ELLiot Lake Technical Note No. 4

Elliot Lake Remedial Demonstration Program

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# TABLE OF CONTENTS

<table>
<thead>
<tr>
<th>Section</th>
<th>Page No.</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. INTRODUCTION</td>
<td>1</td>
</tr>
<tr>
<td>2. PROGRAM ORGANIZATION</td>
<td>1</td>
</tr>
<tr>
<td>2.1 Physical Survey</td>
<td>1</td>
</tr>
<tr>
<td>2.2 Selection of Houses</td>
<td>2</td>
</tr>
<tr>
<td>3. EXPERIMENTAL PROGRAM</td>
<td>3</td>
</tr>
<tr>
<td>3.1 Summary of Results</td>
<td>3</td>
</tr>
<tr>
<td>3.2 Baseline Monitoring</td>
<td>3</td>
</tr>
<tr>
<td>3.3 Temporary Closures</td>
<td>3</td>
</tr>
<tr>
<td>3.4 Post Installation Monitoring</td>
<td>4</td>
</tr>
<tr>
<td>3.5 Permanent Closures</td>
<td>4</td>
</tr>
<tr>
<td>4. ANALYSIS OF RESULTS</td>
<td>5</td>
</tr>
</tbody>
</table>

**Remedial Demonstration Program**

- FIGURE 1 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 2 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 3 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 4 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 5 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 6 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 7 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 8 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 9 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 10 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 11 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 12 - Radon Daughter Monitoring (WL) of Proposed Fixes
- FIGURE 13 - Radon Daughter Monitoring (WL) of Proposed Fixes
1. **INTRODUCTION**

An extensive subsurface investigation program carried out in the fall of 1977, led to the conclusion that the radon source at Elliot Lake was local soil. The small amount of radium naturally present in the soil produced radon concentrations in the soil gas of 1000-2000 pCi/l depending on porosity, and movement of this soil gas into houses resulted in the high radon/radon daughter concentrations.

This was followed by a route of radon entry survey which found that houses often had their groundwater collection system (weeping tile) connected into the basement floor drain or sump without a water trap. A trap was not required at the time the houses were built. As a result, there was a 10 cm diameter pipe connecting the house basement to the soil. The resistance to air movement of the system was measured by pumping air from the weeping tile at 1-3 m$^3$/h, and measuring the pressure drop at that flow. In most cases it was unmeasurable with our equipment - less than 0.2 mm water.

To demonstrate that it would be possible to reduce the radon concentrations in houses by simply preventing the entry of soil gas, a Remedial Demonstration Program was started in December 1977. It also provided an opportunity to field test a variety of materials and methods that could be used to close soil gas entry points temporarily or permanently.

2. **PROGRAM ORGANIZATION**

The program was organized in seven steps. These were physical survey, selection of houses, baseline monitoring, installation of temporary closures, post installation monitoring, closure removal, post removal monitoring, and in some cases, permanent closure and post closure monitoring.

2.1 **Physical Survey**

A physical survey was made of 135 houses for which there were access agreements, and the results are shown in Table 1. In addition to the weeping tile connection, a number of other entry routes were found. These included open holes in the basement floor, such as soaking pits, and plumbing modifications by the owners, large wall-floor joint cracks, and wall cracks (especially in concrete block houses).
TABLE 1

HOUSE CONSTRUCTION AND WEEPING TILE CONNECTION

<table>
<thead>
<tr>
<th>Weeping Tile Connection</th>
<th>House Construction</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Poured Concrete Basement</td>
</tr>
<tr>
<td>To Floor Drain</td>
<td>83</td>
</tr>
<tr>
<td>Sump</td>
<td>18</td>
</tr>
<tr>
<td>Other</td>
<td>10</td>
</tr>
</tbody>
</table>

Subtotal: 111 17 7

TOTAL OF HOUSE CONSTRUCTION: 135

2.2 Selection of Houses

As houses with poured concrete basements and untrapped weeping tile connections were by far the most common type of house, they received most of the investigational effort. A few houses with less common forms of construction were also included.

