DOSIMETRY AND INSTRUMENTATION

EPR DOSIMETRY OF RADIATION BACKGROUND IN THE URALS REGION

Shishkina EA[1], Fattibene P[2], Wieser A[4], Degteva MO[1], Onori S[2]., Ivanov DV[3]., Shved VA[1], Bayankin SN[3]., Knyazev V.A[5]., Vasilenko EI[5]., Gorelov M[5].

[1] Urals Research Center for Radiation Medicine, 48-A Vorovsky, Chelyabinsk 454076, Russia
[2] Istituto Superiore di Sanità and Istituto Nazionale di Fisica Nucleare, Italy
[3] Institute of Metal Physics, Russian Academy of Sciences, Russia
[4] GSF, Forschungszentrum für Umwelt und Gesundheit, Ingolstädter Landstr, Germany
[5] ZAO, Closed Corporation "Company GEOSPETSECOLOGIA", Russia

ABSTRACT

Method of Electron Paramagnetic Resonance is extensively applied to individual retrospective dosimetry. The background dose is unavoidable component of cumulative absorbed dose in the tooth enamel accumulated during the lifetime of donor. Estimation of incidental radiation dose using tooth enamel needs in extraction of background dose. Moreover, the variation of background doses in the population is a limited factor for reliable detection of additional irradiation especially for low dose level. Therefore the accurate knowledge of the natural background radiation dose is a critical element of EPR studies of exposed populations. In the Urals region the method applies for such two large cohorts as the workers of Mayak (Ozersk citizens) and Techa River riverside inhabitants (rural population). Current study aimed to investigate the Urals radiation background detected by EPR spectrometry. For this aim two group of unexposed Urals residents were separated, viz: citizens of Ozersk and rural inhabitants of Chelyabinsk region. Comparison of two investigated territories has demonstrated that from the point of view of radiation background it is impossible to assume the Urals population as uniform. The reliable difference between the urban and rural residents has been found. The average background doses of Ozersk donors is in average 50 mGy higher than those detected for rural residents. The individual variability of background doses for Osersk has been higher than in the rural results. The difference in background dose levels between two population results in different limits of accidental dose detection and individualization. The doses for "Mayak" workers (Ozyorsk citizens) can be classed as anthropogenic if the EPR measurements exceed 120 mGy for teeth younger than 40 years, and 240 mGy for teeth older than 70 years. The anthropogenic doses for Techa River residents (rural population) would be higher than 95 mGy for teeth younger than 50 years and 270 mGy for teeth older than 80 years.

INTRODUCTION

The method of Electron Paramagnetic Resonance (EPR) is extensively applied to individual retrospective dosimetry. The EPR reconstruction of absorbed doses in tooth enamel has been used in different radiation incidents (Ishii et al., 1990, Desrosiers and Romanyukha, 1998). In the Urals region the method is applied for studies of such two large cohorts as the workers of Mayak (Lyzlov et al., 1998) and the residents of the Techa riverside villages (Vorobiova et al., 1999). These cohorts are most perspective for specification of radiation risks under the conditions of chronic exposure. EPR dosimetry plays an important role in the dosimetric support of the epidemiological studies on exposed Urals residents.

The cumulative dose, detected by EPR method reflects the influence of all types of ionizing radiation absorbed during lifetime of a tooth. The background dose is an unavoidable component of cumulative absorbed dose in tooth enamel. Usually, the term "background dose" implies the influence of natural ionizing (Nilsson et al. 2001). However, in the present study the radiation background also implies radiation from global fallout and from other potential sources, such as medical irradiation. The concentration of stable radicals in enamel induced by background sources of ionizing radiation is generally considered to be age-dependent with an annual component of about 1 mGy (Ivannikov et al. 2000). The fact is that the accumulation rate of enamel dose from background radiation varies for donors living in different geographical regions (Romanyukha et al. 1999).

Estimation of anthropogenic radiation dose needs extraction of background dose. However, based on EPR spectrum it is impossible to distinguish the background dose from that formed due to additional exposure. Therefore, estimation of average background dose in the population which can be assumed as an adequate control for exposed people is an essential task. Moreover, the individual variations in background doses among the population are a limiting factor for reliable individual estimation of anthropogenic dose component (limit of individualization). In other words, it is very important to estimate a dose level above which the doses reconstructed for exposed donors can be assumed as values exceeding background and containing the anthropogenic component. Therefore, the accurate knowledge of the natural background doses is a critical element in the structure of EPR studies.

