HEALTH CANADA’S APPROACH TO MANAGE RISKS TO POPULATIONS AT RISK DURING A RADIOLOGICAL EMERGENCY

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The approach that Health Canada uses to manage risks to individuals and to populations who might be exposed to ionising radiation is based upon the risk management paradigm. The paradigm differs little between an emergency and a non-emergency situations. In both events, technical experts assess the risk by determining the exposure to the source of radiation. They usually calculate the radiation dose and then assess the potential for any health effects. The initial technical assessments often use scoping calculations. The calculations for children recognise that they are smaller and have different metabolic rates and different behaviour from adults. However, most rigorous quantitative models for dosimetry do not differentiate between children and adults. The risk assessments that were conducted to evaluate the contamination of Canadians who were in London during the Litvinenko poisoning are a good example to illustrate this general approach. The scoping risk assessment concluded that the risks to children and adults were low. No Canadian children were exposed to polonium during this event and, to date, there have been no radiation emergencies in Canada where children have been exposed to a significant source of radiation. Therefore, the comparisons between theory and practice are very limited and conclusions are drawn from international experience and other incidents or sources of radiation exposure such as radon and medical exposures.

INTRODUCTION

Shortly after the death of Mr Alexander Litvinenko in a London (UK) hospital on 23 November 2006, it was discovered that he had been poisoned by polonium-210 (210Po). The poisoning probably occurred 3 weeks earlier at the bar in a London hotel. This discovery and the subsequent identification of 210Po in other locations in and around London triggered the emergency response networks in many countries, including Canada, and attracted international media and public attention.

The radiation protection goals of Health Canada following this event were to: (1) assess the risks to Canadians who might have inadvertently been exposed, (2) identify and inform members of the public who might have been contaminated, and (3) test the radiation exposure in individuals who requested a 210Po bioassay.

In the early stages of this investigation, data were very limited. However, this situation is common to many emergencies and is not unique to the Litvinenko situation. Therefore, the methodologies that were developed for this situation have application to other future events. The purpose of this paper is to describe the risk assessment approach that was used in Canada and to evaluate the pathways of exposure to children.

RISK ASSESSMENT METHODOLOGY

In the context of this risk assessment, the contaminated person is the potential source of secondary contamination that could affect others. While the prime reason for examining the risk estimates was the Litvinenko incident, and similar emergency responses, all of the following applies to nuclear medicine patients who have received diagnostic or therapeutic doses of radionuclides.

Transfer pathways

Contamination could occur from the direct touching of the contaminated person by another person. Contamination also could be transferred from the source to a surface, or object, by touch as there may be radioactivity excreted in sweat. This contaminated object may be touched subsequently by another person and the radioactivity transferred from the surface, or object, to that person resulting in a localised skin dose. There is a potential for internalisation if the area around the mouth is touched or food is handled without washing the hands first. In the case of children, the surface, or object, may be a direct ingestion route.

In certain circumstances, radioactive contamination may be exhaled either in gaseous or aerosol form. The immediate area around the contaminated individual may now provide an inhalation pathway to those nearby. After some time has passed, the exhaled contamination will deposit on surfaces and the transfer pathway will become as described above.

A less frequent pathway occurs if the contaminated person is a nursing mother. If breast-feeding is
carried out there is a direct ingestion route from the mother to the infant.

Finally, if the internal contamination has a significant gamma emission then other persons standing nearby will be exposed to external radiation. Distance is a factor here and children are more vulnerable than adults if the contaminated person is their parent, or somebody they are very familiar with, as close contact (i.e. hugging) can often occur.

Calculations

To estimate possible risks to person in and around the source of radioactivity one must have some estimate of the amounts of contamination to which others may be exposed. In the Litvinenko case, radioactivity would have remained behind on surfaces or objects that he had touched. This would have included clothing, etc.

Computer codes like integrated modules for bioassay assessment (IMBA)\(^1\) can provide information about internal contamination as a function of time and predict excretion rates in urine and faeces. Sweat, however, is not an excretion pathway that codes like IMBA include. Therefore, the initial assessment in Canada also considered the behaviour of other elements in the same group on the periodic table (S, Se and Tl) to estimate the amount of polonium in the tissues and sweat of Mr Litvinenko.

The UK Health Protection Agency estimates that the amount of \(^{210}\text{Po}\) contained in sweat is small, probably 10 times lower that the urinary excretion rate. With that information one can estimate the daily amount excreted via sweat for a given intake of \(^{210}\text{Po}\) and then estimate the amount that could be transferred to other surfaces. For example, 2 d after 5 GBq intake, the amount excreted via sweat would be estimated as approximately 214 kBq d\(^{-1}\).

\[ \text{AS} = \frac{I \cdot U \cdot F \cdot L}{A} \div M, \]

where \(I\) is the estimated \(^{210}\text{Po}\) intake in Bq, \(U\) is the uptake from gastrointestinal (GI) tract at 20\%, \(F\) is the ratio of \(^{210}\text{Po}\) in the body soft tissues to that in sweat, \(L\) is the sweat loss per day (500 g d\(^{-1}\)), \(A\) is the surface area of the body (2 m\(^2\)) and \(M\) is the soft tissue body mass that is assumed to equal reference man (60 kg).

Three different ways to estimate AS were evaluated (see Table 1).

