

HEALTH RISK ASSESSMENT OF JOBS INVOLVING IONIZING RADIATION SOURCES

by

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The study included 75 subjects exposed to low doses of external ionizing radiation and 25 subjects from the control group, all male. The first group (A) consisted of 25 subjects employed in the production of technetium, with an average job experience of 15 years. The second group (B) consisted of 25 subjects exposed to ionizing radiation from enclosed sources, working in jobs involving the control of X-ray devices and americium smoke detectors, their average work experience being 18.5 years. The third group (C) consisted of 25 subjects involved in the decontamination of the terrain at Borovac from radioactive rounds with depleted uranium left over after the NATO bombing of Serbia in 1999, their average job experience being 18.5 years. The control group (K) consisted of 25 subjects who have not been in contact with sources of ionizing radiation and who hold administrative positions. Frequencies of chromosome aberrations were determined in lymphocytes of peripheral blood and compared to the control group. The average annual absorbed dose determined by thermoluminescent dosimeters for all three groups did not exceed 2 mSv. In the present study, the largest number of observed changes are acentric fragments and chromosome breaks. The highest occupational risk appears to involve subjects working in manufacturing of the radioisotope technetium.

Key words: chromosome aberrations, ionizing radiation, human lymphocytes, occupational exposure

INTRODUCTION

Most sensitive to radiation is the biological macromolecule – DNA. The most frequent lesions caused by radiation are DNA chain breaks. Breaks may be found in a single-chain or in both chains simultaneously. Damages of single bases also happen, as well as irregular crossings of facing chains of DNA or DNA and proteins. Lesions generated in this way can hardly be completely corrected via reparative enzyme systems. Most frequently, they are repaired inadequately, producing new errors in the DNA duplication process, leading to the appearance of various chromosome forms that normally do not exist in the human karyotype. These forms are observable in the metaphase of the cell cycle and are called chromosome aberrations [1].

Chromosome aberrations can be numerical (changes in the chromosome count) and structural (changes in chromosome structure). Structural chromosome aberrations can be classified as unstable or stable. Unstable chromosome aberrations are indicators of recent irradiation. They manifest themselves as dicentric, ring, and polycentric chromosomes. A characteristic they all share is the existence of an acentric fragment which disappears from the cell's genetic material during cell division, due to the lack of a centromere. With each subsequent division, the number of cells that carry unstable chromosome aberrations in their karyotype is decreased to one half, creating an impression that aberrations also disappear [2]. An aberrant cell can live through ten divisions at the most.

According to the International Atomic Energy Agency, structural chromosome aberrations include chromosome and chromatid abnormalities [3]. If ionizing radiation acts in the G1 phase, before the genetic

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material is doubled, chromosome aberrations occur. If ionizing radiation acts in the S phase of the cell cycle when the genetic material is doubled, chromatid aberrations occur.

The objective of the present work was to determine differences in frequencies of structural chromosomal aberrations with respect to the type of the source, *i. e.* type of radioactive emission [4].

MATERIAL AND METHODS

The study included 75 subjects exposed to ionizing radiation and 25 subjects from the control group, all male.

The first group (A) consisted of 25 subjects, average age 40, working in the production of technetium. Technetium is obtained from molybdenum generators, by passing the physiological solution (0.9% NaCl) through a column. The length of work-related exposure varied between 3 and 30 years. The average job experience was 15 years. Protective gloves were used as a personal protection measure.

The second group (B) consisted of 25 subjects, average age 43, exposed to ionizing radiation from enclosed sources, working in the control of X-ray devices and americium smoke detectors. Their work-related exposure varied from 2 to 34 years. The average length of employment was 18.5 years. In this group, no personal protection accessories were used.

The third group (C) consisted of 25 subjects, average age 43, working on the decontamination of the terrain at Borovac from radioactive rounds with depleted uranium left over after the NATO bombing of Serbia in 1999. These workers mechanically removed the surface layer of soil to a depth of 50 cm. During this procedure, they occasionally encountered parts of depleted uranium rounds. Decontamination is an extraordinary procedure organized in accordance with the law and the individuals involved need to be educated for the task and under constant health control measures. In this case, they were selected from a group of individuals who were otherwise professionally exposed to ionizing radiation from enclosed sources in their everyday jobs. Their work-related exposure varied from 2 to 34 years. Their average length of work experience was 18.5 years. During the decontamination procedure itself, the exposure lasted 30 to 120 days. Protective clothing, gloves, and respirators were used as personal protection means.