The background doses fall into the range of low doses. The problem of measuring small doses is by no means a trivial task. Two main factors limit the sensitivity of EPR dosimetry of tooth enamel. The first is an endogenous EPR signal (attributed to the organic component of enamel) that is spectrally adjacent to the radiation-induced signal and which substantially obscures the measurement of radiation response at doses below 300-400 mGy (Shishkina et al, 2003a). The second factor is the sensitivity limit of EPR instrumentation (Wieser et al., 2000a). A number of international intercomparisons for EPR dosimetry demonstrate the relatively low agreement between low dose measurements, performed in the different laboratories (Wieser et al, 2000b). Therefore, the critical factors which can influence the accuracy of background dose assessment are the following: 1) the reliability of individual EPR measurements of low doses; 2) large statistics of EPR measurements of background.

The aim of the present study is to investigate the Urals radiation background detected by EPR spectrometry. To meet this purpose, two groups of unexposed Urals residents were selected, viz: citizens of Ozyorsk and rural inhabitants of Chelyabinsk region. These two populations serve respectively as a control group for the Mayak workers, since they all resided in Ozyorsk, and for exposed residents of the Techa River villages. Lifestyle, nutrition and medical service are known to be different in the two groups and this could have resulted in different background doses. Large statistics of EPR measurements was achieved due to efforts of 3 research groups, viz: Istituto Superiore di Sanità, Rome, Italy; GSF-National Research Center for Environment and Health (GSF), Neuherberg, Germany; and Institute of Metal Physics (IMP), Ekaterinburg, Russia.

The study presented in this paper was organized in four interrelated tasks. Since EPR measurements were provided by 3 different laboratories which used different equipment and methods, the first task was, hence, the estimation of data comparability and possibility of aggregate analysis for detected doses. The second task involved analysis of individual measurements for data quality *estimation and selection of appropriate statistical parameter for description of expected average background dose of the population. The third task involved the analysis of individual and averaged measurements for estimation of age dependences of age dependences of background doses. The fourth task consisted in evaluation of individual variations for radiation background and estimation of the limit of individualization for anthropogenic dose assessment.*

EXPERIMENTAL MATERIALS AND METHODS

EPR measurements were performed by three laboratories: ISS (Italy), GSF (Germany) and IMP (Russia). The EPR techniques used in these laboratories have been described in detail elsewhere (Wieser et al. 2000a, b; Onori et al., 2000; Shishkina et al. 2003b). The EPR spectrometers and procedures used for enamel-dose reconstruction are shown in Table 1. As can be seen, similar procedures of sample preparation (chemical treatment in concentrated alkali solution), signal evaluation (the best fit of the model to the experimental spectrum), and dose evaluation (universal calibration curve) have been used in the three laboratories.

EPR measurements were carried out on extracted permanent teeth from Urals residents. The teeth under investigation were extracted on medical indications. Only premolars and molars were used in this study (4, 5, 6, 7 and 8 tooth positions). For background dose estimation two approaches were provided. The first is mathematical averaging of individual measurements. The second is physical averaging (using mixtures of tooth enamel powder from several donors). The individual measurements were done in IMP (102 rural and 64 Ozyorsk samples), GSF (52 rural and 12 Ozyorsk samples) and ISS (71 Ozyorsk sample). Here, 46 rural samples had the duplicate measurements in GSF and IMP. Measurements of enamel mixtures were done only in IMP. Mixed enamel samples were prepared using mixtures of enamel powder of 2nd premolars (position 5 in the denture) obtained from different rural donors. The mixes were prepared for teeth of donors subdivided into 5 age groups. Each mix was subdivided into a number of portions having masses optimal for EPR measurements (about 100 mg). The number of portions was determined by total mass of mixed enamel. Each portion was measured, and the results were averaged. Totally, 247 samples were measured for rural residents (108 teeth were measured by EPR individually and 139 teeth were used for preparation of enamel mixtures), and 147 samples for Ozyorsk citizens.