Three groups of houses were chosen for the program. The first group had at least one measurement in excess of 0.05 WL in the months of October and November, the second group had measured radon concentrations in excess of 150 pCi/l in drain or sump air, and the third group had at least one measurement in excess of 0.05 WL and represented an uncommon construction form. A necessary precondition was the willingness of the owners to participate in an extended study.

The features of these groups were:

<table>
<thead>
<tr>
<th>Weeping Tile Connected to:</th>
<th>No Connection</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Floor Drain</td>
<td>Sump (no basement)</td>
<td></td>
</tr>
<tr>
<td>Group 1</td>
<td>11</td>
<td>2</td>
</tr>
<tr>
<td>Group 2</td>
<td>16</td>
<td>2</td>
</tr>
<tr>
<td>Group 3</td>
<td>1</td>
<td>2</td>
</tr>
</tbody>
</table>
3. EXPERIMENTAL PROGRAM

3.1 Summary of Results

Figures 1 through 13 show daily spot sample WL measurements for each house against the installation and removal of various closures.

3.2 Baseline Monitoring

As the radon daughter concentrations are very variable, measurements were taken for 1 to 2 weeks each working day before any closures were installed. The working level (WL) was estimated by the modified Kusnetz method. Some simultaneous measurements of radon concentration were made, and average radon concentrations were measured in some houses with pump and bag averaging units for additional information, but WL's were the prime unit for comparison.

As readings accumulated, it became clear that some of the houses had average WL's that were below the remedial action limit of 0.02 WL. They were maintained in the program, as the intention was to demonstrate that closing routes of entry would reduce WL's, regardless of whether the level was high or low.

3.3 Temporary Closures

Plumber's Ball

The first temporary closure used was a 'plumber's ball'. These are used to seal piping for pressure tests. Two types were tried, mechanical and pneumatic. The mechanical ball is expanded to fit the pipe by a compression screw, but was found to be too large to fit into many drains, and was often unable to seal the weeping tile connection pipe, as the range of adjustment was too small. The pneumatic balls are short rubber cylinders, and can be inflated with a car tire-pump. Two models were tried, one with smooth walls, and the other with corrugated walls. Both could be inserted into the drain pipe easily, but the corrugated type was found to seal better. Both types lost pressure slowly by leakage through the valve, and a reliable seal could only be maintained by daily inflation.
The plumber's balls were used at the start of the program, until the foam water trap became available then their use was discontinued.

**Foam Water Trap**

In those houses where the weeping tile connected into a floor drain, this connection could be water-trapped to prevent the entry of soil gas. A plastic pipe was inserted in the floor drain to below the level of the water in the trap, and the top of the drain closed by injecting a closed cell 2 part urethene foam around the pipe. The excess foam was then cut off level with the floor. Water could still enter the drain, but the weeping tile gas could not enter the house. This technique was used in all houses with weeping tile connected to the floor drain. The urethene foam was also used to form a temporary cover to a number of sumps.

**Tape**

Aluminized cloth duct-tape, and aluminum foil duct-tape were used to cover wall cracks. They had excellent adhesion to unprepared surfaces and were air tight.

**Caulk**

Silicone rubber 'bathtub caulk' was used to close joints and cracks. It was easy to apply, and adhered well to surfaces with the minimum of preparation. The acetic acid given off during curing made it unpleasant to work with in confined spaces, and unpopular with home owners.

Butyl rubber cartridge caulk was also tried, but did not adhere as well as silicone to unprepared surfaces.

**3.4 Post Installation Monitoring**

After a closure was installed, daily measurements for 2-3 weeks were made to discover if it had any apparent effect. If so, the closure was removed to confirm that the change in WL was the result of the closure.