<table>
<thead>
<tr>
<th>Method</th>
<th>F</th>
<th>AS</th>
</tr>
</thead>
<tbody>
<tr>
<td>Po body burden</td>
<td>1.0</td>
<td>400</td>
</tr>
<tr>
<td>S analogue</td>
<td>0.025</td>
<td>10</td>
</tr>
<tr>
<td>Se analogue</td>
<td>0.74</td>
<td>300</td>
</tr>
<tr>
<td>Te analogue</td>
<td>0.29(^a)</td>
<td>120</td>
</tr>
<tr>
<td>IMBA</td>
<td>0.1(^b)</td>
<td>100</td>
</tr>
</tbody>
</table>

\(^a\)Ratio of Te in exhaled breath to body soft tissue.
\(^b\)Ratio of \(^{210}\text{Po}\) concentration in sweat to urine.

(1) A simple mass dilution in which \(^{210}\text{Po}\) was assumed to be one.
(2) The ratio of the AS to soft tissue was assumed to equal to the ratio of sulphur, selenium or tellurium in sweat to soft tissue since these elements are in the same unit of the periodic table as \(^{210}\text{Po}\), and
(3) The biokinetic model (IMBA) was run with default parameters for \(^{210}\text{Po}\) and the loss rate in sweat was estimated to be 1/10 of the concentration in urine.\(^2\)

The different methods of estimating AS produced similar results (Table 1) except for the sulphur analogue estimate. The low estimate using sulphur is not surprising since most sulphur is incorporated into proteins that are not abundant in sweat. Subsequent calculations used the most conservative estimate based upon \(^{210}\text{Po}\) body burden and assumed a loss of 400 Bq cm\(^{-2}\) d\(^{-1}\).

\[^{210}\text{Po}\] contamination transfer

The AS is a source that can be transferred directly to other people through a hand shake. Subsequent internal contamination of the second person could occur when a baby or child places a contaminated hand into their mouth. The contamination could also be transferred from a hand to a sandwich or other finger food that is ingested. The contamination of a second person could also occur indirectly when \(^{210}\text{Po}\) is transferred from a hand to a surface and the \(^{210}\text{Po}\) on the surface is subsequently ingested. An example of this type of transfer that was raised during this event was transfer of \(^{210}\text{Po}\) to a seat cushion on an airplane. This could be followed by subsequent ingestion of \(^{210}\text{Po}\) by an infant if they were teething or sucking on this contaminated surface.

The doses (\(D_i\) in mSv) from ingestion using a transfer model were assessed. The doses were estimated as:

\[ D_i = \text{AS} \cdot H \cdot t \cdot I \cdot U \cdot D_c, \]
where AS is the activity in sweat calculated using equation 1, \( H \) is the ratio of hand-to-body surface area, \( t \) is the fractional transfer to the contaminated surface in the sweat (10%), \( I \) is the fraction that was ingested from the surface, \( U \) is the uptake from the GI tract (20%) and \( D_C \) is the dose conversion factor for an adult or child aged 5- or 1 year old, respectively. All physiological parameters were obtained for an ICRP reference man values. This basic transfer calculation was slightly modified to assess uptake and doses from another contaminated surface rather than direct contact with a contaminated person. In addition, transfer to an infant via lactation and breast-feeding was also assessed. In the breast-feeding scenario, the \(^{210}\)Po update by the mother was diluted in her body and transferred to the infant in breast milk over a subsequent 20 d period.

**RESULTS**

**\(^{210}\)Po transfer in sweat**

All of the doses calculated for individuals are <20 mSv (Table 2). The doses to the infant are larger than those to a 5 year old or adult because they have a smaller body size, which increases the dose conversion factor for an equal intake of \(^{210}\)Po. The doses following \(^{210}\)Po ingestion from a contaminated surface (\( D_i \), Table 2) are all lower than through direct uptake from a contaminated person because the AS is not efficiently transferred from a surface after it is deposited. Babies receive higher doses than children or adults because their sucking on a surface is more pronounced and their body mass is smaller so the dose is higher. Doses from breast-feeding are not significant because only a fraction of the small amount of \(^{210}\)Po uptake to the mother is transferred to the baby via breast milk.

\[ \begin{array}{ccc} 
\text{Calculation} & \text{Group} & \\
 & \text{Baby} & \text{Child} & \text{Adult} \\
D_p^a & 15 & 7 & 2 \\
D_i^b & 7 & 0.4 & 0.1 \\
D_{BF}^c & 1 & — & — \\
\end{array} \]

\(^a\)Dose from direct hand contact.
\(^b\)Dose following uptake of a contaminated surface.
\(^c\)Dose from breast-feeding.

**Other transfer pathways**

Several aerosol pathways were also assessed leading to inhalation and many variations to the ingestion pathways described previously. Aerosol uptake is not significant during short encounters (a few hours) because \(^{210}\)Po is not very volatile at room temperatures and the volatile polonium is diluted into the room’s volume. This behaviour has been confirmed and quantified by Li et al.\(^{(3)}\). Aerosol uptake can only lead to doses of >10 mSv if one room or small area is contaminated for a period of several days and it is used by a person for a similar extensive period.

**SUMMARY**

Secondary contamination of individuals who might have accidentally been exposed to \(^{210}\)Po contamination has been evaluated. The radiation doses calculated for infants, children and adults are all <20 mSv unless there is extensive contact with a contaminated individual. This assessment was originally performed in 2006/07 as part of the risk analyses following the contamination of Mr Litvenenko in London, UK. The methodology is applicable to similar incidents. It highlights that the doses to children are about 10 times higher than doses to adults, largely due to their small body mass. Subsequent measurements of \(^{210}\)Po in individuals who were contaminated confirm that the radiation doses from secondary exposure were low.

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**REFERENCES**