The majority of samples obtained from rural donors were received from the dental clinics of the Chelyabinsk region. The donor birth years were in the range from 1910 to 1955, which in general corresponds to the age of the Techa River exposed population. The selected tooth donors from the Ozyorsk residents were received from Ozyorsk dental clinics. The donors who were found to be occupationally exposed at Mayak or registered as former residents of villages on the Techa River were excluded from the examination. The donors' birth years were in the range from 1921 to 1970. The beginning of the enamel mineralization (hydroxyapatite formation) was assumed as a reference point for estimating the age of tooth samples. Thus, the beginning of enamel formation was defined as follows: 3 years after birth for second premolars and second molars; 2 years after birth for 1st premolars; 9 years for wisdom teeth and 0 for 1st molars, for which the mineralization of permanent teeth begins in pre-natal period (Borovsky and Leontyev, 1991).

Table 1. Summary of methods used for EPR-dose reconstruction.

Laboratory	EPR spectrometer	Sample-preparation method	Signal-evaluation method	Dose-calibration method: universal calibration curve obtained with
GSF, Germany	Bruker, ECS106	Chemical treatment with NaOH (grain size 0.1-0.6 mm)	Deconvolution using a set of Gaussian functions	permanent molars from German donors
IMP, Russia	GDR, ERS231	Chemical treatment with KOH (grain size 0.1-0.6 mm)	Deconvolution using a set of Gaussian functions	permanent molars from Urals donors
ISS, Italy	Bruker, ElexSys	Chemical treatment with NaOH (grain size 0.2-0.5 mm)	Deconvolution using best fit of powder spectrum	permanent molars from Urals donors

RESULTS

1. Possibility of a unified analysis of doses detected at different laboratories

In order to aggregate the dose measurements of the three laboratories, the data comparability was tested. The repeated EPR measurements of 79 teeth (obtained from exposed donors living on the Techa River banks and unexposed residents of the "background areas of the Urals") were performed at IMP and GSF. The comparison of the results provided by the two laboratories is shown in Fig. 1a. The consistency of data and the absence of a systematic shift between the measurements from these two laboratories in the dose range from 0 to 14 Gy was demonstrated (Fig. 1a). Nevertheless, in the low dose range (<400 mGy) the 95% confidence interval of the deviation between the individual IMP and GSF results is equal to ±200 mGy (embedded picture in the Fig. 1a).

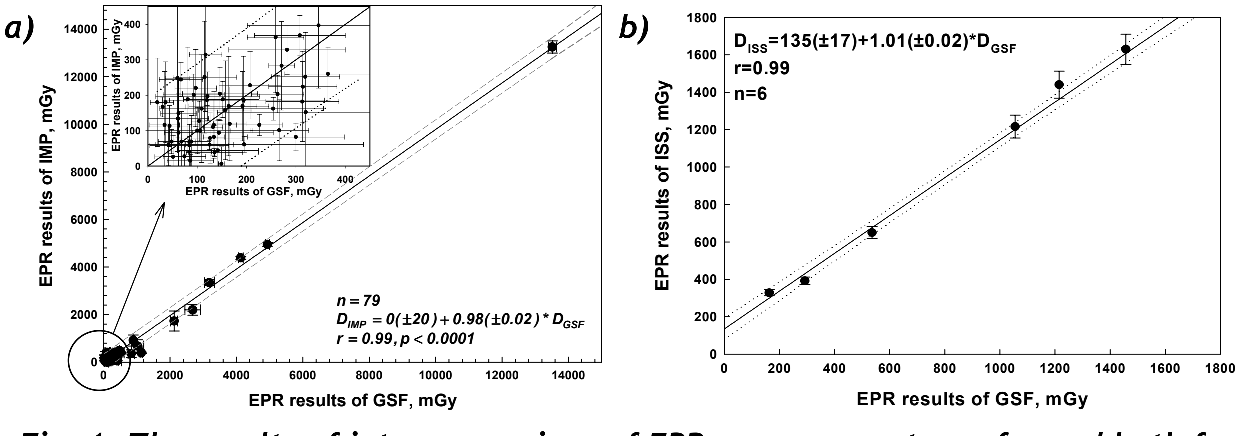

Fig. 1. The results of intercomparison of EPR measurements performed both for exposed and unexposed donors between a) GSF and IMP; b). GSF and ISS.

