with active and passive methods to compare long term measurements with instantaneous measurements made during normal working hours. Measurements were started in November 1998 and were performed during the central heating period. The monitor is left in the offices for a minimum of 24 hours. The monitor measures radon concentration, temperature, air pressure and relative humidity.

Soil measurements started in August 1998 and will be completed after one year to take into account seasonal variations, which may influence greatly the results of outdoor measurements. 38 measurement sites were chosen to cover the whole area of the site. The detectors are changed on a monthly basis in order to expose the seasonal change in radon concentrations. The results will be compared with meteorological factors such as precipitation, barometric pressure and surface temperature. In addition in the same sites TLD dosimeters for $\beta$ and $\gamma$ radiation measurements are being used and to date they indicate only a background level of $\beta$-$\gamma$ radiation.

RESULTS

In all buildings the mean radon concentration is less than 50 Bq/m³ and a direct correlation between changes in meteorological factors and radon concentrations was not found.

The mean soil radon concentration measured is less than 10000 Bq/m³. The variation between different measurement sites is low.

DISCUSSION AND CONCLUSION

The results clearly indicate how much local geology effects radon emission from the subsoil. Several studies were performed in the past in the Angera-Ispra region (Facchini et al. 1983, pp. 985-988). The results of radon measurements made in many houses showed that this region could be considered as a radon risk area. In Angera, for example, radon concentrations were measured in cellars and first floors at levels of 1000-10500 Bq/m³. These high values are certainly due both to the geological situation of the area and to the building materials of the dwellings investigated. Rhyolite and tuff are magmatic rocks which are rich in uranium minerals, these are the main source of radon emission. Faults in the area can also be relevant for high radon concentration increasing permeability of radon from the soil to the atmosphere. In particular old houses in the area are built with local magmatic and metamorphic rocks. These may also be another important cause of the high indoor radon concentrations.

Although measurements made in Angera show very high concentrations, the same was not found in the JRC, only 7 km from Angera.

The thickness, composition, low vertical permeability of superficial deposits and the type of building materials is the reason for the low radon concentrations in this area. Buildings in the JRC are of various types, solid buildings, masonry and metal buildings, wood buildings, metal buildings and prefabricated buildings made of concrete, metal and wood.
It is evident from this study that when performing radon studies it is particularly important, in areas where the geology is variable over short distances, to perform a larger number of measurements.

In conclusion the results so far obtained indicate that the JRC territory is not a radon risk area. The study will be completed with a comparison between results from passive and active methods and a comparison between soil air concentrations during the year and meteorological variations.

REFERENCES


Table 1: The Joint Research Centre: Real Estate Assets

<table>
<thead>
<tr>
<th>Asset</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Total area</td>
<td>160 ha</td>
</tr>
<tr>
<td>Built-on-area</td>
<td>37.5 ha (23.5%)</td>
</tr>
<tr>
<td>Buildings</td>
<td>11.6 ha (7.3%)</td>
</tr>
<tr>
<td>Total number of buildings</td>
<td>232</td>
</tr>
<tr>
<td>Roads</td>
<td>30 km</td>
</tr>
<tr>
<td>Cultivated area</td>
<td>0.3 ha</td>
</tr>
<tr>
<td>Grassland</td>
<td>79.7 ha (49.8%)</td>
</tr>
<tr>
<td>Woodland</td>
<td>27.8 ha (17.4%)</td>
</tr>
</tbody>
</table>
Figure 1: Areal view of Joint Research Centre – Ispra
Figure 2: Geological map of the Angera-Ispra area (1: superficial deposits; 2: moraines; 3: alluvial glacial deposits; 4: Clay (Pliocene); 5: Pudding Stone (Oligocene); 6: Dolomite and Dolomite Limestone (Triassic); 7: Ryolite and Tuff (Permian); 8: faults; 9: Layer direction and dip).
Figure 3: Diffusion chamber for indoor and soil air measurement (Karlsruhe beaker) (1: external chamber wall; 2: ring to hold filter in place; 3: porous cover; 4: paper filter; 5: passive track detector) and measurement method for soil air concentration
Figure 4: Map of JRC indicating the buildings monitored (red) and all soil monitoring points (black)
Figure 5: Results of mean indoor radon concentration
Figure 6: Results of Alphaguard measurements in one of the JRC buildings
Figure 7: Results of mean soil air concentration
Figure 8: Monthly variation of soil air concentration