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Polonium-210 activity in human hair samples and factors affecting its accumulation

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Background: Due to the presence of radioactive minerals such as monazite, the beach sand of the west coast of Kanyakumari exhibits high natural background radiation. Hair is a good indicator of radionuclides in the human body. An attempt is taken to measure the ^{210}Po activity in human hair samples and the factors affecting it. ***Material and Methods:*** ^{210}Po activity was analysed in 47 individuals including males and females living in Kanyakumari district, Tamil Nadu, India. The activities were measured using a Nucleonix® Radiation Counting System (RC 605A). ***Results:*** The activity was in the range of 9.89 ± 4.43 to 58.85 ± 6.27 milli Becquerel per gram. ^{210}Po activity was observed in the hair samples when compared to the global values were comparatively higher. ***Conclusion:*** Hair samples obtained from the users of home-made and medicinal oil had higher concentration of ^{210}Po compared to that of people using branded oils. These high values may be attributed to the hair oil usage and this is a topic of interest for future studies. **Iran. J. Radiat. Res., 2011; 9(1): 41-47**

Keywords: *^{210}Po, human hair, indicator, cosmetics, accumulation.*

INTRODUCTION

Human hair is a good indicator of radionuclides in the human body. Many elements present in human hair have been used as an index of environmental pollution and for studying the effect of heavy metals on human beings [1]. Human hair has been recognized as one of the important monitoring materials by the worldwide biological monitoring system (Global Environment Monitoring System) of the United Nations Environmental Programme [2, 3]. Hair analysis, a non-destructive monitoring tool for metal exposure assessment, has a long tradition in human toxicology [4-6].

Hair cosmetic treatment is gaining momentum in the era of modernization. The use of coconut oil reduces hair damage during grooming, when it is used as a pre-wash conditioner [17]. Frequent shampooing and everyday wear and tear also damage the hair cuticle such that the cuticular scales no longer tightly overlap in an orderly fashion [8, 9]. Even though hair can be a good indicator of metals, cosmetic treatment of hair would definitely affect the accumulation patterns of different metals.

Polonium-210 (^{210}Po) is a more volatile radionuclide than other heavy metals in general and emits high-energy α-radiation, which is more hazardous when received internally [10-12]. ^{210}Po and ^{210}Pb enter the human body through food and water, the ingestion of seafood contributing the most, and through the respiratory route. The normal inhalation pathway contributes only 5% of this [13]. Any polonium that is absorbed in the bloodstream is distributed throughout the soft tissues of the body and in the liver, kidney and spleen of humans. Blood also carries lead and polonium to hair, which can be used for monitoring body exposure to a number of short-lived ^{222}Rn daughters [13-18]. The burden of ^{210}Po in a normal human body may differ from one person to another depending upon the lifestyle, dietary habits, origin of drinking water, residence (which influences radon exposure rate), and also smoking habits. The number of cigarettes smoked per day, the number of years a person has been smoking and the type of materials used for smoking [12].

Kanyakumari, commonly referred to as the 'Land's End', is located at the southernmost tip of peninsular India. Rice

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is the staple food of the population. Though there are some vegetarians, most people eat meat and fish products. Beach sand is mined along the coast for rare earths. Due to the presence of radioactive minerals such as monazite, the beach sand of the west coast of Kanyakumari exhibits high natural background radiation, varying from 0.5 to 5.0 μGy h^{-1}, the values reaching up to 50 μGy h^{-1} in isolated areas, resulting in radiation exposure to villagers varying from 3 to 30 mSv per year [19]. Dose rates due to ^{232}Th and ^{238}U as high as 1451.75 nGy h^{-1} have been observed by Saroja and Roy [20].

Assessment of human hair would reveal the levels to which the population gets exposed to the radionuclide, ^{210}Po. Knowing the various factors affecting the accumulation of polonium in hair would also be of interest. Very little is known about the ^{210}Po level in hair samples of this area; so the present study was undertaken to estimate its level in human hair samples and the underlying factors, which affect its accumulation. In this study, we assumed that hair polonium levels are affected by the use of hair oil, shampoo and other parameters.

