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^{210}Po secretion from sweat glands

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ABSTRACT

The results of the research indicated that the ^{210}Po activity concentration in sweat samples was between 0.22 ± 0.03 to 2.10 ± 0.15 mBq·g^{-1} d.w. The obtained results of the studies showed that smoking and eating fish led to higher activity concentrations of ^{210}Po in sweat in comparison to the control group. Statistical analysis of ^{210}Po activity concentrations in sweat samples showed significant differences between control, smoking, fish eating and age groups, while no significant differences was found for ^{210}Po between volunteers as far as gender is concerned.

1. Introduction

^{210}Po occurs widely in nature, as it is a part of the ^{238}U decay chain and is an alpha-particle-emitting radionuclide with a half-life of 138.376 days (Browne and Firestone, 1986) and a high specific activity of 1.66•10^{-14} Bq·g^{-1}. This radionuclide is present in soil, sand, sediment and naturally occurring water and constitutes an important component of the natural background radiation, contributing significantly to the radiation dose for the population (Narayana and Rajashekara, 2010). The main source of ^{210}Po in the atmosphere is the emanation of ^{222}Rn from the ground. ^{210}Po returns to the earth as dry fallout or is washed out in rain (Brown et al., 2011; Burton and Stewart, 1960; Persson and Holm, 2011). Important anthropogenic sources of polonium are uranium mines, burning of fossil fuels and tetraethyl lead in petrol, dust storms, refineries, superphosphate fertilizers, the sintering of ores in steelworks, the burning of coal in coal-fired power stations and civil construction using cement (Singh and Nikelani, 1976; Marmorstein, 1986; Santos et al., 1999; Shabana et al., 2000; Bernhard et al., 2004a, 2004b; Daish et al., 2005; Aslani et al., 2005; Jia and Torri, 2007; Srinivas et al., 2009; Vandenhove et al., 2009). Polonium is taken up to the body via drinking water, and during cigarette smoking. Dietary factors such as protein-rich food and marine organisms consumption and/or other environmental conditions e.g. residence place are also of great importance (Gouvea et al., 1987, 1988, 1989; 1992; Hunt and Allington, 1993; Shabana et al., 2000; Skwarzec et al., 2001, 2001a,b,c; 2003; Al-Arifi et al., 2006; Henricsson et al., 2012; Boryło et al., 2013; Rosa et al., 2015).

Polonium ^{210}Po is one of the most radiotoxic natural radioactive isotopes to man due to its high specific activity and its emission of high-LET alpha radiation. Less than 0.05 μg of the radionuclide is considered a lethal dose (LD50/30). The reason for the high accumulation of polonium in the body is its affinity to protein, allowing it to pass easily through the food chain. ^{210}Po has been shown to bind to unidentified proteins with high molecular weight, such as hemocyanin or metal-binding enzymes (Waska et al., 2008).

The ^{210}Po activity concentrations in the plasma are distributed throughout the body (Fellman et al., 1994; Henricsson et al., 2012). Landinskaya et al. (1973) reported that the activity concentration of ^{210}Po in different human tissues was proportioned in the following order: hair > bone > liver = kidney > gonads > spleen = lung > muscle > heart = blood.

Some research concludes that excretion of trace metals with sweat can be higher while intensively sweating as a result of daily exercises and/or work in hot environment (Hohnadel et al., 1973; Hoshi et al., 2001, Sears et al., 2012). According to the biokinetic model proposed by Legett and Eckerman (2001) for ^{210}Po, the skin receives 5% of polonium present in plasma. When deposited in the skin, ^{210}Po is removed with a half-life of 50 days, with 50% excreted through hair and sweat and 50% returning to the plasma. This

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suggests that sweating is not the main pathway for elimination of polonium from the human body. A similar relation was described for Tl, As, Se, Mo where excretion efficiency was higher for urine than sweat (Genuis et al., 2011). Due to the chemical similarity of selenium and polonium we can suppose that activity concentrations of polonium in urine and blood will be higher than in sweat. According to the United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR), the annual intake of ^{210}Po ranges from 18 Bq in Argentina to 220 Bq in Japan. In Europe, the annual intake of ^{210}Po is reported to vary from 28 to 55 Bq. The mean annual intake of ^{210}Po in the adult diet is about 58 Bq, causing effective doses of 0.070 mSv y^{-1} (UNSCEAR, 2000).