Control group (K) consisted of 25 subjects, average age 42, who have not been in contact with sources of ionizing radiation, holding administrative positions.

Data for the said groups of subjects were obtained from the respective logs of their periodical medical check-ups in 2005. A modified Morhaed's method was used for the chromosome aberration analysis. Perma-

nent samples were created, Gimza-dyed, and analysed under the microscope. The analysis included at least 200 lymphocytes in the first *in vitro* division. At least once a year, the contamination of the work premises was checked by a GM-counter and, indirectly, by swipes of the work surfaces. A work surface of 10 cm

10 cm was swiped by filter paper which was then measured for radioactivity by a calibrated GM-counter. When activity was found, the radionuclide was identified by a multichannel analyser. Each work surface contaminated above $4 \cdot 10^5$ Bq/m³ was treated as an accident.

For personal protection, the workers carried thermoluminescent dosimeters (TLD) attached to the pockets of their laboratory gowns. Readings of absorbed doses from personal dosimeters were done once in three months. The average annual absorbed dose for all three groups did not exceed 2 mSv.

The results were statistically processed by Student's t-test (software Statistica 5.5 for Windows 98) and a Chi-square test (χ^2) with contingency tables 2 × 3.

RESULTS AND DISCUSSION

Chromosome aberrations in the lymphocytes of peripheral blood in subjects from all groups (A, B, C, and K) are given in fig. 1.

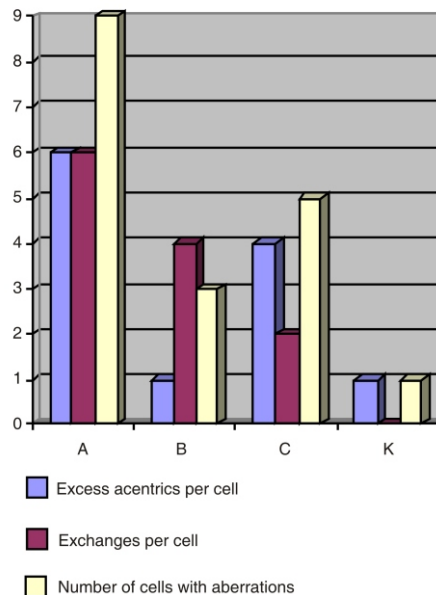


Figure 1. Chromosome aberrations in lymphocytes of peripheral blood in subjects from all groups (A – subjects working in technetium production; B – subjects exposed to ionizing radiation from enclosed sources, employed in the control of X-ray devices and americium smoke detectors; C – subjects involved in the decontamination of the terrain at Borovac from radioactive rounds with depleted uranium left over after the NATO bombing of Serbia in 1999; K – subjects who have not been in contact with sources of ionizing radiation and who hold administrative positions)

By comparing structural chromosomal aberrations in groups under study, as presented in tab. 1, statistically significant increases of the number of structural chromosomal aberrations were found in group A (the group that works in the production of technetium), as compared to control group K. In order to confirm this, a χ^2 test was applied (2 × 3 contingency tables), being an analytical method for the evaluation of significant differences of non-parametric values.

Table 1. Comparative ratio of group A with group K

Group	0*	1**	2***	Total
A	16	6	3	25
K	24	1	0	25
Σ	40	7	3	50

* – without chromosome aberrations

** – with acentric fragments

*** – with chromosome breaks

Table 2 shows the empirical value of the Chi-square test ($\chi^2 = 8.16$) for the degrees of freedom $DF = 2$ and the probability of risk 0.05, which is higher than the theoretical value. It can, thus, be concluded that the frequency of structural chromosomal aberrations is statistically significantly higher in group A, with respect to control group K ($p < 0.05$).