The data comparability of ISS and GSF was tested indirectly. The test was performed with teeth of six donors (3 Ozyorsk citizens and 3 Mayak nuclear workers) each of which donated two teeth. Each laboratory measured one tooth for each donor. The correlation of the dose estimated by GSF and ISS is shown in Fig. 1b. The slope of the regression line in Figure 1b was 1.01±0.04, but a positive bias of 135±17 mGy for the ISS system was evaluated. In the present paper, the doses given by ISS were corrected by this value of bias. Based on *these results, it was derived that the doses measured by ISS, IMP and GSF are comparable and can be aggregated for common data analysis. However, because the investigated background doses relate to low dose level, where the reliability of individual measurements is not high (Fig. 1a), the aggregated analysis should take into account the accuracy of individual measurements for precise estimation of average background doses.*

2 Analysis of individual EPR measurements and selection of appropriate statistical parameters for description of average background dose

In Table 2 the statistical parameters of estimated doses are reported separately for each laboratory and for the two populations. For the Ozyorsk population, the samples measured at IMP and ISS were comparable by number and tooth age distribution, whereas the teeth measured at GSF were younger and the number of investigated samples was significantly smaller. Doses above 400 mGy were found in 5 samples measured at ISS and in 3 samples at IMP. The maximum dose was about 1.5 Gy. Such high doses cannot be related to natural background or influence of global fallouts, but can be the result of repeated medical exposures of cranium and teeth or mistakes in identification of donors which could not be tracked.

Table 2. Statistical parameters of estimated background doses in the three laboratories for Ozyorsk citizens and rural population.

	Ozyorsk citizens			Rural population	
	IMP	GSF	ISS	IMP	GSF
Average age	58±11	43±10	55±12	64±10	68±9
Number of samples	64	12	71	102	52
Minimal EPR dose, mGy	0*	0*	2	1*	11
Maximal EPR dose, mGy	694	221	1495	464	406
Mean, mGy	145	60	163	140	111
Standard deviation, mGy	124	58	222	93	83
Median, mGy	129	50	101	116	93

** - below the detection limit*

The probability of similar abnormal doses can not be excluded from exposed population too. Therefore, the high doses observed were not excluded from analysis of background doses in order to maintain the identity of the control. For the rural population, the tooth age distribution in the two groups of measurements performed at IMP and GSF was similar. Correspondingly, the mean dose values were comparable, within the standard deviation. The highest detected dose was 460 mGy. For the 47 samples measured both at GSF and IMP the weighted average values were used in the statistical analysis of individual data. The distribution of tooth ages of the rural donors was highly non-uniform. The most numerous age groups consisted of teeth in the 60-70 years (47%) and 70-80 years (22%) age ranges, summing up to about 70% of all EPR measurements in a narrow age range (20 years). Most of the tooth samples from Ozyorsk donors were younger, and their ages were distributed more uniformly, spreading over a wider age range (from 27 to 76 years). However, in spite of the lower average age, mean doses and standard deviations estimated for Ozyorsk were higher than those found for rural population of the Urals, whereas median values are comparable. Table 3 shows the statistical parameters of dose distributions for *the five age groups with the higher number of samples and for the total set of samples, separately for rural and Ozyorsk populations.*

Table 3. The statistical characteristics of background dose distributions of rural population and Ozyorsk citizens estimated for most numerous age groups and total selections.

	Age group, years						
	Rural population			Ozyorsk citizens			
	60-69	70-78	41-90 (total)	40-49	50-59	60-69	27-76 (total)
Average age in group	63±2	73±2	65±10	45±3	55±3	64±3	55±12
Number of samples	47	23	110	41	31	38	147
Minimal EPR dose, mGy	4*	1*	1*	0*	2*	0*	0*
Maximal EPR dose, mGy	415	299	464	1495	587	1082	1495
Mean, mGy	121	127	124	149	129	199	147
Standard deviation, mGy	81	90	88	299	110	209	177
Median, mGy	104	112	107	100	118	119	105
Mathematical expectation, mGy	69	91	70	75	68	148	89
Mean sq. dev., mGy	49	79	60	61	80	142	84