The aim of this work was to estimate if and to what extent the amount of ^{210}Po excreted with sweat depends on the factors such as age, gender, smoking and fish consumption.

2. Materials and methods

All subjects agreed to participate in the study voluntarily after receiving —each of them individually —a formal explanation of the aims and the structure of the study. People were chosen taking into account the following variables: age, gender, smoking habits (years of smoking, number of cigarettes per day) and eating habits. Forty-two subjects, 20–45 years old, participated in this study. The questionnaire was given to all the participants and contained questions about gender, age, fish consumption and smoking habits. The continuously smoking individuals who smoked 15 or more cigarettes per day were identified as smokers whereas irregularly smoking individuals were excluded from this study. The volunteers classified as non-smokers had never smoked during their life. The fish-consumers group consisted of volunteers who ate about 0.2 kg per week or more of marine fish (consumption frequency at least 1 dinner fish portion per week). The non-fish-consumer group consisted of volunteers who declared that they did not eat fish at all. The samples were collected by glass microfibre filters stuck to the back of people involved in the study (onto previously cleansed skin). The sweat samples were collected after 3 h of intense exercise. The dry mass of the samples was obtained by subtraction of unused filter mass from dried filter mass. Prepared samples were digested in concentrated acids (HCl, HNO_3 and HF). ^{209}Po as recovery tracer was added to the samples and then they were evaporated to dryness.

Polonium was electrodeposited on silver discs according to the procedure by Skwarzec (Skwarzec, 1997, 2009). The activities of ^{210}Po were measured using an alpha spectrometer (Alpha Analyst S470) equipped with a surface barrier PIPS detector with an active surface of 300 mm^2 placed in a vacuum chamber connected to a 1024 multichannel analyzer (Canberra— Packard, USA). Detectors used are silicon diodes with a thin gold contact layer dusted on the layer "n" at 40 $mg \cdot cm^{-2}$. Detector efficiency ranged from 0.30 to 0.40, the surface was 300 mm^2 and the resolution 17–18 keV. The typical counting time was about 11 days. Minimal Detectable Activity (MDA) for measured ^{210}Po was 0.2 mBq. The accuracy and precision of the radiochemical method were estimated to be less than 7% by participation in international inter-comparative exercises and analysis of IAEA materials. The precision between subsamples was estimated to be less than 3% for analyzed radioisotope. ^{210}Po activities were corrected for decay to deposition day. Analytical yield was about 85%.

R: A language and environment for statistical computing (R Foundation for Statistical Computing, Vienna, Austria). was used for statistical analysis. Values were reported as a mean and standard error (±SE). The Welch *t*-test and ANOVA were used to compare two or more groups respectively. The level of significance was defined as $p < 0.05$.

3. Results and discussion

The results of ^{210}Po activity concentration in sweat samples from Gdańsk agglomeration volunteers are summarized in Table 1 and illustrated in Fig. 1. Activity concentrations of ^{210}Po in analyzed samples ranged from 0.22 ± 0.03 to 2.10 ± 0.15 $mBq \cdot g^{-1}$ d.w. The average ^{210}Po activity concentration in the analyzed samples was 0.98 ± 0.08 $mBq \cdot g^{-1}$ d.w. (Table 1).