MATERIALS AND METHODS

Sampling

Hair samples were randomly collected from 24 males and 23 females of different age groups and food habits belonging to Kanyakumari district (Tamil Nadu; figure 1). Collection of hair samples was made in a non-intrusive way after obtaining the informed consent of the participants. A questionnaire was given to all the participants, eliciting the following information: sex, age, place and type of residence, food habits, hair cosmetic treatments and smoking habits.

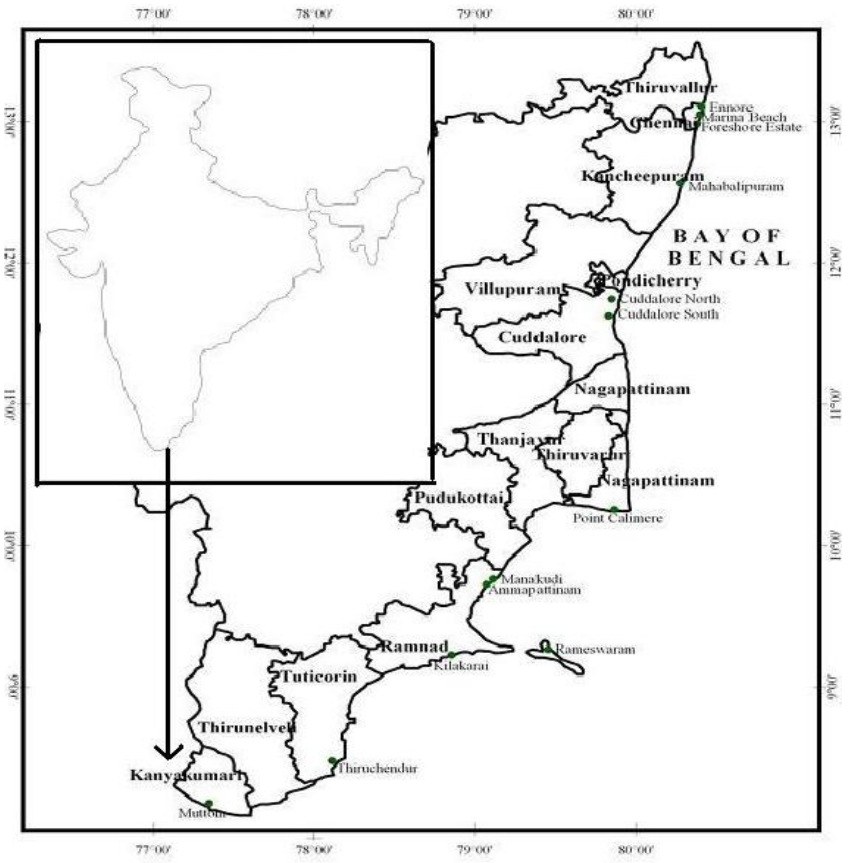

Figure 1. Study area.

Analysis of samples

The collected hair samples were repeatedly washed with detergent solution (Qualigens™, Labolene®) to make them free from foreign matter; they were finally rinsed with distilled water, dried at 110°C for 4-5 hr and stored in polythene bags for further processing. Sample dissolution and plating of polonium were done according to the method adopted by Iyengar and Jia *et al.* [21, 22]. ^{210}Po activity in hair samples was measured using a Nucleonix® Radiation Counting System (RC 605A). Three repeated countings of the same sample were done and the mean was taken for calculating ^{210}Po activity. Tracer experiments with ^{208}Po showed a recovery of 93%. Decay and recovery correction were done and the corrected activity values were considered for further data analysis. The activity concentration is reported on an milli Becquerel per gram (mBq g^{-1}) dry weight basis.

