J. Hum. Ecol., 10(4): 237-244 (1999)

Micronucleated Erythrocytes and Radionuclide Activity in Persons living in a Radiation Contaminated Area Near the Mayak Nuclear Facility (Russia)

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KEY WORDS Radition Accident. Radionuclides. Micronucleus Test.

ABSTRACT Between 1949 and 1957, the Mayak nuclear facility located in the Chelyabinsk region released some discharges of radiochemical production waste into the Techa river and the Karachay lake which resulted in an extensive contamination of large territories with long-lived radionuclides such as ^{90}Sr, ^{137}Cs and ^{239}Pu. During the early 1990s, our research team conducted the micronucleus assay in residents of four settlements in the Techa river basin having been exposed to radiation. We found significantly increased levels of micronucleated erythrocytes in the blood of exposed persons as compared to the controls. Moreover, we observed a good correlation between the level of whole-body ^{90}Sr activity detected by a human radiation counter (HRC) and the estimated frequency of micronucleated erythrocytes. We analyzed the blood smear samples of members of the radiation-exposed staff of Mayak which had been prepared following an accident in 1957. Most of the micronucleated erythrocytes occurred immediately after this accident with a sharp decrease about half a year later and a continuing gradual decrease. The number of micronucleated erythrocytes, however, is persistently higher than in the controls. We suppose that incorporated long-lived radionuclides, particularly in the bone-seeking ones, are responsible for this result.

INTRODUCTION

According to a news-letter of the Urals Radiomedical Research Centre, the Urals region was predominantly contaminated with long-lived radionuclides, such as ^{90}Sr, ^{137}C and ^{239}Pu, due to radioactive releases into the water or air at the Mayak nuclear facility between 1949 and 1957 (Bulatov, 1993). The radioactive contamination of the environment was mainly caused by the process of the wind's blowing away some radioactive aerosols from the banks of the Karachay lake. Approximately 28000 residents of the revierside settlements were exposed to the discharges of radioactive wastes into the Techa river within the Chelyabinsk and Kurgansk regions. By the 1990s, only four settlements with a total 9000 population have left in the Techa river basin (Muslyumovo, Brodokalmak, Russkaya Techa and N. Petropavlovka, see Fig.1). The individuals were exposed to as external irradiation from the water and riverside ground polluted by ^{137}Cs and ^{239}Pu as radioactive particle inhalation and ingestion. The internal irradiation was mainly induced by ^{90}Sr particles in bones and other organs. The main critical organ in the individuals was bone marrow. In our previous investigation (Ilyinskikh et al., 1995 a,b) we found significantly high frequencies of micronu- cleated lymphocytes and erythrocytes in peripheral blood of the persons residing in the radiation polluted zone around Mayak nuclear facility. The aim of present investigation is to conduct a correlation assay between radionuclides activity in the body and high frequencies of micronucleated blood cells in peripheral blood of the radiation-exposed individuals.

MATERIALS AND METHOD

In 1993, ^{90}Sr and ^{137}Cs activity in the body of each person residing in the settlements of Muslyumovo, Brodokamak, Russkaya Techa and N. Petropavlovka was estimated by the human radiation counter (HRC) in accordance with the mebprogramm project of the Federal Republic of Germany (Mebprogramm der Bundesrepublik Deutschland). The activity unit used was the nonnacurie (nCi). Each of the residents was given a certificate (bescheinigung) attesting the radionuclide activity in the body. During the early 1990s, the Siberian Medical University research team (Tomsk) conducted the micronucleus

