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Article

Excretion rate of ^{210}Po in urine of general population (a review)

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ABSTRACT **Knowledge of excretion rates of naturally occurring ^{210}Po in non-exposed people is a prerequisite for assessment of potential internal contamination with polonium. Significant differences in published data on excretion rate of ^{210}Po in urine have been long known. In this paper we study the differences of excretion rates of ^{210}Po in urine of non-exposed population in detail. All available studies of this field published by the middle of 2008 (according to INIS abstracts) have been evaluated.**

Keywords: ^{210}Po / urine / internal contamination

RÉSUMÉ **Taux d'excrétion urinaire de ^{210}Po pour la population générale (revue).**

L'acquisition de connaissances concernant le taux d'excrétion urinaire de ^{210}Po présent naturellement dans la population non-exposée est nécessaire pour l'évaluation d'une éventuelle contamination interne par le polonium. Les données publiées concernant le taux d'excrétion urinaire de ^{210}Po présentent des différences significatives connues depuis longtemps. Dans cet article, nous étudions en détail la question des différences dans les taux d'excrétion urinaire de ^{210}Po dans la population non-exposée. Toutes les études accessibles dans ce domaine publiées avant mi-2008 (selon les extraits d'INIS) ont été évaluées.

1. Introduction

^{210}Po cannot be measured directly in the human body; its content can only be assessed indirectly, using values of the excretion rate in urine. ^{210}Po, similarly to its progenitors is widely distributed in the biosphere including human organism.

When studying papers dealing with internal exposure of workers to ^{210}Po or also to its parent radionuclides, especially radon (*e.g.* spa workers, workers at cement production and phosphate industry, but also workers at uranium mines) we have found that the dose estimate is strongly influenced by the ^{210}Po background value in urine. The excretion rate of ^{210}Po in urine of exposed workers (except miners in uranium mines) usually only slightly exceeds the value of non-exposed people. Similar findings can be observed in papers concerned with the exposure of tobacco-smokers to ^{210}Po. Average values of excretion rate at groups of

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non-exposed people found by various authors usually differ. This suggests a question: what are the values of the excretion rate of ^{210}Po in urine of non-exposed peoples?

The aim of this work is to study and evaluate all the available papers concerning the excretion rate of ^{210}Po in urine of non-exposed people published so far. The evaluation was focused mainly on (1) the comparison of mean excretion rates of ^{210}Po in groups of people found by various authors, (2) the comparison of excretion rates of ^{210}Po in a given group, (3) clarification of time variations of the excretion rate of ^{210}Po in urine. Publications concerning content of ^{210}Po in urine of non-exposed persons were found in Chemical abstracts (1917-1970) and INIS (International nuclear information systems) abstracts (1970-midle of 2008).

2. Published data on the excretion rate of ^{210}Po in urine

Data on ^{210}Po contents in urine of non-exposed people were first published by Sultzer and Hursh (1954) who studied the excretion rate of ^{210}Po in urine of uranium miners. The value found in miners was > 74 mBq l^{-1}, polonium was not measurable in non-exposed persons (total of 14 samples of 24-hours urine from 7 persons).

Table I includes data on the excretion rate of ^{210}Po in urine of non-exposed people by other authors. Studies are sorted from the oldest to latest ones. The average excretion rate, standard deviation (if included in the work), range of values, n-number of ^{210}Po determinations in urine and incidence of tobacco smoking are given. Some authors express the concentration of ^{210}Po in urine in mBq l^{-1} while others in mBq d^{-1}. In the most of the papers ^{210}Po is determined in 24-hour urine (in these cases n represents number of subjects investigated in a given group). Some authors, however, proceeded rather differently.

Juan and Ballelos (1976) determined ^{210}Po contents in single spot samples. Glöbel *et al.* (1966) measured ^{210}Po contents in 24-hours urine of one subject for 39 consecutive days. Boeck *et al.* (1971) determined ^{210}Po in 5 samples of the 24-hour urine coming from three persons. The mean value 3.13 mBq d^{-1} in Table I was calculated by the authors on the basis of data in the original work. Similarly the mean value was calculated with data of Santos *et al.* (2000). Mixed samples of urine were prepared by Bale *et al.* (1975) (13 samples of urine from several persons), Okabayashi *et al*. (1975) (31 samples of urine from 6 non-smokers and 5 samples of urine from 3 smokers). Spencer *et al.* (1977), measured ^{210}Po contents in urine more times for each investigated person. The authors were closely studying ^{210}Po intake and excretion of 12 hospital patients. For each

TABLE I
Excretion rates of ^{210}Po in urine in general population.
Taux d'excrétion de ^{210}Po dans l'urine pour la population générale.