*- below the detection limit

The data of Table 3 suggest that the dose distribution is asymmetric. The choice of the method for data averaging strongly depends on both data reliability and data distribution. As can be seen from the median values of dose distributions in Table 3, fifty percent of measured doses, independently on tooth age or residence place, are smaller than 120 mGy and, correspondingly, the difference between most of measurement results is not significant (according Fig. 1a).
The standard deviation of the mean value of individual doses was estimated by repeating three measurements and can then be assumed as the measurement repeatability. Analysis of dose dependence of this indicator has shown no correlation of repeatability with dose both for data analyzed separately for each laboratory and for aggregate measurements. *The distribution of standard deviations has a symmetric shape and can be precisely described by truncated normal distribution* both for *measurements of each laboratory and for total pull of data. A separate analysis of the standard deviations for ISS, GSF and IMP demonstrates that the peaks and widths of distributions are equal to 30±18 mGy, 38±28 mGy and 54±47 mGy, respectively. The peak of the truncated normal distribution of all available measurements is observed at the values of 40±40 mGy.*
Since the standard deviations do not depend on the estimated doses, and most of individual results for background dose reconstruction do not significantly differ from each other, the EPR measurements of background doses can be assumed as the repeated measurements of the same value with different order of reliability. The independence of standard deviations on estimated dose values and normality of their distribution allow using this parameter as a statistical weight (criterion of reliability). Thus, the model for repeated measurements can be proposed for statistical analysis of the non-Gaussian distributed individual measurements to estimate the most probable value of background dose (mathematical expectation) for investigated populations. This model ignores the individual variability of accumulated doses and takes into account only the relative reliability of each measurement. Actually, the repeated measurement model comes to the estimation of mathematical expectations which are

calculated as the weighted average dose value for the different age groups of the investigated donors.

One of the main requirements for value** of mathematical expectation **is proof of estimate unbiasedness. The unbiasedness of model predictions was validated by comparison between mathematical and physical averaging performed for rural samples. For this purpose, 5 age groups were selected from the pull of measured samples in such a way as to be equal to age of mixed samples. EPR measurements of mixed enamel samples were provided for minimization of the uncertainty contributed by the variability of individual background doses. Analysis of the measurements was based on the assumption that each portion in each group of enamel mixed samples had the same dose. This assumption was verified by analysis of dose distribution of the portions in each mixture. It was found that the dose distribution of the portions in each mix can be described by normal shape with high probability, which confirms our assumption. A description of the groups and measurement results is shown in Table 4.

Table 4. The EPR measurement results for 5th teeth using the mixes of enamel separated by age groups.

Group number	Physical averaging			
	Number of mixed teeth in the group	Number of portions	Average tooth age for group, years	Average dose and St. Dev, mGy
1	17	20	78±3	122±42
2	39	50	70±3	55±42
3	23	16	62±1	82±48
4	35	26	55±3	50±26
5	25	25	48±1	57±31

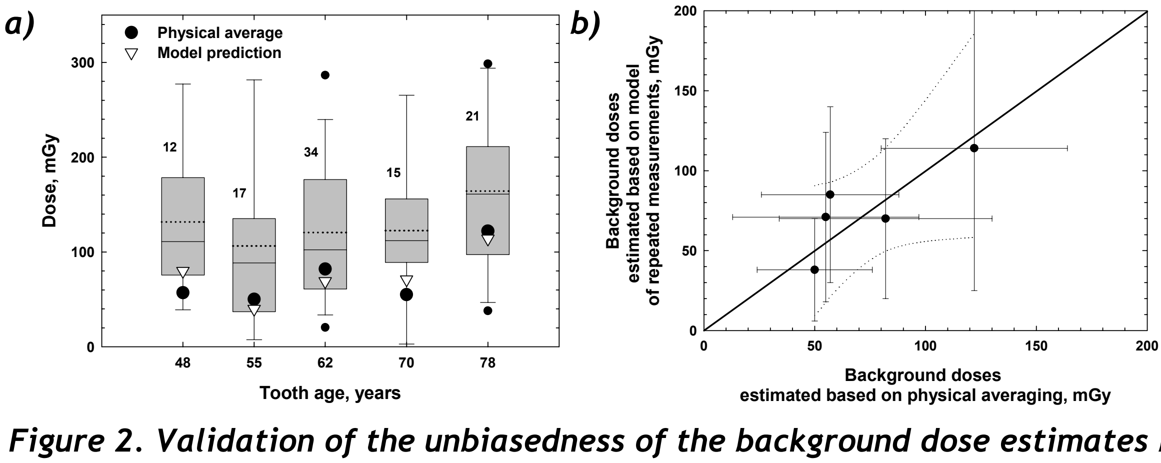

Figure 2. Validation of the unbiasedness of the background dose estimates based on the model of repeated measurements: a) comparison of statistical parameters of individual dose distributions for different age groups, model predictions and results of physical averaging. Numbers indicated above the boxes represent the number of individual data in each group; dotted lines correspond to the mean doses and solid lines correspond to the medians; whiskers above and below the boxes indicate the 90th and 10th percentiles; b) directional comparison of two methods of averaging.

