Results and perspectives of application of the tooth enamel EPR dosimetry at wide-scale radiation accidents

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Abstract

The experience of using the tooth enamel EPR dosimetry method at wide-scale radiation accidents is analyzed in order to estimate the real possibilities and area of application of the method. The summary results of our investigations and results of other authors on the application of the EPR dosimetry method for investigation of the radiation effects of nuclear tests on the population of the Semipalatinsk region are presented. Also, our results of application of the EPR method for investigation of radiation effects on the population of radioactively contaminated territories after the Chernobyl accidents are presented in order to perform joint cross verification of the EPR method and other methods of dose reconstruction, such as the calculations based on the level of radioactive contamination and information about individual behavior. The experience of using the EPR method at control radiation uncontaminated territories is analyzed in order to estimate the real sensitivity of the method and effectiveness of its application for the population of territories with low level of radioactive contamination.

INTRODUCTION

The aim of this presentation is to estimate the real potential and perspectives of using the teeth enamel EPR dosimetry method basing on the analysis of the experience of using this method at wide scale radiation accidents (taking into account limitations on its sensitivity and possibilities of sample collection).

The main limitations of application of the EPR dosimetry method are connected with its detection limit and possibility of sample collection. Sample collection is restricted by possibility of obtaining teeth extracted by medical appointments and presence of population group in interest, which may be restricted because of medical appointments for teeth extraction and reducing the population group in interest because of long period after radiation accident. The detection limit of the method is directly connected with its accuracy.

The accuracy of the method may be estimated from analysis of the data obtained from the following investigations:
- calibration and methodical investigations;
- blind tests in the course of interlaboratory comparisons;
- measurements for population of radiation free territories;
- comparison results of EPR dosimetry with results of dose measurement and dose reconstruction by other methods.

The estimates of accuracy of the teeth enamel EPR dosimetry method achieved at these kinds of

investigations are conducted in this presentation.

RESULTS AND DISCUSSION

Accuracy achieved at calibration and methodical investigations

At methodical investigations directed to find out an optimal protocol of dose determination, two types of enamel samples were used – heterogeneous samples, each was prepared from different teeth and homogeneous samples prepared from pooled enamel. Accuracy of dose determination was defined as standard deviation of determined doses from nominal doses using regression line obtained at calibration with a set of samples irradiated in different doses [2, 3, 10].

For a dose range 0 – 500 mGy for homogeneous samples at calibration the accuracy about 15 mGy is achieved [10]. This value is limited mainly by noises at spectra measurement. For heterogeneous samples, the accuracy at calibration about 20-25 mGy is achieved [3], which is limited mainly by variation of the shape native background signal in enamel, which is different for each sample. The accuracy of dose determination is improved as the sample mass and the number of repeated measurements are increased (Fig. 1). But some level of these parameters exists over which the accuracy may not be improved [10].
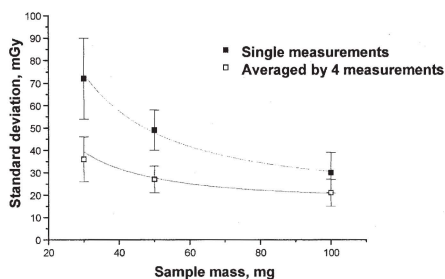

Fig.1. Dependence of the accuracy of calibration on the sample mass at different number of measurements obtained for heterogeneous samples (Ivannikov et al., 2002 [3]) .

Accuracy demonstrated at intercomparisons

Several international comparisons of the tooth enamel EPR dosimetry method were conducted in order to test its feasibility and achievable accuracy. Results of one of such intercomparisons conducted by Hiroshima University in 2006 [5] are presented in Fig. 2. The heterogeneous samples from different teeth were used the same for all laboratories: three samples irradiated in nominal dose 143 mGy and two samples - in dose 226 mGy. The same set of calibration samples was used for all laboratories. The accuracy was characterized by root mean square deviation of reported doses from nominal doses. Large variation of the accuracy is demonstrated for different laboratories. Typical accuracy demonstrated by the most of laboratories is 30-50 mGy.
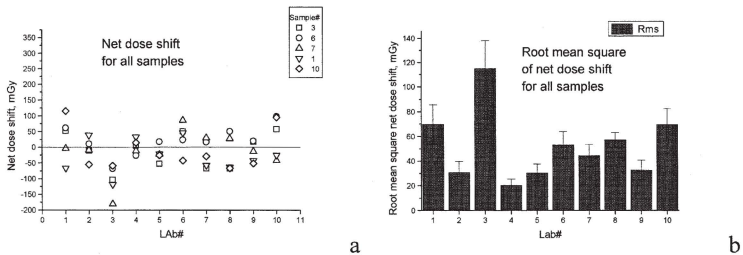
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Fig.2. Results of different laboratories at international comparison conducted by Hiroshima University in 2006 [5]: a – deviation of reported doses from nominal doses; b – root mean square deviation of reported doses from nominal doses.