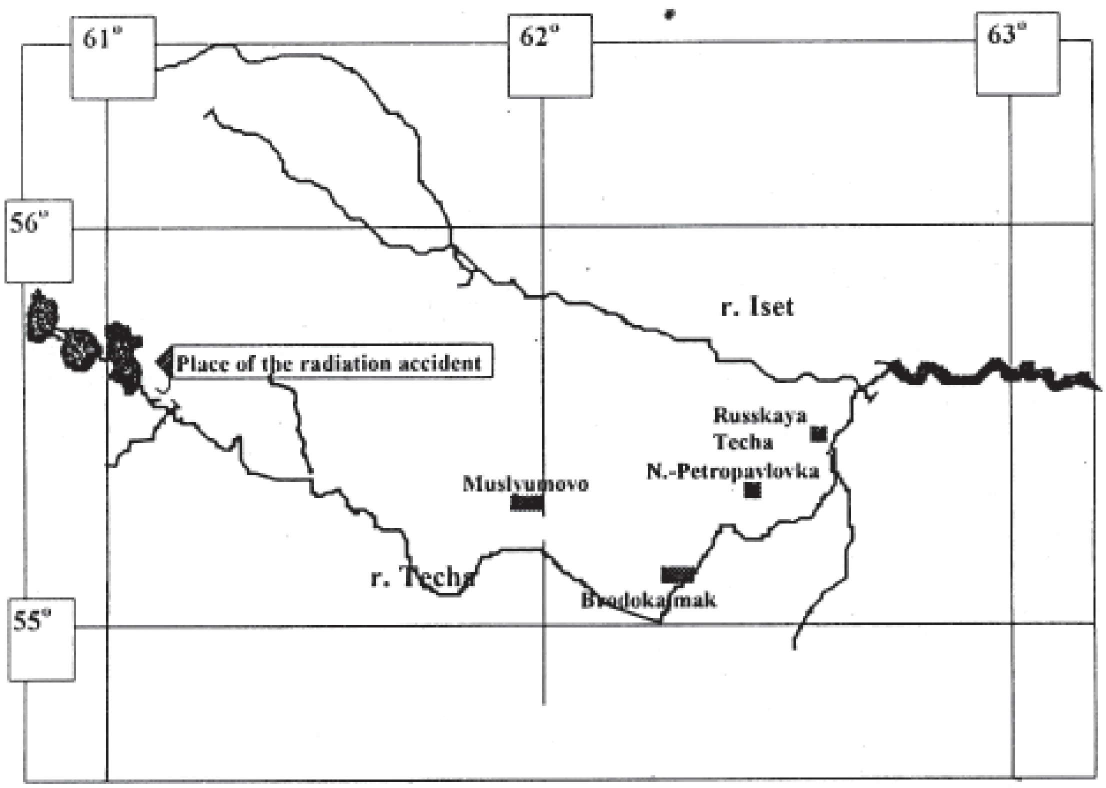

Fig. 1. Map of the place of the accident at MNF and discharges of radiochemical production waste into the Techa river

assay in the same radiation-exposed resident of Muslyumovo (56 individuals), Brodokalmak (24 individuals), Russkaya Techa (28 individuals) and N-Petropavlovks (16 individuals). Besides, 96 residents of the settlement of Loskutovo located outside the radiation polluted zone (in the Tomsk region) were used as a control. The radionuclide activity in the body of each control individual was also detected by HRC. We have assessed frequencies of micronucleated erythrocytes in peripheral blood of the radiation-exposed and control individuals. Blood of each individual was collected and smeared on clean greese-free slides following a standard method (Aahby et al., 1986; Almassy et al., 1987) which did not differ from the method described previously (Ilyinskikh N.N. et al., 1992, 1996, 1997). We analyzed 10,000 erythrocytes of each individual. The data have been evaluated for inter individual variations.

Statistical analyses of the data were made by correlation assay and Student's "t" test. In the statistic analysis of the results we took into account suggestions described by Hart and Engberg-Pederson (Hart et al., 1983). We used procedures available in the SAS statistical package (SAS, 1989). A statistical level lower than 0.05 is reported in the figures as "**" significance level lower than 0.01 is reported as "*" (Hazard Murino et al., 1986).

Moreover, blood smears from 26 persons who have been exposed to radiation during an accident at Mayak nuclear facility in 1957 were kindly donated by Dr. Max Severin, Department of Genetics, the Urals Medical Academy. The blood smears from the radiation-exposed persons have been prepared since 1957. According to official data, doses to all the persons were estimated at between 0.5 to 2 Gy (gray).