The results of physical averaging were compared with the statistical parameters of individual dose distributions separately for each age group of rural population (Fig. 2 a). Both physical and mathematical averaging results were found close to

the bottom of boxes (25 percentile of dose distribution) that is typical of lognormal distribution of individual data. Fig. 2 b demonstrates the correlation between the two methods of dose estimation. Horizontal error bars are the standard deviations of measurements of mixed enamel samples. Vertical error bars are the mean square deviations. Solid line represents the line of regression ($r^2 = 0.54$, p=0.15). This test demonstrated that the dose estimate found using model of repeated measurements can be assumed as unbiased estimate of the most probable background dose measured by EPR methods used in the study.

3 Background doses of Urals populations

Individual data were grouped in tooth age intervals of 10 years .Age dependences of background doses were found for both populations based on distribution-free analysis of median values. Fig. 3 demonstrates the tendency of median dose increase with age of teeth. The vertical bars represent the quartile ranges which also demonstrate an evident widening of individual dose variations with age.

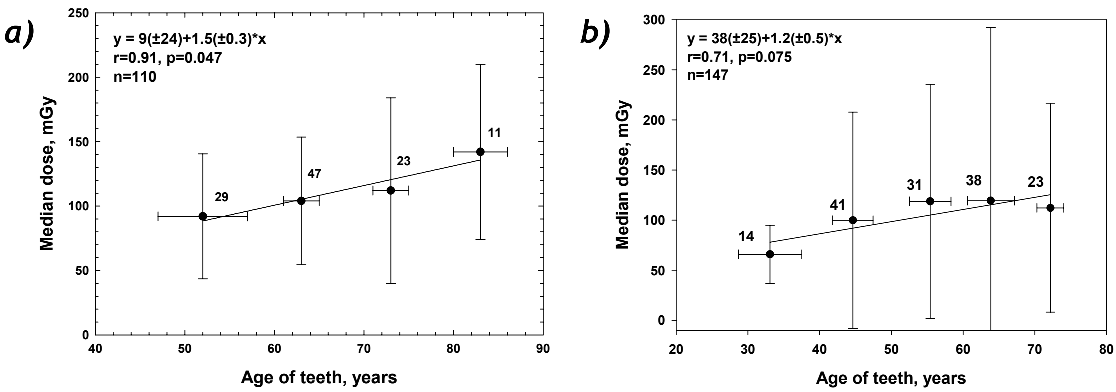

Fig. 3. Age dependence of median values estimated for background doses of a) rural and b) urban populations.

For estimation of background doses based on individual EPR data the model of repeated measurements was applied. The most probable background dose (the mathematical expectation reported in Table 3) of all the individual measurements was 70mGy (mean sq. dev is 60 mGy) that corresponds to average age 65±10 years, and 89 mGy (mean sq. dev is 84 mGy) that corresponds to average age 55±12 years for rural and Ozyorsk citizens respectively. For each age group more than 50% of individual EPR doses fall in the range limited by mean square deviation.

Results of dose estimation for rural population obtained by both physical averaging and individual measurements were combined for aggregate analysis of age dependence of accumulated dose (Fig. 4). As can be seen, there is a tendency towards an increase in the background dose with donor's age (correlation coefficient is equal to 0.63 with the probability P=0.04). The slope of regression line under linear approximation for accumulated dose was found to be 2.1±0.7 mGy per year. Likewise, the age dependence of radiation background dose found for Ozyorsk citizens was 2.1±0.8 mGy per year with a correlation coefficient of 0.67 and the probability P=0.091 that practically is equal to the slope estimated for rural population. Unfortunately, the narrow interval of tooth age and high uncertainties of dose assessments does not allow estimation of the slopes of dose increasing with precision better than 35-40%. Therefore, the trend of averaged dose with age seems to be not linear. Therefore, the age dependences are relevant to only the age range studied, and cannot be extrapolated to younger teeth.