Table 2. Empirical values of the Chi-square test ($\chi^2 = 8.16$)

f*	f'***	f – f'	(f – f') ²	(f – f') ² /f'
16	20	–4	16	0.80
6	3.5	2.5	6.25	1.78
3	1.5	1.5	2.25	1.50
14	20	4	16	0.80
1	3.5	–2.5	6.25	1.78
0	1.5	–1.5	2.25	1.50
Σ				8.16

* – f means theoretical frequency

** – f' means empirical frequency

In the present study, the highest number of structural chromosomal aberrations involves acentric fragments and chromosome breaks [5]: the type of aberrations that are called unstable structural chromosome aberrations, those that disappear during cell division. Upon exposure to low doses, there is no difference in disease risk. However, 5% to 10% of the population are naturally radiosensitive, and all radiation doses above natural levels may result in biological damage. Exposure to low doses lasting more than 3 years may result in cumulative biological aberrations and damage of DNA [6].

It has been documented that exposure to ionizing radiation (X-rays) may cause chromosomal damage of cells [7]. Structural chromosome aberrations, dicentric and acentric, are induced by ionizing radiation and represent a result of enzyme mechanisms of

repair in the cell's nucleus, followed by chromosome damage [8]. In cases of exposure to low and very low doses of X-rays, the damage which does not correlate with the doses in question is the result of a cumulative effect, while the probability of DNA lesions increases with the duration of exposure time [9].

In subjects exposed to low doses of radiation (external exposure) of alpha, beta, and gamma rays that cover a period lasting between 7 and 34 years, higher frequencies of dicentric and acentric chromosomes were found than in the control group [10].

The decontamination of the terrain from depleted uranium did not contribute to the relative radiation risk. The frequency of the damaged biological material was 0.12%, *i. e.* 12 in 10,000 or, 1 in 1,000 workers. The highest risk was found in workers involved in the production of technetium: 0.245% *i. e.* 24.5 in 10,000 or 2 in 1,000 workers. Workers in the production of isotopes also have an exposure of at least 2 years and an average of more than 10 years of everyday laboratory work, whereas the decontamination lasted only a few months. It has also to be said that these procedures were carried out by trained staff, professionals in radiological protection, wearing appropriate protective gear.

It is interesting that none of the groups showed characteristic chromosome figures (forms) induced by radiation (of the dicentric or ring type), probably because all professional subjects carried protective gear. An acentric fragment can be considered as its dicentric equivalent, but, it also appeared sporadically, in individual cases only. However, one should not neglect the appearance of complete chromosome breaks (double break DNA), because they precede the induction of dicentrics. Besides, such a lymphocyte is less damaged for the subsequent mitosis, thus living longer and capable of accumulating new doses in subsequent exposure during which complete aberrations occur. This is why such subjects should be monitored, especially if the exposure continues [11, 12].

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ПРОЦЕНА ЗДРАВСТВЕНОГ РИЗИКА ПРИ РАДУ СА ИЗВОРИМА ЈОНИЗУЈУЋИХ ЗРАЧЕЊА

Истраживањем је обухваћено 75 лица професионално изложених јонизујућем зрачењу и 25 особа из контролне групе; све су особе мушког пола. Испитаници су били изложени малим дозама зрачења (спољна експозиција). Прву групу чини 25 лица која раде на пословима производње техницијума, са просечним радним стажом од 15 година. Другу групу чини 25 лица изложена јонизујућем зрачењу из затворених извора, која раде послове контроле рендген апарата са Х-зрачењем и јављача пожара у којима се налази америцијум, са просечним радним стажом од 18,5 година. Трећу групу чини 25 лица која су радила на деконтаминацији терена Боровац од радиоактивне муниције са осиромашеним уранијумом остале од НАТО бомбардовања 1999. године, са просечним радним стажом од 18,5 година. Контролну групу чини 25 лица која нису у контакту са изворима јонизујућих зрачења и која раде финансијско-економске послове. Испитивана је учесталост хромозомских аберација у лимфоцитима периферне крви и упоређивана у односу на контролну групу. Просечна годишња апсорбована доза мерена термолуминисцентним дозиметрима за све три групе нија прелазила 2 mSv. У овом раду највећи број нађених промена су типа ацентричних фрагмента и хромозомских прекида.

Највећи професионални ризик имају испитаници који раде у производњи радиоизотопа техницијума.

Кључне речи: хромозомске аберације, јонизујуће зрачење, хумани лимфоцити, професионална експозиција