RESULTS AND DISCUSSION

We observed a significant increase in frequencies of micronucleated erythrocytes in peripheral blood of the persons residing in the radioactive polluted zone around Mayak nuclear facility as compared with the control individuals (see Fig. 2).

We have found a good correlation between the increasing of ^{90}Sr activity in the body detected by HRC and the significantly high frequency of micronucleated erythrocytes in the individuals residing in the Muslyumovo settlement (Fig. 3).

As there were clearly differences in the frequencies of micronucleated erythrocytes in individuals of different age, we performed analysis depending on the year of birth of the individual examined (Fig. 4).

As is seen from figure 4, the persons born between 1957-1962 have very high frequencies of micronucleated erythrocytes. The peak of the index was registered for the individuals born in 1957 when there was an accident at Mayak nuclear facility. Moreover, the lowest frequencies of micronucleated erythrocytes were determined in the individuals born before 1957 and after 1962. Although every individual with ^{137}Cs activity detected by HRC in the body had a significantly high frequency of micronucleated erythrocytes (as compared with controls) we did not observe a increase in ^{137}Cs activity to correlate with the growing of the frequency of micronucleated erythrocytes in the individuals (see Fig. 5).

We have found that the frequencies of micronucleated erythrocytes in 46 radiation exposed individuals (equivalent doses about 250 mSv) who moved to other regions of Siberia (the Tomsk and Novosibirsk regions) immediately after the accident at Mayak nuclear facility in 1957 were significantly lower than in the

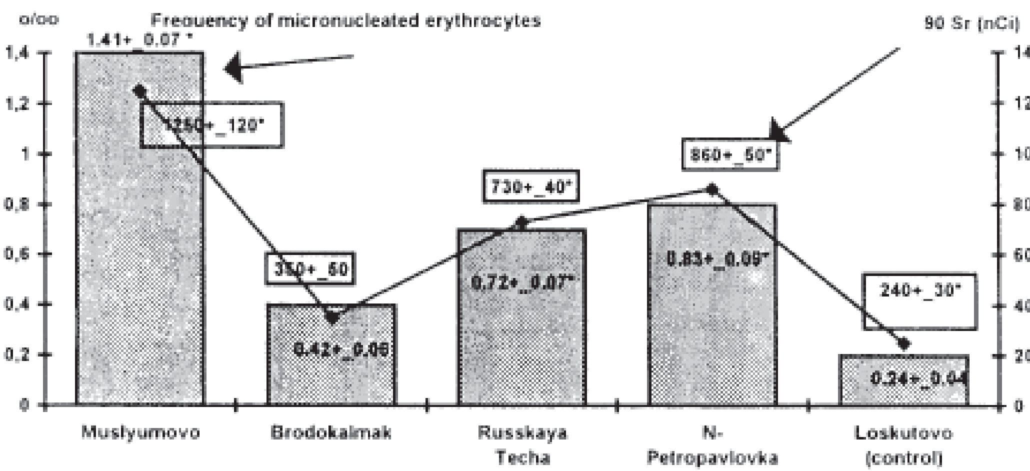

Fig. 2. Radionuclide (^{90}Sr) activity in the body detected by the human radiation counter (nCi) and the frequencies of micronucleated erythrocytes (o/oo) in peripheral blood of residents of four radiation-exposed settlements close to Mayak nuclear facitlity and a control settlement (Loskutovo).