**3.5 Permanent Closures**

In some cases, a new floor drain incorporating a permanent water seal to the weeping tile was installed.
4. ANALYSIS OF RESULTS

The results obtained are illustrated in figures 1-13, and are discussed house by house under their selection groups.

**GROUP 1**

Selection basis - at least one reading of 0.05 WL

<table>
<thead>
<tr>
<th>HOUSE NUMBER</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Levels were reduced to near 0.02 WL by water trapping the weeping tile. Closing wall cracks gave no further reduction. - Other routes of entry in addition to weeping tile.</td>
</tr>
<tr>
<td>23</td>
<td>Levels were reduced to near 0.02 WL by blocking and water trapping the weeping tile, opening weeping tile led to a marked increase. - Other routes of entry in addition to weeping tile.</td>
</tr>
<tr>
<td>50</td>
<td>Blocking and water trapping weeping tile made no perceptible difference. - Other major routes of entry in addition to weeping tile.</td>
</tr>
<tr>
<td>12</td>
<td>Blocking and water trapping weeping tile, closing open sewer cleanout, and tapping wall cracks made no perceptible difference. An attempt to caulk the wall floor joint was unsuccessful, as the Butyl caulk did not adhere well, and a significant part of the joint was inaccessible. - Other major routes of entry in addition to weeping tile.</td>
</tr>
<tr>
<td>18</td>
<td>Blocking and water trapping weeping tile reduced levels markedly. Installation of a new floor drain reduced levels to below 0.02 WL, but not to background levels. - Minor routes of entry in addition to weeping tile.</td>
</tr>
<tr>
<td>88</td>
<td>Blocking and water trapping the weeping tile, and taping wall cracks made no apparent difference. - Other major routes of entry in addition to weeping tile.</td>
</tr>
</tbody>
</table>
Annual average probably below 0.02 WL, but water trapping the weeping tile reduced average to background level, rising when the block was removed. Levels returned to background on installation of new drain. - Weeping tile was the major route of entry.

Blocking and water trapping the weeping tile reduced levels to below 0.02 WL, but not to background levels. - Minor routes of entry in addition to weeping tile.

Annual average probably below 0.02 WL, but blocking and water trapping the weeping tile reduced levels to background, rising when the block was removed.

Blocking the weeping tile and closing the top of the sump with foam reduced levels to below 0.02 WL. Removal of the blockage led to a marked rise. - Weeping tile was the major route of entry.

Blocking and water trapping the weeping tile reduced levels to below 0.02 WL. Removal of the blockage led to a marked rise. Installation of a new drain reduced levels to below 0.02 WL. Minor routes of entry still remain.

Blocking the weeping tile and closing the top of the sump with foam reduced levels to below 0.02 WL. Removal of the blockage led to a rise. - Other minor routes of entry in addition to weeping tile.

Water trapping the weeping tile reduced levels to near 0.02 WL, and removal led to an increase. - Other routes of entry in addition to weeping tile.

**SUMMARY**

Preventing the entry of soil gas through the weeping tile connection reduced the average WL in 10 houses of this group of 13. In 5 houses, this reduction was sufficient to reduce the average to less than 0.02 WL, and in a further 3 houses, the average was reduced from near 0.02 WL to background levels.

Preventing the entry of soil gas through the weeping tile connection made no perceptible difference in 3 houses.
CONCLUSION

The weeping tile was the major route of radon entry in 8 houses. There were additional minor routes of entry in 2 houses, and additional major routes of entry in 3 houses.