The difference between the regression lines for two populations is equal to 47 mGy. The reasons for such high difference can be as follows: (1) Ozyorsk citizens received a better medical assistance, which included radiological examinations, and 50 mGy (on the average) can reflect the average dose of medical exposure for Ozyorsk; (2) The intercomparison between three laboratories was undirected and in spite the efforts to make data uniform the possibility of some systematic bias of ISS data (half of Osyorsk measurements) can not be ruled out. Currently, an accurate intercomparison is in progress, which should allow to specify the present results.

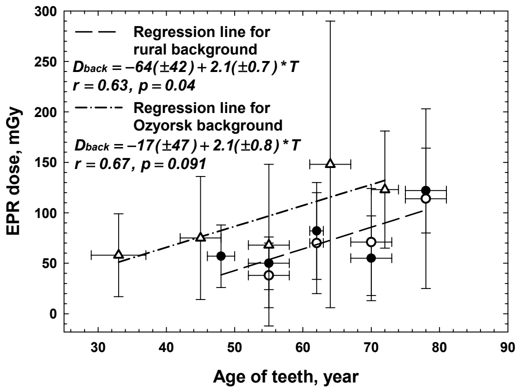

Fig. 4. Age dependences of background dose for rural and urban population. The triangles indicate the mathematical expectations of background EPR doses computed for Ozyorsk citizens. The circles are the results of averaging of background EPR doses for rural inhabitants estimated based on both physical averaging (black) and mathematical expectation (white).

4 Limit of individualization for anthropogenic dose assessment

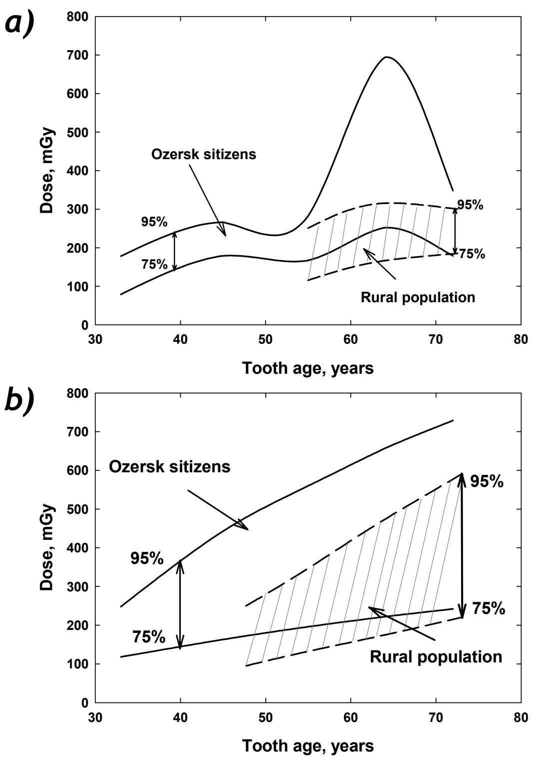

Fig. 5. Comparison of 75% □ 95% percentile of background dose distributions of rural and urban population depend on tooth age: a) observed based on cumulative probability; b) predicted based on lognormal model of background dose distribution.

The limit of individualization for anthropogenic dose estimation can be defined as such an EPR dose limit beyond which individual EPR measurements can be interpreted with a definite degree of assurance as containing an anthropogenic fraction, in addition to the background component. Such limit can be established based on knowledge about background dose distribution. Figure 5a demonstrates 75 and 95 percentile of cumulative probability calculated for observed dose distributions inside Ozyorsk and rural groups of samples. As can be seen, the data of Ozyorsk demonstrates the abnormal peak between 60 and 70 years of tooth age. Such peak has been conditioned by the presence of 3 high doses (from 500 to 1,080 mGy) in this pool of data. In principle, the presence of such high doses may be observed in other age groups. The insufficient number of samples in most of the age groups does not allow us to be sure of the reliability of the analysis based on the cumulative probability. To estimate the 75 and 95 percent of probability the lognormal model of background dose distribution was applied. The probability density function for lognormal distribution is described by Eq. 1.

The parameters of lognormal fitting of experimental data were evaluated for different age groups.