Activity concentrations of ^{210}Po in the smoker group ranged from 1.29 ± 0.13 to 2.10 ± 0.15 $mBq \cdot g^{-1}$ d.w. with an average value of 1.68 ± 0.08 $mBq \cdot g^{-1}$ d.w. This was higher than the average activity concentration of ^{210}Po in sweat samples from non-smokers (0.48 ± 0.04 $mBq \cdot g^{-1}$ d.w.) (Fig. 2). Based upon these average values, the ^{210}Po activity concentration in the smoker group was 3.5 times higher than in the non-smoker group. The statistical analysis shows significant differences between ^{210}Po content in smoker group and non-smoker group (Tukey HSD, $p \ll 0.05$). As shown by numerous studies, intake of ^{210}Po is associated with environmental factors, place of residence and employment, as well as smoking. Smoking period, type of smoking material and number of cigarettes per day can have different impacts on ^{210}Po activity concentrations in the body. (Okabayashi, 1982; Shabana et al., 2000; Sisti et al., 2009; Schayer et al., 2010). Where the number of cigarettes smoked was less than 10 per day, ^{210}Po activity concentrations were similar for smokers and non-smokers, while ^{210}Po activity concentrations in the body increased significantly when more than 20 cigarettes per day were smoked (Sisti et al., 2009). SActivity concentrations of ^{210}Po in sweat samples from the group of people eating fish once or more than once a week ranged from 0.63 ± 0.08 to 1.24 ± 0.16 $mBq \cdot g^{-1}$ d.w., with an average value of 0.90 ± 0.05 $mBq \cdot g^{-1}$ d.w. (Fig. 2). Significant statistical differences based on ANOVA were also found for the fish and non-fish consumer groups (Tukey HSD, $p \ll 0.05$). Based upon these average values, the ^{210}Po activity concentration in sweat samples from fish consumers is almost 1.9 times higher than from the group of non-fish consumers. We should also remember that it has been shown that seafood can contain higher activity concentrations of ^{210}Po compared to other foodstuffs (e.g. Muikku and Li, 2012). Kelecom and de Cássia dos Santos Gouvea (2011) showed a 300% increase in ^{210}Po activity concentration was observed in human semen fluid after consumption of mussels.

In the control group, the activity concentrations of ^{210}Po in analyzed sweat of women ranged from 0.22 ± 0.03 to 0.67 ± 0.08 $mBq \cdot g^{-1}$ d.w. with an average of 0.44 ± 0.05 $mBq \cdot g^{-1}$ d.w. For men in the control group, ^{210}Po activity concentrations in analyzed sweat samples ranged from 0.36 ± 0.05 to 0.70 ± 0.06 $mBq \cdot g^{-1}$ d.w. with an average of 0.56 ± 0.06 $mBq \cdot g^{-1}$ d.w. (Fig. 3). There was no significant difference for gender and the amount of ^{210}Po excreted from the body (Welch *t*-test, $p = 0.132$) in the control group.

Furthermore, there was no significant difference (Welch *t*-test, $p = 0.615$ and $p = 0.816$, respectively) for gender in ^{210}Po activity concentrations in sweat samples from the smoking group (women average 1.63 ± 0.12 $mBq \cdot g^{-1}$ d.w., men average 1.72 ± 0.12 $mBq \cdot g^{-1}$ d.w.) and fish eating group (women average 0.88 ± 0.06 $mBq \cdot g^{-1}$ d.w. men average 0.92 ± 0.09 $mBq \cdot g^{-1}$ d.w.) (Fig. 3).

Other studies have shown that ^{210}Po activity concentrations and trace metal levels in urine can be higher for men than for women and that this difference could depend on lifestyle differences rather than any difference in metabolism (e.g. Cohn and Emmett, 1978; Sisti et al., 2009). Indeed, several studies have shown that ^{210}Po urine excretion rates among different population groups were found to vary depending on diet (Pietrzak-Flis et al., 2001; Skwarzec et al., 2001; Al-Arifi et al., 2006; Meli et al., 2009, 2014; Muikku et al., 2011).