Statistical analysis

Pro UCL 4.0 [23], a software package developed by the United States – Environmental Protection Agency (US-EPA), was used to calculate the mean concentration of ^{210}Po and the 95% Upper Confidence Limit (UCL 95%) of the unknown population with bootstrap re-sampling, outliers and distribution. A normal distribution denotes that the samples represent the population and a log-normal distribution indicates that the distribution tends to be normal. The difference between the groups was analysed with Student's't' test. Since most of the underlying distributions were normal or log-normal, application of parametric Student's 't' test was found to be appropriate.

RESULTS AND DISCUSSION

Hair polonium range

In the present study, the activity of ^{210}Po in the hair samples was found to range from 9.89 ± 4.43 to 58.85 ± 6.27 mBq g^{-1}, with a mean value of 26.4 ± 11.92 mBq g^{-1} (table 1). In the seafood-consuming population of Japan, the ^{210}Po activity in hair samples ranged from 4.0 to 59.3 mBq g^{-1}, with a mean value of 18.2 ± 12.2 mBq g^{-1} [1]. In the control group of Pocos de Caldas, Brazil, the ^{210}Po range was 2-4.58 mBq g^{-1} [24] and in the control group of Santa Catarina, Brazil, the range was 2.3-4.9 mBq g^{-1}, with a mean value of 3.8 mBq g^{-1} in human hair samples [25]. In Iran, the average ^{210}Po concentration was 2.3 mBq g^{-1} in hair samples [26]. Thus the ^{210}Po range in this study is comparable to that of the hair samples from Japan [1] but the mean activity was higher in the present study (table 2).

Male and Female Groups

In the hair samples of males, the ^{210}Po activity concentration ranged from 8.9 ± 4.65 to 57.62 ± 10.9 mBq g^{-1}, with a mean value of 29.34 ± 12.46 mBq g^{-1} and in females, it varied from 12.67 ± 5.75 to 38.21 ± 5.28 mBq g^{-1}, with a mean of 21.72 ± 7.45 mBq g^{-1} (table 1). In the hair samples of females, ^{210}Po observed in a 22-year old from Kanyakumari was a statistical outlier. Student's *'t' test* in ^{210}Po concentration between males and females showed a significant variation (table 2). When the population sub samples were comparable with regard to age, living environment and socio-economic status, the observed differences of heavy metals in hair samples between males and females may be considered to be due to an actual biological difference between the sexes [27]. In the present study, the mean ages of males and females were 28.4 and 28.3 years, respectively, and the difference in ^{210}Po concentration between the sexes can be attributed to physiological differences.

Fish consumers and ^{210}Po activity

Among fish consumers, the hair ^{210}Po activity ranged from 10.25 ± 5.03 to 58.85 ± 6.27 mBq g^{-1}, with a mean value of 27.36 ± 12.67 mBq g^{-1} (table 1) and this range is comparable with ^{210}Po activity recorded in the fish-consuming population of Japan [1].

Ermolaeva-Makovskaya [28] has reported a high ^{210}Po concentration of 22.2 mBq g^{-1} in the hair samples of the inhabitants of Petropavlovsk-Kamchatsky of USSR. They attributed this high value to their seafood-consuming habit. In this study, the statistical difference between the consumers and non-consumers could not be established, because of the lesser number of observations under the non-consumer category (table 1). Apart from seafood, enhanced natural radioactivity has been recorded in terrestrial foodstuffs including dairy products from Brazil, reindeer meat from Sweden, and cereals, vegetables, tubers and fruits from the region in India having monazite deposits, containing up to 30 Bq kg^{-1} of nuclides such as ^{228}Th, ^{222}Ra, ^{210}Pb, and ^{210}Po [29].

Cigarette Smoking and ^{210}Po Activity

Among non-smokers the hair ^{210}Po activity ranged from 9.59 ± 4.65 to 58.85 ± 6.27 mBq g^{-1}, with a mean value of 25.15 ± 11.23 mBq g^{-1} and among smokers the hair ^{210}Po activity ranged from 23.32 ± 7.5 to 57.36 ± 10.9 mBq g^{-1}, with a mean value of 37.4 ± 12.96 mBq g^{-1} (table 1). Due to the reduced sample size as far as cigarette smokers is concerned, Students' *'t' test* could not be done between smokers and

Table 1. Summary statistics of different groups.