Estimation of the accuracy of the method at investigation the population of radiation free territories

Direct estimation of the accuracy of EPR dosimetry method may be obtained from results of dose determination for population of territories, which are not contaminated by technogenic radiation. Results of EPR dosimetry for population of control radiation free territories of the central region of Russia (*Kaluzhskaya oblast*) are presented in Fig. 3 [1, 8]. The increasing of the radiation induced signal intensity in enamel samples with individual age observed in Fig. 3a is explained by effect of accumulation of natural background radiation. This effect can be easily taken into account by subtraction of the accumulated natural background dose to obtain the additional (excess) dose, age dependence for which is presented in Fig. 3b. Width of the histogram of distribution of the additional dose, 27 mGy, characterizes the accuracy of the EPR dosimetry method applied at real wide scale investigation of population.
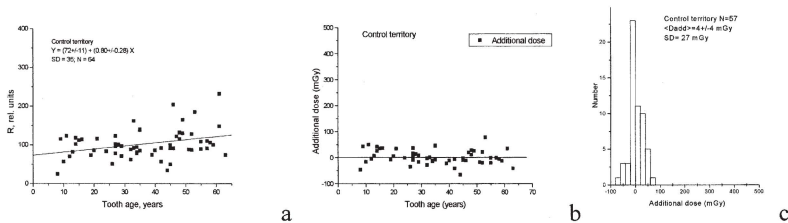

Fig.3. Results of EPR dosimetry for population of control radiation free territories: a – dependence of the individual radiation induced signal intensity on the age of enamel after its formation; b – age dependence of the individual additional dose (excess dose) obtained after subtraction of the accumulated natural background dose; c – histogram distribution of the additional dose.

The accuracy of dose determination is increased if to perform averaging of the results for groups of population. The age dependence of measured by EPR doses absorbed in enamel averaged by five adjacent age values is presented in Fig. 4. This dependence is obtained for the same population group as

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presented in Fig. 3. The increasing of doses with age is caused by accumulation of natural background radiation. The accuracy of dose determination defined by standard deviation from the regression line is improved because of averaging and characterized by value of 13 mGy.
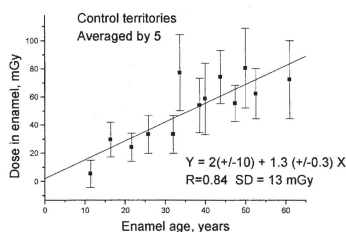

Fig. 4. Dependence of doses absorbed in enamel averaged by five adjacent age values of enamel age for radiation free territories.

Results of application of the EPR dosimetry method for the population of Chernobyl region

The EPR dosimetry method for applied for investigation of the population of radiation contaminated territories as result of Chernobyl region [8]. Results obtained for one of population group *(Bryanskaya oblast, Gordeevsky rayon)* are presented in Fig. 5. In comparison with control territories (Fig. 3), width of additional dose distribution is higher and doses are higher, which is result of technogenic radiation. Individual doses were determined by the EPR method performed for other territories, average results for population groups are presented in Table 1. In the same table results of average dose calculation according to [12] for the same population groups are presented.
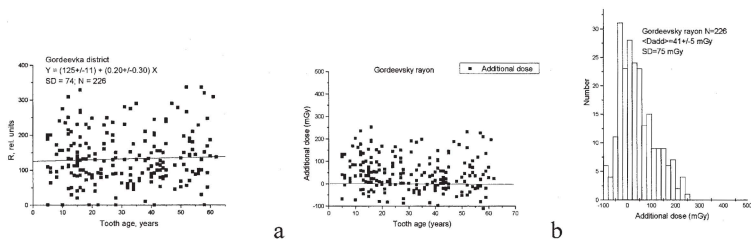

Fig. 5. Results of EPR dosimetry for population of control territories and radioactive contaminated territories after Chernobyl accident *(Bryanskaya oblast, Gordeevsky rayon).* The figure panel notations are the same as in Fig. 3.