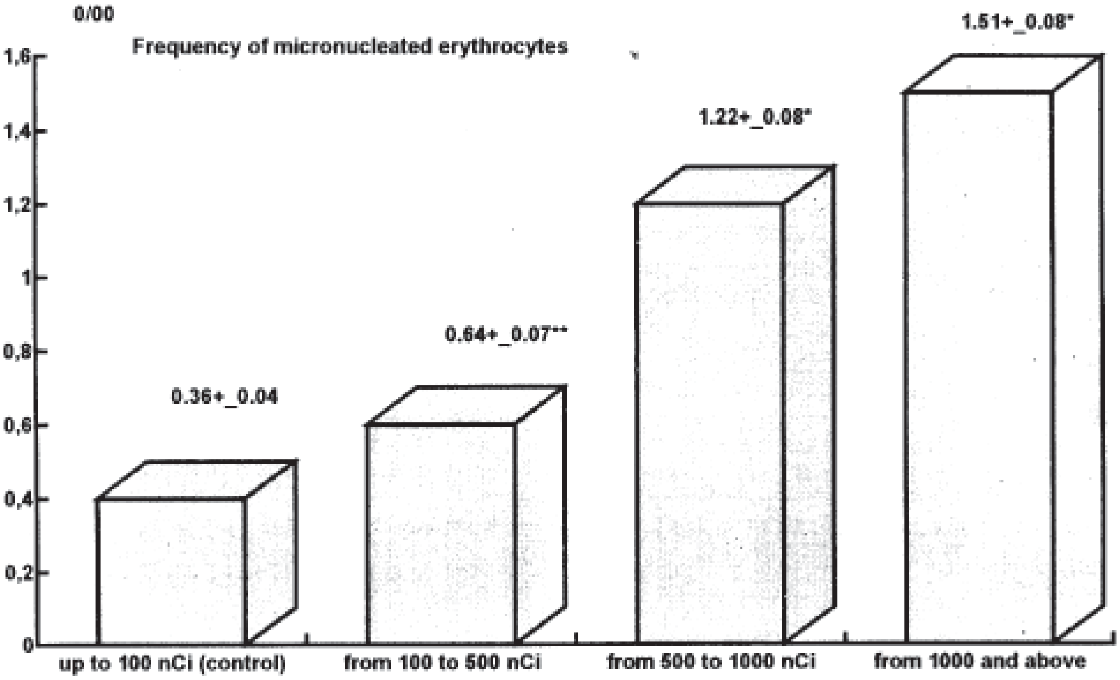

Fig. 3. The ^{90}Sr activity in the body detected by the human radiation counter (HRC) and the frequencies of micronucleated erythrocytes in individuals residing in the Muslyumovo settlement (the dose-dependent effect of ^{90}Sr activity).

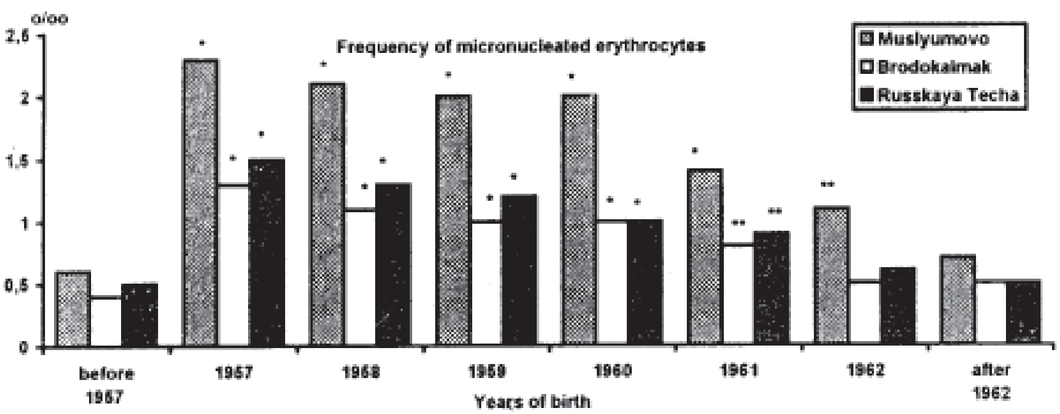

Fig. 4. Analysis of the frequencies of micronucleated erythrocytes (o/oo) in individuals residing in radiation polluted area around Mayak nuclear facility depending on the year of birth