Group	Range (mBq g^{-1})	Mean (mBq g^{-1})	Distribution	95% UCL (mBq g^{-1})
Male & female (47)**	9.89±4.65 - 58.85±6.27*	26.47±11.92#	Log-normal	29.78
Male (24)	9.89±4.65 - 57.36±10.9	29.34±12.46	Normal	33.86
Female (22)	12.67±5.75 - 38.21±5.28	21.72±7.45	Normal	24.46
Fish consumers (43)	10.25±5.03 - 58.85±6.27	27.36±12.67	Log-normal	30.01
Fish non-consumers (4)	9.89±4.65 - 21.75±5.35	16.77±6.4	-	-
Smokers (5)	23.32±7.5 - 57.36±10.9	37.4±12.9	-	-
Non-smokers (42)	9.89±4.65 - 58.85±6.27	25.15±11.23	NDD##	28.13
Concrete houses (39)	9.89±4.65 - 58.85±6.27	25.76±12.16	Log-normal	29.43
Tiled houses (6)	22.60±3.58 - 47.14±6.70	31.8±10.6	-	-
Thatched (1)	-	15.49±5.51	-	-
Asbestos (1)	-	32.52±5.26	-	-
Cement floor (29)	9.89±4.65 - 58.85±6.27	26±11.92	Log-normal	30.28
Tiled floor (11)	13.45±… - 48.03±8.35	27.05±10.5	Normal	33.3
Marble floor (6)	12.72±5.35 - 57.62±10.9	28.5±17	-	-
Mud floor (2)	15.5±5.25 - 32.6±5.26	24.1±12.1	-	-
Home-made coconut oil(23)	12.72±5.44 - 48.03±8.25	26.64±8.32	Normal	29.62
VVD brand oil (5)	9.89±4.65 - 25.51±7.91	16.1±5.8	-	-
Parachute brand oil (3)	14.88±5.51 - 22.62±3.58	19.7±4.24	-	-
Oil non-users (2)	13.7±5.92 - 21.76±5.39	17.8±5.8	-	-
Medicinal oil (12)	10.25±5.03 - 47.14±6.7	28.86±14.29	Normal	36.27
Shampoo users (35)	9.89±4.65 - 58.85±6.27	23.22±9.19	Log-normal	26.3
Shampoo non-users(11)	19.48±5.12 - 57.36±10.92	33.87±12.8	Normal	40.87

*Counting uncertainties, #Group standard deviation,**Number of samples, ##No discernable distribution.

Table 2. Difference in-between the groups.

Groups	P value (5% level)	Significance
Male and female	0.01	Significant difference
Cement and tiled flooring	0.4	No Significant difference
Home-made coconut oil and medicinal oil	0.3	No Significant difference
Shampoo users and non-users	0.01	Significant difference

non-smokers. It has been recorded that cigarette smoking may increase the polonium load to humans [12]. In the blood samples of Saudi Arabian non-smokers, cigarette smokers and shisha smokers the activity concentrations of ^{210}Po were 29 ± 13, 41 ± 11 and 50 ± 15 mBq ml^{-1} respectively. And in the hair samples of Saudi Arabian non-smokers, cigarette smokers and shisha smokers the ^{210}Po activities were found to be 2.8 ± 0.4, 3.8 ± 0.4 and 4.8 ± 0.4 mBq g^{-1} respectively [12]. Polonium received from cigarette is retained in the blood and is expected to be reflected in the hair. It may be noted that the pH of the intestinal juice (7.7) and blood (7.4) is one of the reasons for the increased mobility of ^{210}Po and its higher accumulation in the hair [30].