Number of samples	Concentration (mBq l^{-1})		Concentration (mBq d^{-1})		Reference
	Average	Range	Average	Range	
4			0.41[a]		Radford and Hunt (1964)
3			2.4[b]		
30			2.2 ± 1.9[c]	0.26-9.3[c]	Taylor *et al.* (1964)
16	14.8[c]				Tibor *et al.* (1966)
39			11.1[c]		Glöbel *et al.* (1966)
20	8.5[c]				Hölgye (1969)
5			3.13[c]	2.04-5.66[c]	Boeck *et al.* (1971)
32			15.91 ± 1.48[c]		Ladinskaya *et al.* (1973)
13	0.85[c]				Bale *et al.* (1975)
31	15.9 ± 7.8[a]	4.4-38.9[a]			Okabayashi *et al.* (1975)
5	41.4 ± 25.9[b]	20.4-74[b]			
				7.4-14.8	Novakova *et al.* (1975)
20			6.94 ± 4.4[a]	1.86-21.08[a]	Juan and Ballelos (1976)
20			9.89 ± 3.98[b]	4.81-23.44[b]	
			9.25 ± 1.85[c]		Spencer *et al.* (1977)
3	1.11[c]				Helmkamp *et al.* (1979)
5	25.9 ± 22.2[c]				Okabayashi (1982)
34		<7.4-23.7[c]			Irlweck (1982)
25	11.1 ± 6.5[a]				Mancini *et al.* (1984)
25	20.3 ± 9.4[b]				
20	16.3 ± 1.9[c]				Fenzi (1986)
6	7.8 ± 1.5[c]				
15			5.2 ± 2.2[a]	1.5-9.3[a]	Azeredo and Lipsztein (1991)
13			9.9 ± 4.1[b]	5.2-17.4[b]	
8	5.3[c]	4.0-6.5[c]			Santos *et al.* (1995)
98	19.9 ± 9.4[c]				Knezevic and Novak (1995)
3	6.19[a]	4.87-8.5[a]			Santos *et al.* (2000)
5	6.03[b]	4.4-8.22[b]			
12			4.1[c]	<MDA-13	Naumann *et al.* (1998)
14			12[c]	1-35[c]	Thomas *et al.* (2001)
23	5.9 ± 1.8[a]	1.5-10[a]			Al-Arifi *et al.* (2006)
27	8.9 ± 2.6[b]	3.3-15.9[b]			
34			3.5[c]		Schäfer *et al.* (2006)

[a] non-smokers; [b] smokers; [c] smoking not mentioned in the work.

person (except persons 1, 2 and 3) ^{210}Po was determined in consecutive cumulative samples. For each cumulative sample urine was collected usually for 6 days. The authors give an average value of ^{210}Po excretion in urine as 9.25 ± 1.85 mBq d^{-1}. Other findings: Ladinskaya *et al.* (1973) also determined the excretion rate of ^{210}Po in urine of 12 children and found the average excretion rate 7.4 ± 1.1 mBq d^{-1}. The value is approximately two times lover than they found in urine of adults (Tab. I).

In the review published by Parfenov (1974) he mentioned three further papers published before 1973 containing data on ^{210}Po in urine of general population. We, however, have failed to obtain them in the original version. The author of the first paper (Kuroda) gives a value for the excretion rate of 11.2 mBq d^{-1}, the second (Ermolaeva-Makovskaya) of 14.8 mBq d^{-1} and the third (Margocsy *et al.*) of 34.8 mBq l^{-1}.

3. Variability of the average excretion rate of ^{210}Po found by various authors

The data from Table I suggest that the average excretion rate of ^{210}Po in urine of the investigated groups range from 0.41 to 36.3 mBq d^{-1} (final value 36.3 mBq d^{-1} was obtained by multiplying of 25.9 mBq l^{-1} (Okabayashi, 1982) by factor 1.4 (ICRP, 1974) for 24-hours excretion). Nevertheless, the average values published by most of authors fall into narrower range of excretion rate. Figure l shows size distribution of average values of the excretion rate of ^{210}Po in 24-hour urine as determined by individual authors. Papers investigating the excretion rate of non-smokers and papers, where the influence of smoking is not taken into account were included in this investigation. Excretion rates given by the authors in mBq l^{-1}, were corrected for excretion by 24-hour urine. The figure clearly shows that in the chosen interval of the excretion rates 29% of authors present the average excretion rate in the 2-8 mBq d^{-1} range. 29% authors give the average excretion rate in the range of 8-14 mBq d^{-1}. The figure also suggests that in 70% of the papers the average excretion rate is in the range of < 2-14 mBq d^{-1}.