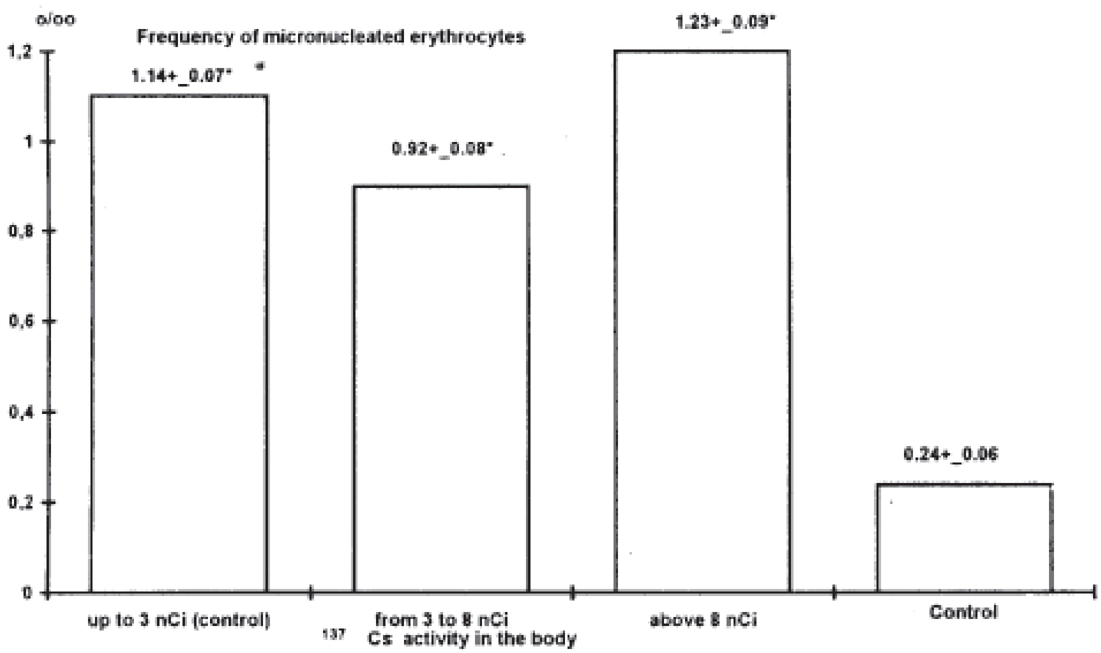

Fig. 5. Data of the ^{137}Cs activity in the body detected by the human radiation counter (nCi) and the frequency of micronucleated erythrocytes (o/oo) in residents of the Muslyumovo settlement

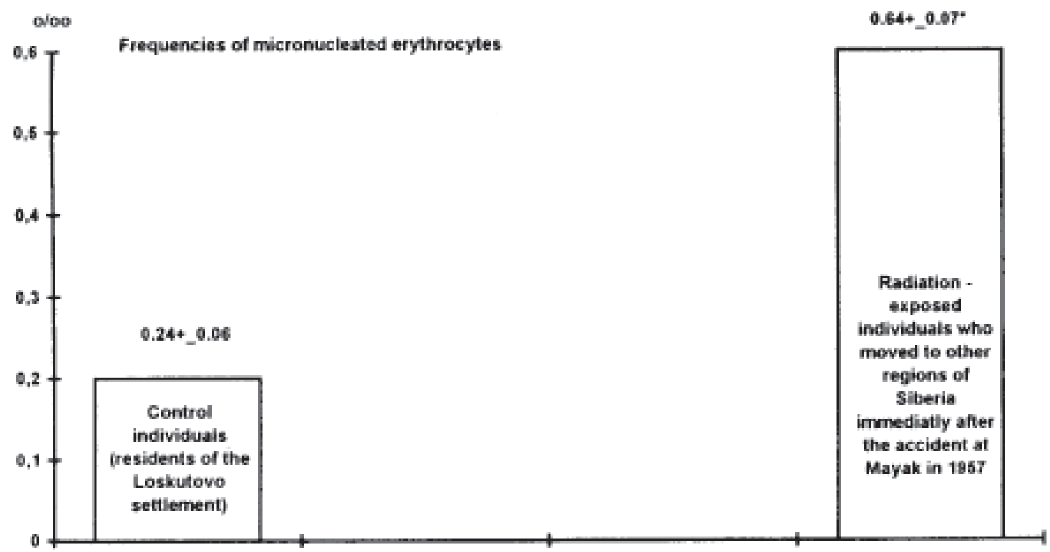

Fig. 6. The frequency of micronucleated erythrocytes (o/oo) in radiation-exposed individuals (equivalent dose about 250 mSv) who moved to other regions of Siberia immediately after the accident at Mayak in 1957 as compared with control individuals (residents of the Loskutovo settlement