Table 1. Average additional doses determined by EPR dosimetry method for radiation contaminated territories after Chernobyl accident and for control territories. Comparison with average calculated doses.

Notations: N – number of measurements; EPR dose – additional dose by EPR averaged for settlements and groups of population; Calculated dose – average doses for groups of population obtained by calculations [12]

	N	EPR dose, mGy	Calculated dose, mGy
Bryanskaya oblast			
Gordeevsky rayon	*226*	*29*	*33*
Gordeevka	34	51	40
Tvorishino	15	51	31
Strugova Buda	10	23	26
Klintsy	*150*	*28*	*12*
Klintsivsky rayon	*114*	*30*	*30*
Smotrova Buda	16	40	23
Smolevichi	16	40	11
Gulevka	11	19	19
Zlynkovsky rayon	*104*	*50*	*41*
Zlynka	28	28	31
Vyshkov	25	71	39
Klymovsky rayon	*34*	*12*	*16*
Klimovo	11	26	12
Kaluzhskaya oblast (control territory)			
Borovsky rayon	*64*	*1*	*1*

Relationship between average doses determined by EPR and average calculated doses is presented in Fig. 6. Discrepancy between EPR doses and calculated doses averaged for settlements is within 15 mGy. The error of doses for groups of population is reduced in comparison with error of individual dose determination because of averaging.
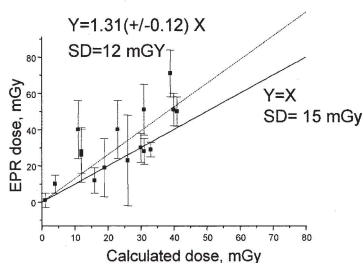

Fig. 6. Relationship between doses in enamel determined by EPR and calculated doses averaged for settlements of Bryanskaya oblast contaminated after the Chernobyl accident.

Special investigation was conducted to compare individual EPR doses and individual calculated

doses absorbed in enamel for residents of Zaborie village (Bryansk region) with high level of radioactive contamination after the Chernobyl accident were compared [4, 9]. Mean square deviation between results of these two independent methods appeared to be 34 mGy. It means that dose determination by both methods is performed with uncertainty less than 30 mGy. This result verifies both methods.

Results for the Semipalatinsk region

Results of individual excess dose determination by EPR dosimetry for population of villages placed close to the radioactive trace formed after the first nuclear test in 1949, are presented in Fig. 7. Bimodal distribution is observed for all these settlements for persons with enamel formed before 1949. That may be explained by that only part of population was exposed.

- Part of distribution with center close to zero dose - not exposed population.
- Part of distribution from 250 to 450 mGy - exposed population.
- High dose for Mostik correspond to dose in air at the center of trace.

Mean dose for enamel formed after 1949 is 32 mGy. This elevated dose, probably, is caused by contribution of tests conducted after 1949.
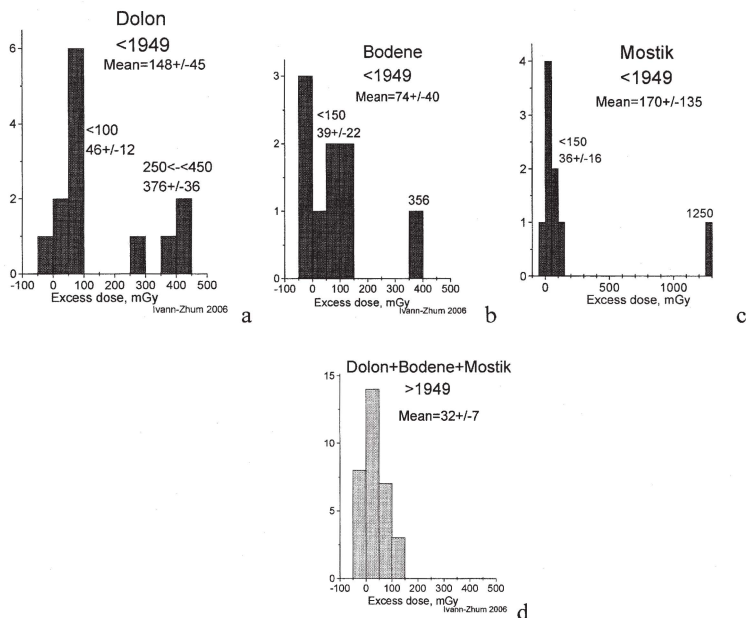

Fig. 7. Excess EPR doses for the trace of 1949 year (by Zhumadilov et al. 2006 [11]) for samples formed before (a-c) and after 1949 yr (d)..

