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APPLICATION OF DOSIMETRY METHODS FOR INTERNAL ORGANS EXPOSURE AND POSSIBLE INFLUENCE TO REMOTE EFFECTS

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Internal dosimetry study is conducted during rats exposure by dust of ^{56}Mn powder during experiment to study exposure effect in Kurchatov reactor complex Baical-1 (Kurchatov city, East-Kazakhstan region). This study was performed by group of scientists from Japan, Kazakhstan, and Russian Federation. It was important to study effect of radiation, due to effect of possible influence to human, and effect of possible internal exposure because of close location to Semipalatinsk Nuclear Test Site and post effect of irradiation due to Hiroshima and Nagasaki atomic bomb, Chernobyl accident and others. It was comparison of data of two scenarios of rat irradiation: a) the experimental box was supplied with air filter only (targeted for animal's breathing); b) the experimental box was supplied with the system of forced ventilation. After exposure to radioactive powder of ^{56}Mn radioactivity in organs and tissues of the rats was measured. The result of assessments of internal doses from neutron-activated ^{56}Mn in powder, sprayed over experimental animals was compared.

***Keywords*:** internal exposure, Kurchatov, rats, organs, powder of ^{56}Mn, samples.

Introduction

The Semipalatinsk Nuclear Test Site (SNTS) is located in Kazakhstan, served for nuclear tests of the USSR in the atmosphere from 1949 to 1962. Radiation doses in this area have been reconstructed in several ways. All the problems of dosimetry at this site were covered in an earlier publication [1-3]. In general, the average doses estimated by biophysical (individual) methods, were lower than the average doses received by physical (environmental) methods. This difference is still the subject of ongoing research [4, 5].

Doses were reconstructed for a cohort of Russian and Ukrainian workers in response to the accident and residents in contaminated Russian territories due to Chernobyl accident. Due to the large number of restored doses, these studies revealed endogenous (with an internal cause or origin) dental Electron Paramagnetic Resonance (EPR) dosimetry problems that appear when the method is applied to large-scale reconstruction of doses [6]. EPR dosimetry is currently used to validate other dosimetry methods that are used in case-control studies to assess the risk of radiogenic cataracts and leukemia [7].

The study of the EPR reconstruction of the dose in survivors of atomic bombing is described in various articles [8, 9]. EPR dosimetry with tooth enamel was used in this case to check doses assessed using cytogenetic dosimetry [6]. EPR doses estimated from 100 tooth samples (69 donors) were compared with doses for the same individuals that were determined cytogenetically from lymphocytes. The agreement between doses evaluated using the two methods confirmed that the

cytogenetic method can be used even several years after acute exposure and that the translocation yield after irradiation in vivo and in vitro were similar. It should be noted that the radiation sensitivity of the tooth enamel to neutrons was not taken into account in this study, as well as in an earlier article [10], which used EPR dosimetry to estimate the dose of external radiation [6].

The applied dose data are based on the tables listed in the DS86 final report such as the free-in-air kermas, the house shielding factors, and organ dose factors for the active bone marrow and the breast. Calculations for the 13 other organs provided in DS86 are possible. To obtain the organ doses for each survivor, it is necessary to obtain information concerning (1) place exposed, (2) whether they were shielded or not, and (3) age. ABS93D body transmission factors for active bone marrow for neutrons and gamma rays agreed with DS86 to within a few percent. Of the survivors studied, 35.123 of them were used for the relative risk estimation of leukemia mortality, adopting the same method as the Radiation Effects Research Foundation (RERF) for comparison. For the observation period from 1968 to 1989, the analyzed relative risks for leukemia mortality at 1 Gy by shielded kerma and by active bone marrow dose are 2.01 and 2.37, respectively, which are consistent with the RERF results [11].

After the atomic bombing of Hiroshima and Nagasaki, Japan, initial radiation directly produced during or shortly after the explosions and residual radiation contributed towards a radiation exposure of the survivors [12]. There are two sources of residual radiation: (1) neutron-activated radioisotopes from materials on the ground and (2) radioactive fallout containing fission products and residual fissile materials from the bombs. Understanding the former is particularly important for evaluating the risks to those people who moved to these cities soon after the detonations and might have inhaled radioactive dust [12-14]. Such individuals were reported to suffer from various syndromes similar to acute radiation effects [15].

1. Materials and methods

a. Animals

Male Wistar rats were delivered from Karaganda State Medical University, Kazakhstan. With purpose to understand the effect of ^{56}Mn radiation, neutron activated $^{56}MnO_2$ powder was sprayed over rats, and its biological effects were evaluated. The highest doses of internal irradiation were detected in the digestive system, followed by the lungs [16, 17].

