ELLiot Lake Technical Note No. 18

Revised Radon Concentration Equations
For the RDR-511

DSMA ATCON LTD.
Acres Consulting Services Limited

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1. **INTRODUCTION**

Technical Note 15 derived a recursive equation to correct for the presence of deposited radon daughters in the scintillation cell. An explicit form of the equation in terms of the counts observed in each counting period is more convenient, and is derived in this note.

2. **THEORY**

If \( C_n \) is the number of counts due only to the radon and associated daughters collected in the \( n \)th sampling period and \( N_n \) is the net number of counts observed in the \( n \)th counting period, then

\[
C_n = N_n - F_1C_{n-1} - F_2C_{n-2} - F_3C_{n-3} - F_4C_{n-4} \quad \text{etc.} \quad (1)
\]

where the 'Fs' represent the fractions of the deposited activity remaining from the previous sampling period. The radon concentration
is given by \( R_n = C_n/E \).

This equation can be transformed from its recursive form by expansion in terms of \( N_n \).

By recursion,

\[
C_{n-1} = N_{n-1} - F_1C_{n-2} - F_2C_{n-3} - F_3C_{n-4} \quad \text{etc.}
\]

\[
C_{n-2} = N_{n-2} - F_1C_{n-3} - F_2C_{n-4} - F_3C_{n-5}
\]

\[
C_{n-3} = N_{n-3} - F_1C_{n-4} - F_2C_{n-5} - F_3C_{n-6}
\]

\[
C_{n-4} = N_{n-4} - F_1C_{n-5} - F_2C_{n-6} - F_3C_{n-7}
\]

Truncating the series at terms in \( N_{n-1} \), we obtain:

\[
C_{n-1} = N_{n-1}
\]

\[
C_n = N_n - F_1N_{n-1}
\]
Truncating at terms in $N_{n-2}$, we obtain:

$$C_{n-2} = N_{n-2}$$

$$C_{n-1} = N_{n-1} - F_1N_{n-2}$$

$$C_n = N_n - F_1(N_{n-1} - F_1N_{n-2}) - F_2N_{n-2}$$

$$C_n = N_n - F_1^2n_{n-1} + (F_1^2 - F_2) N_{n-2}$$

Truncating at terms in $N_{n-3}$, we obtain:

$$C_{n-3} = N_{n-3}$$

$$C_{n-2} = N_{n-2} - F_1^2n_{n-3}$$

$$C_{n-1} = N_{n-1} - F_1(N_{n-2} - F_1N_{n-3}) - F_2N_{n-3}$$

$$C_n = N_n - F_1(N_{n-3} - F_1N_{n-3} - F_2N_{n-3}) - F_2(N_{n-2} - F_1N_{n-3}) - F_3N_{n-3}$$

$$C_n = N_n - F_1^2n_{n-1} + (F_1^2 - F_2) N_{n-2} + (2F_1F_2 - F_1^3 - F_3) N_{n-3}$$

Truncating at terms in $N_{n-4}$, we obtain:

$$C_{n-4} = N_{n-4}$$

$$C_{n-3} = N_{n-3} - F_1^2n_{n-4}$$

$$C_{n-2} = N_{n-2} - F_1^2n_{n-3} + (F_1^2 - F_2) N_{n-4}$$

$$C_{n-1} = N_{n-1} - F_1(N_{n-2} - F_1N_{n-3} + F_1^2 - F_2)N_{n-4} - F_2(N_{n-3} - F_1N_{n-4}) - F_3N_{n-4}$$
\[ C_n = N_n - F_1 \{(N_{n-1} - F_1(N_{n-2} - F_1N_{n-3} + (F_1^2 - F_2) N_{n-4})
- F_2(N_{n-2} - F_1N_{n-3} + (F_1^2 - F_2) N_{n-4})
- F_3(N_{n-3} - F_1N_{n-4}) - F_4N_{n-4}\}
+ (F_1^2 - F_2)N_{n-2} + 2F_1F_2 - F_1^3 - F_3\) N_{n-3}
+ (2F_1F_3 + F_2^2 + F_1^4 - 3F_2F_1^2 - F_4) N_{n-4}\]

We may write these equations in the form of:

\[ C_n = N_n + K_1N_{n-1} + K_2N_{n-2} + K_3N_{n-3} + K_4N_{n-4} \text{ etc.} \quad (2) \]

where

\[ K_1 = -F_1 \]
\[ K_2 = F_1^2 - F_2 \]
\[ K_3 = 2F_1F_2 - F_1^3 - F_3 \]
\[ K_4 = 2F_1F_3 + F_2^2 + F_1^4 - 3F_2F_1^2 - F_4 \]
\[ K_5 = 2F_1F_4 + 2F_2F_3 + 4F_1^3F_2 + F_1^5 - 3F_1^2F_3 - 3F_1F_2^2 - F_5 \]

Calculating numerical values for the 'F's by the methods of Development Report No. 13, and substituting in the above expressions, we obtain the following numerical values of K for the following count regimes:

<table>
<thead>
<tr>
<th>Sample/Count regime</th>
<th>1/29</th>
<th>1/59</th>
<th>30</th>
<th>60</th>
</tr>
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<tbody>
<tr>
<td>Counts/pCi/L</td>
<td>13.7</td>
<td>31.60</td>
<td>13.9</td>
<td>31.8</td>
</tr>
<tr>
<td>( K_1 )</td>
<td>.277</td>
<td>.347</td>
<td>.295</td>
<td>.135</td>
</tr>
<tr>
<td>( K_2 )</td>
<td>.188</td>
<td>.012</td>
<td>.112</td>
<td>.019</td>
</tr>
<tr>
<td>( K_3 )</td>
<td>.039</td>
<td>.002</td>
<td>.037</td>
<td>.001</td>
</tr>
<tr>
<td>( K_4 )</td>
<td>.002</td>
<td>---</td>
<td>.008</td>
<td>---</td>
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</table>
3. CONCLUSION

These coefficients decrease more rapidly than the 'F' coefficients, as the gross count contains information concerning previously deposited activity as well as the present radon activity, and so fewer terms are required to estimate the present radon activity. As a result, only three terms are required to provide a reasonable estimate of radon concentration for 30 minute count periods and 2 terms for 1 hour count periods.