The age dependences of scale and inverse value of shape parameters for background dose distribution for Ozyorsk and rural residents are shown in Eq. 2, 3. The tendency to increasing of both the scale and shape parameters with tooth age should be reflected in the significant widening of the range limited by 75% and 95%. This peculiarity of background dose distribution in Ozyorsk is shown in Fig. 5b. As can be seen, the peak which was found by analysis of cumulative probability (Fig. 5a) is not contradicted by the theoretical prediction. For rural population only three most numerous age groups were available for prediction of 75% and 95% level of lognormal distribution. An increase in the scale parameter with age was found for rural population too. However three points of shape parameter inside the narrow age range (from 50 to 80 years) were not sufficient for estimation of age dependence and the average value of shape parameter (Eq 3) used in the computations shown in Fig. 5 (b).

$$f(x) = \frac{1}{x * \sigma * \sqrt{2\pi}} * e^{\left[-0.5*\left(\frac{ln\left(\frac{x}{x_0}\right)}{\sigma}\right)^2\right]} \quad (1),$$

$$\text{Ozyorsk□}\begin{cases} x_0 = 35.6 + 1.1 * T \\ \frac{1}{\sigma} = 0.76 + 31.1 * e^{-0.11*T} \end{cases} \quad (2)$$

f(x) - relative probability of x (background dose detection); x_0 - scale parameter corresponds to max probable value of background dose; □ - shape parameter.

$$\text{Rural population□}\begin{cases} x_0 = -71 + 2.5 * T \\ \frac{1}{\sigma} = 1.01 \end{cases} \quad (3)$$

The estimated 75% bounds can be assumed as an absolute limit of anthropogenic dose estimation. The detected dose, which is lower than this border, can be assumed as a background dose with 75% of probability. The dose detected above the 95% bound can be used for individual dosimetry with high reliability. The doses, which will fall in the range between 75 and 95% bounds can be used mostly for statistical analysis taking into account the probability of the presence of some additional dose (above background).

The anthropogenic doses for "Mayak" workers (Ozyorsk citizens) can be reliably estimated if the EPR measurements exceed 120 mGy for teeth younger than 40 years and 240 mGy for teeth older than 70 years. The anthropogenic doses for Techa River residents (rural population) can be evaluated if EPR detection would be higher than 95 mGy for teeth younger than 50 years and 270 mGy for teeth older than 80 years.

According Fig. 5b, it can be concluded that EPR doses found for urban population of Ozyorsk can not be assumed as equal to background doses of rural residents in both the difference in average values and individual variability. It is possible that the following methodological improvements will reduce the difference registered. However the current status of investigations does not allow assuming the rural and urban inhabitants of Urals region as a unified population.

CONCLUSIONS

The approximation of repeated measurements for background dose estimation, proposed based on the analysis of data reliability and distributions, was verified by frequentative measurements of physically mixed samples. It was shown that

the model of repeated measurements gives an unbiased estimate characterizing the most probable background dose, measured by EPR method.
Comparison of two investigated territories has demonstrated that from the point of view of radiation background it is impossible to assume the Urals population as uniform based on available EPR measurements. The background doses of Ozyorsk donors are on the average 47 mGy higher than those detected for rural residents. The individual variability of background doses for Ozyorsk citizens is higher than that shown by the rural population. But both populations have a similar tendency to an increase, at about the same rate, in dose with age, and a similar asymmetric character of dose distribution.
Both populations demonstrate an increase in individual dose variability with age of teeth that results in different limits of anthropogenic dose detection and individualization. The doses for "Mayak" workers (Ozyorsk citizens) can be classed as anthropogenic if the EPR measurements exceed 120 mGy for teeth younger than 40 years, and 240 mGy for teeth older than 70 years. The anthropogenic doses for Techa River residents (rural population) would be higher than 95 mGy for teeth younger than 50 years and 270 mGy for teeth older than 80 years.
Obviously, the reliability of anthropogenic dose detection is still strongly dependent on accuracy of the EPR method. As yet, the comparability of low dose detection between the different laboratories demonstrates the unsatisfactory value of ±200 mGy. Therefore, the improvement of EPR dosimetry for low dose assessment is an essential task. The directional interlaboratory comparison is also a necessary step for validation of the difference of EPR detected background doses between urban and rural population.

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