They were maintained with free access to basal diet and tap water. In Experiment 1, rats were divided into four groups, with six rats for the ^{56}Mn group and three rats per group for the Mn and control groups. The ^{56}Mn and Mn groups were exposed to ^{56}MnO2 and non-radioactive MnO_2, respectively. Three rats organs of the ^{56}Mn group were used for dosimetry 3.5–4 h after the exposure. One rat per each group was used on days 3, 14, and 60. In Experiment 2, the exposure was repeated with 12 rats in the ^{56}Mn group and nine rats each in the Mn and control groups. Three rats of the ^{56}Mn group were used for dosimetry 3.5–4 h after the exposure. Then, three rats from each group were killed and examined on days 3, 14, and 60 after the irradiation [18].

b. Irradiation and dosimetry of each organ of rats

Details of irradiation using ^{56}Mn and the corresponding internal dose estimation have been described in previouse publications [16, 17]. In brief, $^{56}MnO_2$ was obtained by neutron activation of 100 mg of MnO_2 powder using the Baikal-1 nuclear reactor at Kurchatov, Kazakhstan. A thermal neutron fluence of 4×10^{14} n/cm^2 was applied to produce 2.74×10^8 Bq of ^{56}Mn activity.

The activated MnO_2 powder was sprayed into sealed boxes containing six rats per box (one box was used for Experiment 1, and two boxes were used for Experiment 2) [18]. In Experiment 1, the exposure box was equipped with air filters only, while an additional forced ventilation system was installed to improve animal welfare in the boxes in Experiment 2. The same total activity of ^{56}Mn equal to 2.74×10^8 Bq was used for irradiation in both experiments. The specific activity of

^{56}Mn powder was the same (2.74 x 10^9 Bq/g) as well. After 1 h, rats were removed from the exposure box(es) into clean (not contaminated) cages, cooled down for 2.5–3 h. Then, three of the animals were killed by intraperitoneal injection of an excessive dose of pentobarbital. A piece of each organ was dissected, weighted and put into a vial. The radioactivity of ^{56}Mn in samples of each organ was measured with a gamma spectrometer. Assessment of internal radiation doses was performed by measuring of ^{56}Mn activity in each organ and calculating the absorbed fractions of internal exposure to photons and electrons. Details of the dosimetry are described in an accompanying paper [16, 19].

2. Results and discussion. Radiation doses due to ^{56}Mn exposure

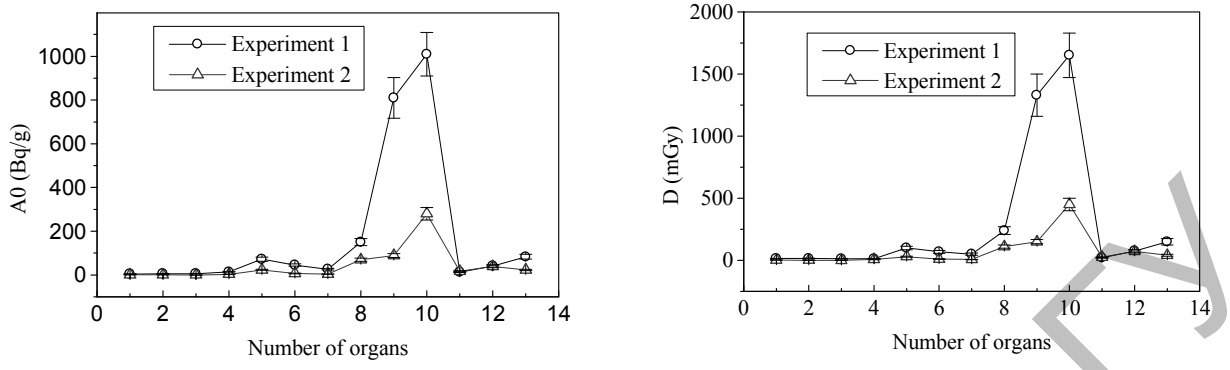
The radiation dose received from ^{56}Mn varied among different organs (Figure 1). Although the initial activities of neutron-activated MnO_2 powder were similar in Experiments 1 and 2, the radiation doses of each organ received in Experiment 2 were substantially lower than those received in Experiment 1, i.e., the small intestine received 1330 mGy in Experiment 1 while 150 mGy in Experiment 2. However, the distribution of dose values between tissues was similar in the two experiments, being very high in the digestive system, followed by the lungs and skin. Details are given in Stepanenko et al. [16].

In figure 1 shown Specific activity of ^{56}Mn, A_0, and accumulated doses of internal irradiation, D, in different organs of experimental rats. In Figure 1 we compared two types of results. First is comparison between boxes without ventilation and with ventilation. With same influence of neutron fluencies. In figure 1 (a) is data of activity in different organs and in Figure 1 (b) is data of absorbed dose in organ with two different scenario of irradiation. Numbers of organs are shown in Table 1.