The presence of a higher average excretion rate of ^{210}Po in urine can be caused by the different content of polonium in foodstuffs and the preference of certain foodstuffs types by the population. ICRP (1980) states for daily intake of ^{210}Po (foodstuffs, beverages and from air) a value of 0.1 Bq. As far as the Japanese population is concerned, the intake is significantly higher due to more frequent consumption of sea products (containing high concentration of ^{210}Po), which is considered the cause of the higher excretion rate of ^{210}Po in urine of the Japanese population (Okabayashi, 1982).

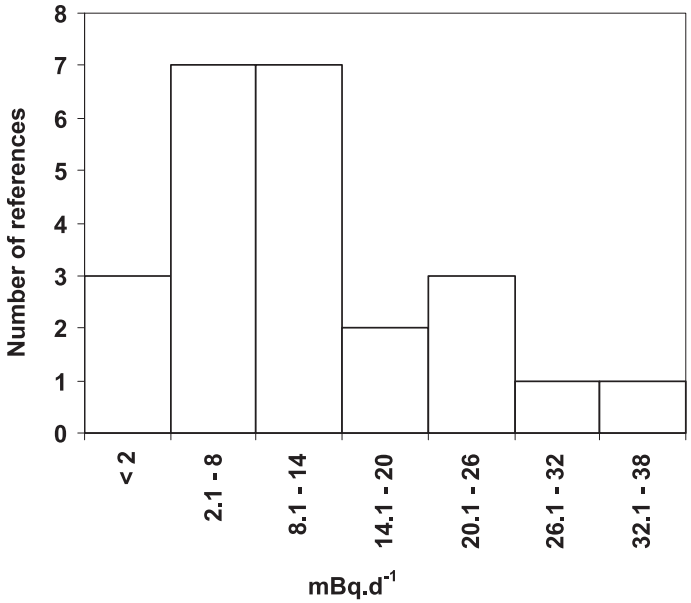

Figure 1– ***Size distribution of average excretion rates published by various authors. Distribution moyenne des taux d'excrétion publiées par divers auteurs.***

The increased presence of polonium in an environment where uranium ore can be found and where it is mined is probably the cause of the increased excretion of persons living in this area compared to areas with no mining (Fenzi, 1986). The value of 16.3 ± 1.9 mBq l^{-1} (Tab. I) was found in people living in uranium-mining area and the value 7.8 ± 1.5 mBq l^{-1} in persons living a non-mining area.

4. Variation of the excretion rate of ^{210}Po in urine of people of given groups

The excretion rate of ^{210}Po in urine of most of Irlweck's group (Irlweck, 1982) was not measurable (< 7.4 mBq l^{-1}). The excretion rate of ^{210}Po in urine of other people was: 10.4, 8.9, 16.3, 7.4, 7.4, 23.7 (persons in the Vienna-Seibersdorf area) 7.4, 10.4, 12.6 and 11.8 mBq l^{-1} (persons in the Böckstein-Badgastein area). It is evident that for 8 out of 10 people the excretion rate of ^{210}Po is kept in a narrow range of 7.4-12.6 mBq l^{-1}, *i.e.* the lowest and the highest excretion differing less than 100%. The data differ roughly three times in just one case. Azeredo and Lipsztein (1991) found a similarly small variation of the excretion rate of ^{210}Po in the investigated group. In 10 cases, out of 14 people the excretion rate of ^{210}Po was

in a range of 4-8 mBq d^{-1}. In one person it was rather higher (9.3 mBq d^{-1}) and in three people it was rather lower (1.5, 1.9 and 1.9 mBq d^{-1}). Even smaller variations were detected by Santos *et al.* (1995) in 8 farmers as a control group. The excretion rate of ^{210}Po of these persons kept in a very narrow range of 4.0-6.5 mBq l^{-1}. The size of the arithmetic average and standard deviation (15.9 ± 1.5) suggest a very small variation of excretion of ^{210}Po in daily urine in 32 people given by Ladinskaya *et al.* (1973). On the other hand, significantly higher variations of the excretion rate of ^{210}Po of the investigated group were found by *e.g.* Taylor *et al.* (1964), Okabayashi *et al*. (1975), and Mancini *et al.* (1984).

