Geographical variations of naturally occurring $^{210}$Pb-supported $^{210}$Po in teeth of juveniles in the UK

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Summary

This study examines geographical variations in the level of naturally occurring $^{210}$Pb-supported $^{210}$Po in permanent teeth of juveniles in the UK. Permanent teeth extracted from 278 juveniles for orthodontic purposes were obtained from 48 counties in the UK. $^{210}$Po activity concentration was measured on the outer enamel surface using TASTRAK $\alpha$-particle sensitive plastic track detectors. $^{210}$Po levels in teeth were associated with domestic radon concentration. The geometric mean ± SE activity concentrations in teeth from urban, suburban and rural areas, excluding the high radon area of Devon were 8.41 +0.25/-0.24, 7.76 +0.37/-0.35 and 7.20 +0.49/-0.46 Bq kg$^{-1}$ respectively. Overall, there was no significant association between $\alpha$-activity of permanent teeth and proximity to major UK motorways. However, a statistically significant association with respect to donors living downwind (on the easterly side) of the motorways was found. This effect was greater for sections of the M5 and M6 motorways which traverse urban areas. Inhalation uptake is an important pathway of exposure to $^{210}$Pb-supported $^{210}$Po, especially with respect to domestic radon exposure.

Introduction

In teeth, the most important $\alpha$-emitter present is $^{210}$Pb-supported $^{210}$Po (hereafter for simplicity termed $^{210}$Po) and the highest levels of $^{210}$Po are found on the outer enamel surface (Henshaw et al. 1994). $^{226}$Ra is the second most important emitter and is found preferentially concentrated in the circumpulpal region. In the skeleton generally, $^{210}$Po is the most important $\alpha$-emitter with typical concentration in the range 2 - 9 Bq kg$^{-1}$ (Hunt et al. 1963, Hill 1965, Jaworoski 1969, Henshaw et al. 1988). Activity concentrations on the outer enamel surface recorded from teeth across the UK were log-normally distributed and shown to be composed almost entirely of $^{210}$Po. Average activity concentrations were around 10 Bq kg$^{-1}$, but values extended to over 30 Bq kg$^{-1}$ (James et al. 2004). This paper reports the results of a targeted analysis of $^{210}$Po $\alpha$-activity in permanent teeth with respect to domestic radon exposure and vehicle exhaust pollution.

Materials and Methods

Tooth collection

Over 6000 permanent teeth extracted from juveniles for orthodontic purposes were obtained from across the UK by arrangement with Local Health Authority District Dental Officers. For each tooth, information on tooth type, age of donor, gender and the postcode of the donor’s address was requested. Teeth were predominantly of the pre-molar 4 type since their removal is a common procedure to reduce overcrowding in the mouth. For permanent teeth, the most common ages of extraction were between 11 and 14 years.

Influence of radon

Since $^{210}$Po occurs at the end of the $^{222}$Rn radioactive decay chain, domestic radon exposure should be considered as another potential source of increased $^{210}$Po in teeth. Clemente et al. (1982, 1984) found an association between $^{210}$Po in teeth and high cumulative radon exposure in persons living near to the Badgastein spa in Austria. It is of interest to determine whether such an association can be seen at much lower radon concentrations in UK homes. Analysis of the variation in radon concentration by postcode in England carried out by the National Radiological Protection Board (Lomas et al. 1996) reveals a significant negative correlation between radon concentration and urban residence type ($r = -0.26$, $p<0.0005$, $n = 251$). This indicates that the higher the level of urbanisation of a region the lower the mean domestic radon level. This effect is likely to be coincidental, with urban population sites centred in low radon regions purely by chance. However, it does appear to confirm that an urban effect on $\alpha$-activity concentration in teeth may directly conflict with any radon effect present. Therefore, in the present analysis possible relationships between $^{210}$Po activity concentration in
teeth and radon concentration have been examined both for all individuals and for individuals by residence type, confining the analysis to England to match the data available in Lomas et al. (1996).

**Influence of motorways with respect to wind direction.**

It is of interest to consider the airborne transport of $^{210}$Pb from exhaust emissions. To do this, $^{210}$Po levels in permanent teeth with distance from motorways were compared in both the upwind and downwind directions of the prevailing westerly to south-westerly wind across the UK. This was possible for the M5/M6 motorways, the M4 and the M25.

**Tooth analysis**

The outer enamel surface of permanent teeth was analysed by $\alpha$-particle autoradiography using TASTRAK plastic track detectors, stored against each tooth for periods ranging between 380 and 1120 days. It was assumed that the majority of recorded activity arose from $^{210}$Po. The analysis was based on permanent teeth from 278 juveniles in 48 counties, as 4,000 teeth were used in radiochemical analyses to measure levels of plutonium (in batches of 50) and strontium (in batches of 8) across the UK (O'Donnell et al. 1997). For the remaining available teeth, their value was limited by inadequate information concerning the donor. Alpha-particle autoradiographs of the outer surface of teeth were analysed by automated image analysis as described in Henshaw et al. (1994). Repeat analyses using the Bristol image analysis system are generally well reproducible and to minimise the possibility of systematic errors, all autoradiographs were analysed in one batch with careful checking of the optical set-up throughout.

**Results**

**Radon**

Table 1 shows the geometric mean $^{210}$Po $\alpha$-activity concentration in teeth by residence type. For all residence types together, there is an association with radon but this was just short of statistical significance, $p=0.08$. However, the corresponding associations for rural and small town residences were significant, $p=0.04$ and 0.02 respectively. No association was found for urban residences. Figure 1 shows a plot of the data for non-urban residences.