GROUP 2
Selection basis - drain air reading of at least 150 pCi/l

<table>
<thead>
<tr>
<th>HOUSE NUMBER</th>
<th>COMMENT</th>
</tr>
</thead>
<tbody>
<tr>
<td>34</td>
<td>Annual average WL near 0.02 WL, but water trapping the weeping tile reduced the level to about 0.01 WL. Removal of the trap led to a rise, and installation of a new drain reduced the level to near background. Minor routes of entry still remain.</td>
</tr>
<tr>
<td>13</td>
<td>Annual average WL probably less than 0.02 WL but water trapping the weeping tile made no perceptible difference. Other minor routes of entry in addition to weeping tile.</td>
</tr>
<tr>
<td>25</td>
<td>Covering the sump with foam made no perceptible difference. The foam did not seal properly. No conclusions possible.</td>
</tr>
<tr>
<td>32</td>
<td>Water trapping the weeping tile and taping wall cracks made no perceptible difference. Other major routes in addition to weeping tile.</td>
</tr>
<tr>
<td>19</td>
<td>Water trapping the weeping tile made no perceptible difference. Other major routes in addition to weeping tile.</td>
</tr>
<tr>
<td>22</td>
<td>Water trapping the weeping tile reduced levels to near 0.01 WL. Opening the weeping tile led to a rise, and installing a new drain again reduced levels to near background. Minor routes of entry still remain.</td>
</tr>
<tr>
<td>31</td>
<td>Water trapping the weeping tile reduced levels to near 0.01 WL. Opening the weeping tile led to a rise, and installing a new drain reduced levels to near background.</td>
</tr>
<tr>
<td>94</td>
<td>Water trapping the weeping tile decreased levels to near 0.01 WL. Opening the weeping tile led to a rise, and installation of a new drain reduced levels to near background.</td>
</tr>
</tbody>
</table>
Water trapping the weeping tile made no perceptible difference. - Other major routes in addition to weeping tile.

Water trapping the weeping tile made no perceptible difference. Installation of a new drain reduced levels to near 0.02 WL. - Another major route remains.

Closing the sump with foam gave a marked reduction to near 0.02 WL. Installing a new water trapped sump reduced the level to near background. - Weeping tile was the major route of entry to near background.

Annual average below 0.02 WL, but water trapping the weeping tile reduced levels to background. - Weeping tile is the major route of entry.

Water trapping the weeping tile made no perceptible difference. - Other major routes in addition to weeping tile.

Water trapping the weeping tile reduced levels to near 0.02 WL. - Weeping tile is the major route, but other minor routes exist.

Annual average probably below 0.02 WL, but water trapping the weeping tile and installing a new drain reduced levels to background. - Weeping tile is the major route of entry.

Annual average probably less than 0.02 WL, but water trapping the weeping tile had no perceptible effect. - Other major routes in addition to weeping tile.

Water trapping the weeping tile had no perceptible effect. - Other major routes in addition to weeping tile.

Water trapping the weeping tile had no perceptible effect. - Other major routes in addition to weeping tile.

Water trapping the weeping tile had no perceptible effect. - Other major routes in addition to weeping tile.
SUMMARY

Preventing the entry of soil gas through the weeping tile connection reduced average WL in 9 houses of this group of 18. In 6 houses this reduction was sufficient to reduce the average to less than 0.02 WL, and in a further 3 houses, the average was reduced from near 0.02 WL to near background levels.

Preventing the entry of soil gas through the weeping tile connection made no perceptible difference in 9 homes, of which 4 had averages near 0.02 WL.

CONCLUSION

The weeping tile was the major route of radon entry in 9 homes, and a minor route in 4 homes. There were additional minor routes of entry in 4 houses, and additional major routes of entry in 5 houses.

GROUP 3

Selection basis - A reading in excess of 0.05 WL and unusual construction features.

HOUSE NUMBER COMMENTS

26 This is a one story house with an extensively finished concrete block basement. Two weeping tile lines enter a sump which is drained to the sewer. The basement floor is radioactive, with 30 $\mu$R/h at waist level. Blocking the weeping tile connections and covering the sump with foam made no perceptible difference. - Other major routes in addition to weeping tile.