5. Variation of excretion rate of ^{210}Po in urine of a given person over a period of time

We only have data from three papers. One of them is presented by Glöbel *et al*. (1966) who determined concentration of ^{210}Po in 24-hours urine collected from a subject for 39 consecutive days. Unfortunately, the authors present their results not on a "from day to day" basis but from the highest to the lowest values measured. Despite that, a significant variation of daily excretion of ^{210}Po in urine in a range of 2.2-37 mBq d^{-1} is evident. The second source (Holtzman *et al*., 1976) includes the first tree members of Spencer's 12-member group of hospital patients. For each subject ^{210}Po was determined in consecutive 24-hour urines and than in several consecutive cumulative samples. For each cumulative sample urine was collected mostly for 6 days. At person No. 1 the following values were measured on 9 consecutive days: 9.3, 20.5, 13.1, 14.6, 9.5, 16.3, 15.6, 14.3, and 13.9 mBq d^{-1} (average value of 14.1 ± 3.4). It is evident that the values are within a range of 9.3-20.5 mBq d^{-1}, *i.e.* the lowest and highest excretion differ approximately 100%. At 8 determinations from cumulative samples the excretion values are in a very narrow range of 14.5-16.6 mBq d^{-1}, (average of 15.7 ± 0.9). For subjects No. 2 and 3 average values are given only. For subject No. 2 the average from daily excretion (9 days) and from 5 cumulative samples were 17.7 ± 3.9 and 14.7 ± 1.9 mBq d^{-1}, respectively. For subject No. 3 the average from daily excretion (9 days) and from 13 cumulative samples were 5.1 ± 1.9 and 2.8 ± 0.5 mBq d^{-1}, respectively. It is evident that in the case of the second subject the variation of ^{210}Po in both daily urine and cumulative samples is similar to that of subject No. 1. As far as the third subject is concerned, however, the variation of excretion rate of ^{210}Po is different. The disadvantage of this study is that all three persons were given diuretics. In another study (Okabayashi *et al*., 1975) the contents of ^{210}Po in daily urine on three various days of one month were measured in one subject and the same was done in the following month and finally for 5 consecutive days of the next month. The measured values were: 10.0, 9.3, 8.9, 26.3, 8.5, 21.8 and then 26.6, 10.7, 14.4, 7.4, 10.0 mBq d^{-1}. It is evident that out of 11 measurements taken, eight of them

are in a narrow range of 7.4-14.4 mBq d^{-1} and later the excretion rate is significantly higher.

The higher excretion rate of ^{210}Po in urine of some people of a given group and the rapid increase of excretion of the given subject in time can be caused by consumption of foodstuffs with higher contents of ^{210}Po (sea products, liver, kidney) before urine sampling. According to Thomas *et al.* (2001) approximately 3% of the absorbed ^{210}Po is excreted by urine in course of several days after the intake.

6. Conclusions

1. The average excretion rate of ^{210}Po in urine in a non-exposed group found by individual authors' ranges from 0.41 to 36.3 mBq d^{-1}. In 58% of the papers the average excretion rate is within a range of 2-14 mBq d^{-1}. The increased excretion rates in some groups can be explained by higher consumption of sea food containing higher concentration of ^{210}Po.

2. The variation of the excretion rate of ^{210}Po in urine of various subjects from a given group is small according to some authors while other authors see this difference as significantly greater.

3. Data on the time course (on a "from day to day" scale) of the excretion rate of ^{210}Po in urine of a subject from natural sources have been very scarce so far.

4. The question is how to proceed. In our opinion, it will be suitable to continue the determination of the excretion rate of ^{210}Po in other groups of non-exposed subjects. It should be based on the work by Taylor *et al.* (1964), Azeredo and Lipsztein (1991), Santos *et al.* (1995), Naumann *et al.* (1998), Schäfer *et al.* (2006) *i.e.* a recent work determining more often a lower average excretion rate of ^{210}Po in urine in groups of subjects, caused by apparently low or no consumption of sea products (continental excretion rate). The aim of new studies should include obtaining other knowledge on the excretion rate of ^{210}Po including the influence of age, weight and height, sex, drinking habits, etc. on this rate. It will also be advisable to add findings on the time course of the excretion rate of ^{210}Po of human organism. The future results should serve as a basis for the determination of potential occupational exposure based on investigation of individual results (not based on investigation of groups of persons as so far). This approach would be useful *e.g.* in the assessment of the exposure of persons living in dwellings with increased radon concentration. It is advisable that in the new studies the investigated subjects should not consume foodstuffs rich in ^{210}Po for at least one week before urine collection.

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