Table 1. Numbers for different organs which were subjected to internal exposure.

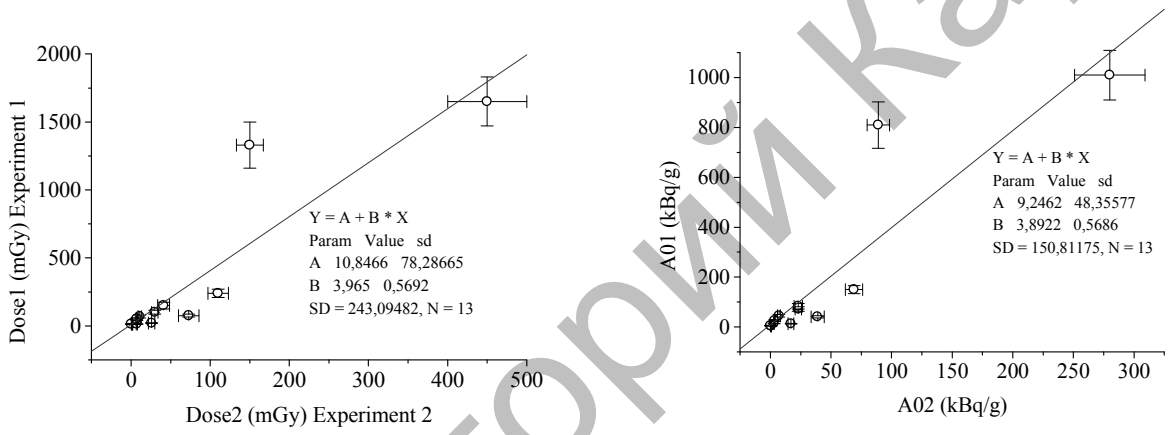
Numbers	*Organs*
1	Liver
2	Heart
3	Kidney
4	Trachea
5	Lung
6	Tongue
7	Esophagus
8	Stomach
9	Small intestine
10	Large intestine
11	Eyes
12	Skin
13	Whole body

According to figure 1, the highest value of Activity and dose are detected in organ number 10 (Large intestine) for both experiments, but due to ventilation in Experiment number 2, those data were smaller. And all data are showed the same tendency for decreasing data for experiment number 2 compare to activity and dose in experiment number 1.



a) b)

Fig.1. Specific activity of ^{56}Mn, A_0 (a), and accumulated doses of internal irradiation, D (b), in different organs of experimental rats.



a) b)

Fig.2. Dependence a) of doses from experiment # 1 versus dose of experiment #2; b) activity from experiment #1 versus activity from experiment #2 in different organs of experimental rats

Correlation between of dose and activity for two scenarios are almost linear, except two values of Dose and Activity for Small intestine and large intestine. The reason for these high doses and activity already explained in [17, 18].

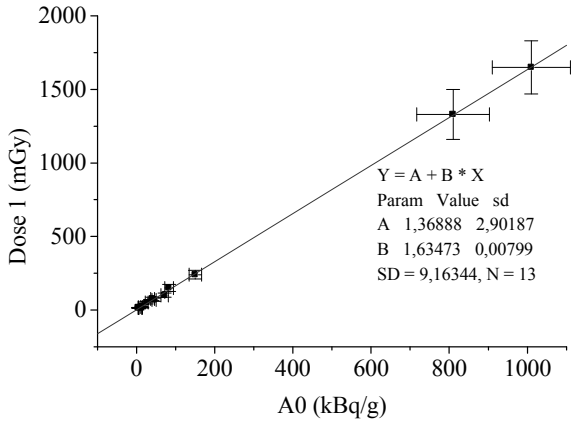


Fig. 3. Dependence of doses from experiment # 1 versus activity of experiment #1 in different organs of experimental rats

Figure 3 is showing the correlation between dose and activity of different organ, which is linear and can confirm correct calculation of internal dose due exposure. Also data of two scenarios compares by statistical t-test with 95% confidence interval of this difference. The two-tailed P value equals 0.1696 and by conventional criteria, this difference is considered to be not statistically significant.

Conclusion

This study investigated the effects of radiation exposure by $^{56}MnO_2$ powder in male Wistar rats over 60 days and amount of activity and dose calculation in different organs for two scenarios of irradiation. Comparison of this type of irradiation showed significant difference. And it will be recommended to use first scenario of irradiation of rats for better efficiency of irradiation. Although whole body radiation doses from ^{56}Mn were relatively low, higher internal doses were noted in the small intestine and lungs. Increasing of neutron fluencies in future can lead to increasing doses in some other organs like a liver.

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