49 This is a two story slab on grade house, with no basement, and no internal weeping tile connection to the floor drain. The annual average is probably below 0.02 WL. Blocking the floor drain made no perceptible difference. - Other minor routes of entry.

A detailed examination of the slab found no openings or cracks in the slab with the exception of the furnace plenum. This house has the hot air distribution pipes placed under the slab, and it is believed that soil gas enters the system through gaps in the piping.
This is a single story house with an extensively finished poured concrete basement and similar design and location to house 26. It has a combination sump/soak away for the weeping tile water. Blocking the weeping tile connections made no apparent difference, but covering the sump with foam reduced levels to below 0.02 WL.

- Other minor routes of entry besides weeping tile.

This is a two story house with an unfinished poured concrete basement. This house was included because of consistently high readings, and detailed examination was possible with minimum disturbance to the owner.

Blocking and water trapping the weeping tile made no perceptible difference, to the average of 0.1 WL. Most of the wall-floor joint was then caulked with silicone, and levels fell to below 0.02 WL. Removal of the water trap from the drain led to an immediate rise back to 0.1 WL. Subsequent installation of a new drain reduced levels to below 0.02 WL.

This is a single story slab on grade house with no basement, and no internal weeping tile connections. There is no floor drain.

An open service entry connecting direct to the subsoil was discovered beneath the bath. Filling this with foam made no perceptible difference. This house has the hot air distribution pipes placed under the slab and it is believed that soil gas is entering the system through gaps in the piping and the gap between the slab and the furnace plenum.

**SUMMARY**

Two slab on grade houses without weeping tile connections were found to have large penetrations through the slab in the form of the sub-grade hot air distribution system. In two similar houses with sumps, a perceptible reduction in WL was achieved by closing the sump only in the house with the poured concrete basement.
In one house, both the weeping tile and the wall floor joint were major routes of entry. Closing either individually made no perceptible difference to the WL, but a major reduction could be achieved if both were closed.

**CONCLUSION**

Any direct connection to the soil may serve as a route of radon entry. Openings such as wall-floor joints can be major routes of entry, and if two major routes exist in the same house, closing one of them will not produce a perceptible reduction.

**PROGRAM EVALUATION**

In total, 36 houses were examined in this program. Preventing the entry of soil gas through the weeping tile connection alone was sufficient to reduce the average WL to less than 0.02 WL in 11 houses. In a further 6 houses, preventing the entry of soil gas through the weeping tile connection reduced levels from near 0.02 WL to near background. The weeping tile connection was therefore the only major route of entry in 17 houses (47%).

In the remaining 19 houses, there were obvious additional routes of entry (e.g. wall-floor joint cracks) in 7 houses. Closing the wall floor joint in the one house where it was easily accessible reduced the level to below 0.02 WL, demonstrating the importance of alternate routes of radon entry. In the remaining 12 houses, the additional routes of entry were not obvious, and were probably concealed behind paneled walls, or under wood subfloors.

Interestingly, although these houses were all identified as candidates for remedial action by the Task Force survey of 1976, 5 of the houses (15%) had averages below the action criteria of 0.02 WL.

Extrapolating these results to the 140 houses identified as candidates for remedial action, we can expect that at least 15% (21 homes) will have average below the action criteria. Of the remaining 119 homes, modifying the floor drain or sump alone will be sufficient in about 50% of the cases - or 60 homes. The remaining 60 will require more extensive work in addition to that - paneling walls and floors will have to be removed to gain access to the wall floor joint and other penetrations of the floor slab. The results obtained at house 29 give assurance that
if all the openings into the basement can be closed, then the radon concentrations will fall to near background levels.
FIGURE 1
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 2  REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 3

REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 4
REMEDIALSENATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 5
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 6
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 7
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 8
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 9
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 10
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE II
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 12
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES
FIGURE 13
REMEDIAL DEMONSTRATION PROGRAM
RADON DAUGHTER MONITORING (WL) OF PROPOSED FIXES