<table>
<thead>
<tr>
<th>Residence type</th>
<th>Including Devon</th>
<th>Excluding Devon</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Total $\alpha$-activity concentration (Bq kg$^{-1}$)</td>
<td>(number of children)</td>
</tr>
<tr>
<td>Rural</td>
<td>7.83 +0.47/-0.45 (35)</td>
<td>7.20 +0.49/-0.46 (25)</td>
</tr>
<tr>
<td>Small town</td>
<td>7.94 +0.38/-0.36 (72)</td>
<td>7.76 +0.37/-0.35 (55)</td>
</tr>
<tr>
<td>Urban</td>
<td>8.48 +0.25/-0.24 (169)</td>
<td>8.41 +0.25/-0.24 (166)</td>
</tr>
</tbody>
</table>

**Motorways**

Overall there was no significant association between $\alpha$-activity on the outer enamel surface of permanent teeth and proximity to the M5/M6, the M4 or the M25 motorway, either collectively or individually, confirming the earlier findings. However, there was a statistically significant association with respect to donors living downwind (on the easterly side) of the motorways (for <10 km, $p=0.03$; for <5 km, $p=0.07$) (figures 3a and b). Sections of the M5 and M6 which traverse urban areas were isolated and no significant association with downwind distance was observed, but a significant association was found for urban areas (for <10 km, $p=0.01$; for <5 km, $p=0.11$) (figures 3c and d).
Discussion

Radon

Toth et al. (1982) compared $^{210}\text{Pb}$ and $^{210}\text{Po}$ levels in teeth from country-people, towns-people and coal miners in Hungary. Higher levels were seen in the teeth from coal miners and this was related to cumulative radon exposure in coal mines. Clemente et al. (1982, 1984) found an association between $^{210}\text{Po}$ in teeth and high cumulative radon exposure in persons living near to the Badgastein spa in Austria. In the centre of the town, water from thermal springs originates with a mean radon concentration of $1.5 \times 10^6$ Bq m$^{-3}$. The rate of uptake of $^{210}\text{Po}$ was 1.2 mBq g$^{-1}$ per WLM lifetime exposure.

The association reported in this paper between $^{210}\text{Po}$ in children’s teeth and radon at the much lower radon levels in UK homes is unexpected. In teeth, $\alpha$-activity concentrations are high and there are marked features of the spatial distribution. The proportion of $^{210}\text{Po}$ in children’s teeth attributed to radon at the UK average exposure of 20 Bq m$^{-3}$ is approximately equal to that attributed to traffic density (i.e. $7 - 9$ Bq kg$^{-1}$ within 10 km of a major motorway (Henshaw et al. 1995)) and becomes progressively more important at higher levels of indoor radon. A general feature of the associations found here is the relative importance of inhalation compared with ingestion sources of $^{210}\text{Pb}$-supported $^{210}\text{Po}$. Salmon et al. (1998) modelled the relative contribution of inhalation and ingestion to the skeletal uptake of $^{210}\text{Pb}$. In the UK, in the absence of radon, inhalation accounts for only 5% of uptake.

The average UK radon concentration of 20 Bq m$^{-3}$ was estimated to add an additional 1.8% only to the total skeletal burden. The findings here testify to the importance of inhalation uptake since dietary sources of $^{210}\text{Pb}$ would be expected to be approximately uniform across the UK. Thus, in table 1, $^{210}\text{Po}$ levels in teeth are 17% higher in urban compared with rural areas, and according to figure 1, mean levels of $^{210}\text{Po}$ in teeth at zero, 20 and 100 Bq m$^{-3}$ are respectively 6.2, 7.2 and 13.6 Bq kg$^{-1}$.

Upwind and downwind of motorways

In Henshaw et al. (1995) statistically significant associations between $\alpha$-activity in teeth and residence within 10 km of the M5/M6 and M1/A1 were found for deciduous but not for permanent teeth. For permanent teeth the association became significant only when distances within 2 km were considered. Thus, the lack of an overall association with proximity to the M5/M6, the M4 and M25 motorways agrees with the previous findings. For the upwind/downwind analysis, statistical power was limited. Nevertheless, in the pooled data, an association was found with $\alpha$-activity concentration in teeth downwind of motorways with respect to the prevailing west or south-westerly wind across the UK. This association is consistent with the airborne transport of vehicle exhaust pollution. It is interesting to note that in both Henshaw et al. (1995) and in this work, the significant associations extend to 10 km from the motorway. This is consistent with the view that a significant proportion of vehicle exhaust pollution exists in the form of ultrafine aerosols, around 200 nm in size, which can be carried comparatively large distances from their source and constitute a particular health hazard when inhaled, due to their ability to penetrate deeply into the lung.

Conclusions

In the UK, geographical variations have been found in the level of $^{210}\text{Pb}$-supported $^{210}\text{Po}$ on the outer enamel surface of permanent teeth extracted from juveniles for orthodontic purposes. These variations relate to exposure to urban pollution: living downwind of motorways and domestic radon exposure. The relationship with downwind distance from motorways is based on limited statistics. The magnitude of the association with radon is approximately equal to that from traffic density at the average UK radon exposure of 20 Bq m$^{-3}$, but becomes more important at higher levels of indoor radon.
Figure 3. $^{210}$Po α-activity in teeth with distance from motorways, upwind and downwind with respect to the prevailing west to south-westerly wind across the UK.

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References