Results of individual dose determination obtained by other research group [7] are presented in Fig. 8. Combined results of different research groups [6, 7, 11] are presented in Fig. 9. Bimodal distribution is
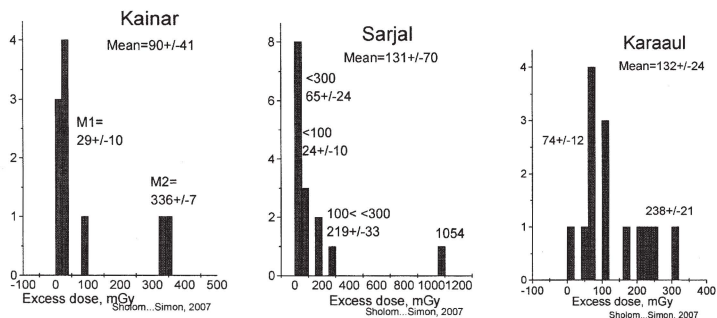
also observed for these results.

Fig. 8. Excess EPR doses for the radioactive traces of 1951 and 1953 years [7] (enamel formed before 1949. These results are used for analysis and presented here by permission of the authors.): a, b – for Kainar and Sarjal, radioactive trace of 1951 yr; c – for Karaaul settlment, trace of 1953 yr.
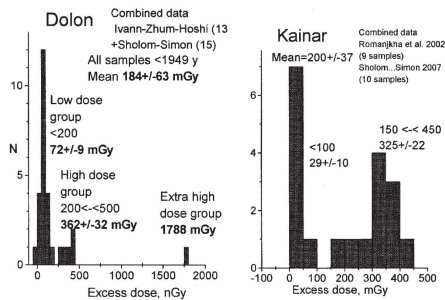

Fig. 9. Excess EPR doses for Dolon and Kainar (combined results of [6, 7, 11], enamel formed before 1949 yr).

Comparison of individual dosed for Dolon village inhabitants (with enamel formed before 1949) determined by EPR method [11] and by calculations based on the level of radiation contamination and the individual questionnaires [13] was performed. Results of such comparison are presented in Fig. 10. Mean ratio of calculated dose and EPR dose: 0.98+/-0.25. Mean root square deviation between results is 35 mGy, which is within specified errors of both methods.
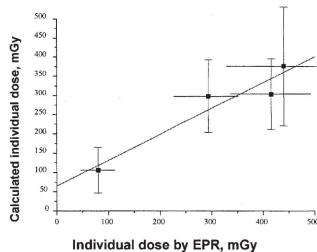
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Fig. 10. Relationship between calculated individual doses and doses determined by EPR for inhabitants of Dolon with teeth formed before 1949.

CONCLUSIONS

The analysis of experience of application the tooth enamel EPR dosimetry at methodical investigations, interlaboratory comparisons and wide scale investigation of population of radiation free and contaminated territories is performed. Based on this analysis, the achievable accuracy of the EPR dosimetry method is estimated by value of 20-30 mGy. At averaging for groups of population, the error of dose determination may be reduced up to 10-15 mGy.

Results of EPR dosimetry well agree with results of dose reconstruction by calculations, which validate both methods.

Results obtained by EPR dosimetry are not always stable. In some cases the error is much higher than the lowest achievable value. In case of using the modern sensitive spectrometers, the reasons of increased error may be the following: (1) Variation of the EPR signal because of improper sample preparation. (2) Not optimal spectra processing procedure.

An optimal unified method should be developed, which involves optimal procedures of sample preparation, spectra measurement and, which is the most important, spectra processing. At present, a version of this program passed the State registration in Russia. Nevertheless, work on this program should be continued in order to develop an algorithm giving stable results with highest accuracy.

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