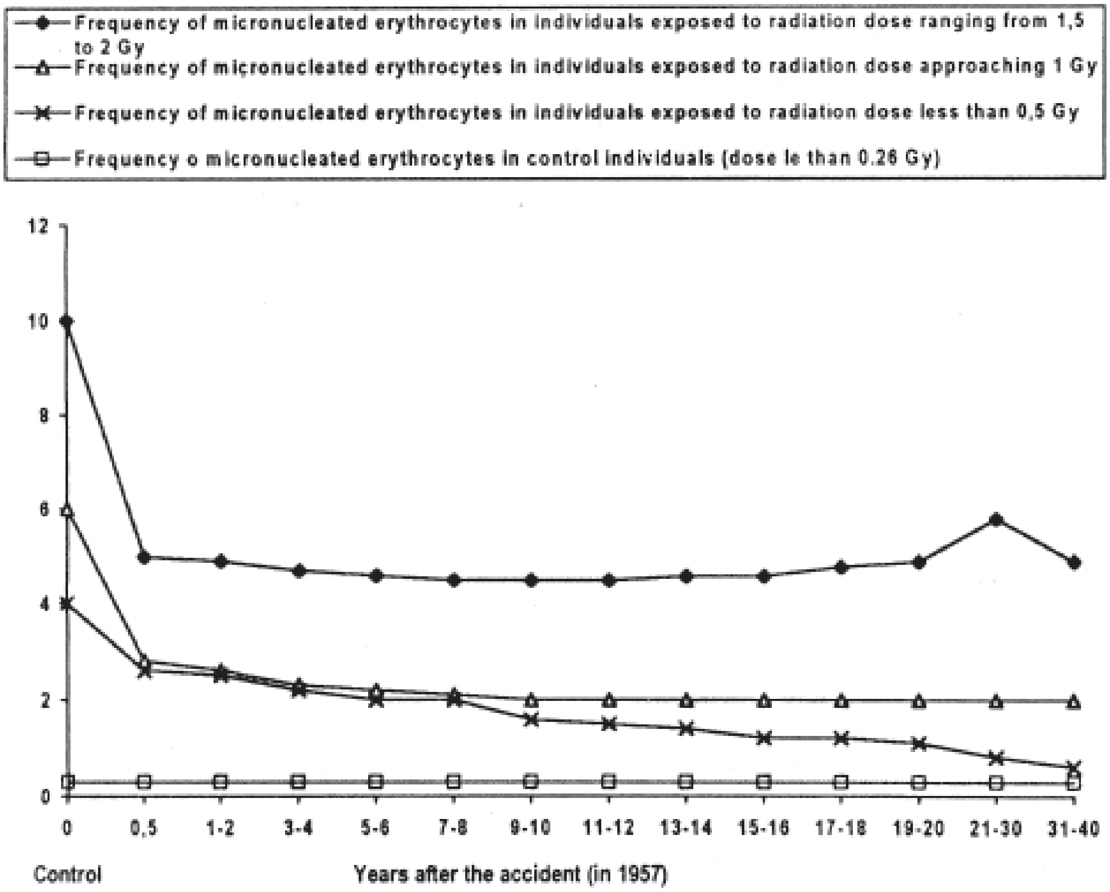

Fig. 7. Relationship between the exposure dose estimated (Gy) and frequencies of micronucleated erythrocytes (o/oo) in radiation-exposed individuals at intervals from about a week after the accident to 35-40 after the accident at Mayak in 1957