Residence Types and ^{210}Po Activity

^{210}Po activity in hair samples of donors living in concrete houses ranged from 9.59 ± 4.65 to 58.85 ± 6.27 mBq g^{-1}, with a mean value of 25.76 ± 12.16 mBq g^{-1} and in the hair samples of donors living in cement-floored houses ^{210}Po ranged from 9.89 ± 4.65 to 58.85 ± 6.27 mBq g^{-1}, with a mean value of 26 ± 11.92 mBq g^{-1} (table 1). In the present study no statistical difference was found between the hair ^{210}Po activities of persons living in different types of houses, which were classified based on the flooring (table 2). Accumulation of certain elements (e.g. Cr) in hair is region-specific and that of others (Pb, Cd and As) is similar between regions as reported by Kasperek *et al.* [31], who studied toxic elements in Vienna and Rome. The gaseous ^{222}Rn from the ^{238}U decay series enters into homes from outdoor air and building materials. Two of the most significant routes through which ^{222}Rn enter homes are soil gas coming in through foundations and municipal water [32]. The ^{210}Po content in air varies between locations. In the United States, it was found to vary from 10 to 40 µBq m^{-3} and in Germany it was found to range from 12 to 80 µBq m^{-3}, with a UNSCEAR reference value of 50 µBq m^{-3} [29].

Hair Oil Usage and ^{210}Po Activity

Among those applying various brands of coconut oil to their hair, the concentration of ^{210}Po in hair samples of users of home-made oil varied between 12.72 ± 5.35 and 58.85 ± 6.27 mBq g^{-1}, with a mean value of 26.64 ± 8.32 mBq g^{-1}. In the hair samples of the users of the *VVD* brand of coconut oil, the ^{210}Po activity concentration varied from 9.89 ± 4.65 to 25.51 ± 7.91 mBq g^{-1}, with a mean value of 16.1 ± 5.8 mBq g^{-1}. Among those using the *Parachute* brand of coconut oil, the activity concentration of ^{210}Po ranged from 14.88 ± 5.51 to 22.62 ± 3.58 mBq g^{-1}, with a mean value of 19.7 ± 4.24 mBq g^{-1} and among medicinal oil users, the activity concentration ranged from 10.5 ± 5.3 to 47.14 ± 6.7 mBq g^{-1}, with a mean value of 28.86 ± 14.28 mBq g^{-1} (table 1). There was no significant difference in ^{210}Po concentration in the hair samples of those using home-made coconut oil and those using medicinal oil. The use of hair oil has been on the rise in India [33] and in certain areas hair oil usage is traditional. *VVD* and *Parachute* oil are refined oils and home-made oil and medicinal oil are similar except for the addition of an herbal extract to the latter. The finding of the present study is important because it signifies the type of oil which enhances polonium accumulation. Application of home-made oil and herbal oil increases ^{210}Po accumulation than that of branded coconut oils. But we were not able to test this statistically due to the small sample size.

Shampoo Users and ^{210}Po Activity

In shampoo users, the activity concentration of ^{210}Po ranged from 9.89 ± 4.65 to 58.85 ± 6.27 mBq g^{-1}, with a mean value of 23.22 ± 9.19 mBq g^{-1} and in shampoo non-users, it ranged from 19.48 ± 5.12 to 57.36 ± 10.92 mBq g^{-1}, with a mean value of 33.87 ± 12.8 mBq g^{-1}. There is a significant difference between the shampoo user and non-user category, with the non-user exhibiting high hair polonium activity than the user (table 1). The possible reason for

this could be the cleaning action of shampoos which removes or prevents the accumulation of ^{210}Po in hair. Alkaline shampoos weaken the hair by breaking the disulphide bond in hair keratin which may prevent ^{210}Po from combining with sulphur bonds since polonium is chalcophilic and siderophilic [34].

CONCLUSION

Interesting observations were made as regards hair ^{210}Po activity, in various people. All the groups were not analysed statistically for their differences due to less number of observations and we underline that future studies should be able to fill these gaps. Hair samples obtained from the users of home-made and medicinal oil had higher concentration of ^{210}Po compared to that of people using branded oils. Shampoo very likely damages the hair cuticle so that polonium becomes accumulated to a lesser extent, which is evident by the low ^{210}Po concentration in hair samples of shampoo users and high activity in those of shampoo non-users and these are topics of interest for future studies.

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