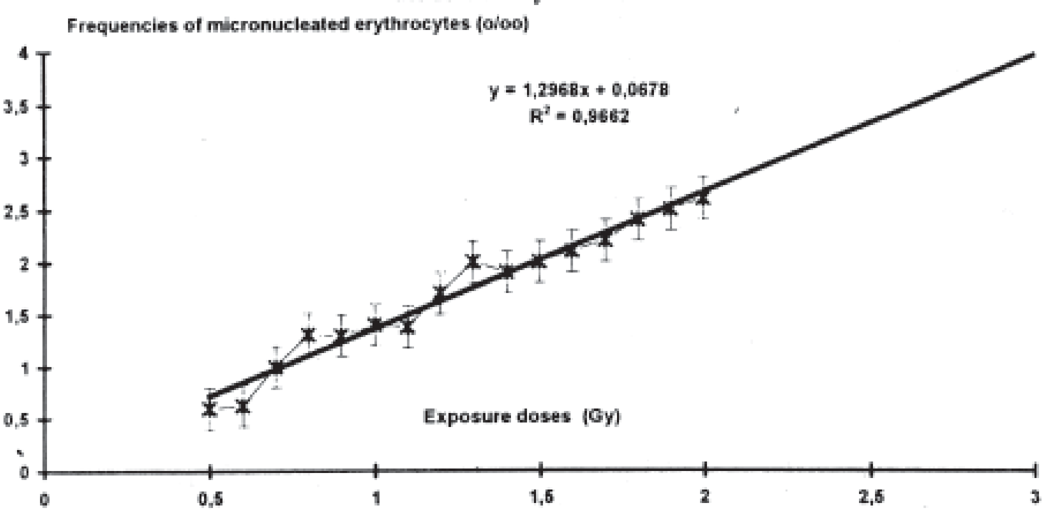

Fig. 8. Relationship between the exposure doses estimated (Gy) and frequencies of micronucleated erythrocytes (o/oo) in radiation-exposed individuals 35-40 years after the accident at Mayak nuclear facility

residents of Muslyumovo and higher than in the control individuals (see Fig. 6).

Moreover, we conducted the micronucleus assay in the radiation-exposed staff of Mayak nuclear facility (26 individuals) whose exposure doses were precisely estimated at between 0.5 and 2 Gy. The blood smears from the radiation-exposed persons have been prepared since 1957. While assaying the blood smears we have drawn the following conclusions:

1. The frequencies of micronucleated erythrocytes in the radiation exposed individuals ranged from 0.4 to 16 o/oo (frequencies of micronucleated erythrocytes in the control individuals were estimated at 0.2 - 0.3 o/oo).

2. Raditation doses approaching 1 Gy produced 4-6 o/oo micronucleated erythrocytes in individuals at 3d-6th day after the accident.

3. Radiation doses ranging from 1.5 to 2 Gy produced 7-16 o/oo micronucleated erythrocytes at the same days.

4. The frequencies of micronucleated erythrocytes were half as much as the initial levels (cited under point 2 and 3) half a year after the accident.

5. The frequencies of micronucleated erythrocytes were four times as low as the initial levels (see point 2 and 3) 5 to 10 years after the accident. Then the frequencies of micronucleated erythrocytes in the individuals whose doses approached 1Gy were gradually decreasing throughout life (Fig. 7).

6. Alternatively, the frequencies of micronucleated erythrocytes in the individuals whose doses were estimated at 1.5 - 2 Gy were gradually increasing between 10 and 20 years after the accident. Between 20 and 35 years after the accident we observed a sharp increase in frequencies of micronucleated erythrocytes in those individuals (Fig. 7).

7. An average frequency of micronucleated erythrocytes in the individuals exposed to a radiation dose between 1.5 and 2 Gy was 2.6 o/oo 35-40 years after the accident. At the same time, radiation doses ranging from 0.5 to 1 Gy were associated with 1.4 o/oo micronucleated erythrocytes. Doses less than 0.5 Gy induced 0.6 o/oo micronucleated erythrocytes (see Fig. 8).

Besides, we found several women who had been exposed to radiation in 1957 during pregnancy (residents of the Muslyumovo settlement). The children of mothers exposed to radiation during pregnancy showed a significantly higher micronucleated index than the mother herself (see Fig. 9).

DISCUSSION

Thus, we have found the significantly high frequency of micronucleated erythrocytes in the radiation exposed persons residing in a vast territory around Mayak nuclear facility as compared with the control individuals.

The average frequency of micronucleated

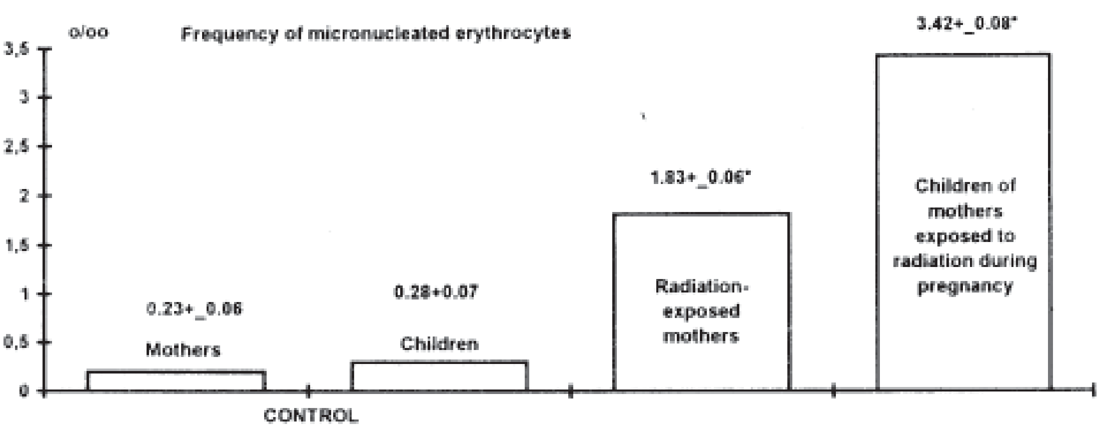

Fig. 9. The frequencies of micronucleated erythrocytes in mothers exposed to radiation in 1957 during pregnancy and their children (residents of the Muslyumovo settlement) as compared with those in control individuals (residents of the Loskutovo settlements)

erythrocytes in the persons was rapidly decreasing for half a year after the accident. Since then the index have been decreasing gradually. Even 35-40 years after the acident there still was a higher freqency of micronucleated erythrocytes in the individuals exposed to radiation doses between 1.5 and 2 Gy than in the controls. We suppose that the high level of micronucleated erythrocytes observed for such a long time is due to incorporation of radionuclides into the human organism, particularly in bone marrow. Our previous investigations (Ilyinskikh et al., 1984, 1995 a,b, 1996) showed that radiation by radionuclide incorporation in the predelivery period leads to damaging stem erythroid bone marrow cells which results in the formation of clones of erythroid cells with micronuclei in the newborn and then in the adult organism throughout life. It is accepted that micronucleated erythrocytes in humans are rapidly eliminated in the spleen. Usually, only splenectomized people are suitable for studies of micronuclei in erythrocytes (Schlegel and Mac Greger, 1984). In the present case, presumably the incorporated radionuclides (in particular, ^{90}Sr) supply the body with a constant, comparatively high radiation dose; so that continually a large number of micronucleated erythrocytes is produced which cannot be effectively removed by the spleen. It is known that children and adults have different kinetics in the removal of micronucleated erythrocytes. Identification of these erythrocytes in the spleen could be less efficient in children so that the half life is longer than in adults. We found a dose-dependent correlation for ^{90}Sr, but not for ^{137} Cs activity. The most probable answer seems to be that the ^{90}Sr localization is much closer to the stem cells of erythrocytes than that of the ^{137}Cs.

ACKNOWLEDGEMENTS

We wish to thank Professor Max Severin for the kind gift of the blood smears.

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