Genetic monitoring tools for radon pollution research

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Abstract. A critical target for ionizing radiation is DNA that damage to a cell. Thus, when dealing with the general irradiation of the body, we observe the diverse effects of radiation. As a result of irradiation, somatic cells retain the ability to reproduce, but can give rise to the growth of a clone of altered cells, leading to a malignant neoplasm. The manifestation of ionizing radiation on germ cells can lead to prolonged effects, morphological changes and hereditary diseases. It is quite difficult to study the genetic consequences of radiation on patients due to the difficulties of compiling or selecting comparable control groups or samples and maintaining their representativeness. On the solutions to this problem is to simulate the genetic effects of irradiation on model objects, in our case, this is Drosophila melanogaster. The genetic effects of alpha radiation are main manifested in the morphology form of the wing, thorax and antenna morphoses. However, alpha particles very often cause the development of colored tumors, which have been allied melanomas. Genotoxic, mutagenic and carcinogenic effects of α-radiation were detected in the test systems of the gene white (white eyes), linked X chromosomes and Basc (Me-5).

1 Introduction

The main sources of natural radiation on Earth are the decay products of radon related to ionizing radiation. The radioactive decay of radon isotopes caused the emission of alpha particles, which inducted to the formation of other elements known as daughter decay products of radon (DDP). Despite their limited ability to penetrate tissues, alpha particles can cause significant biological damage in exposed tissues due to their high relative biological efficiency (RBE), despite their reduced penetrating power [1].

According to the UNSCEAR, the contribution of radon is 42% (or 1.26 mSv/year) to an individual dose from all natural and man-made sources. At the same time, the global contribution from diagnostic procedures in medicine is no more than 20%, and contributions from pollution caused, for example, by the production of atomic energy (including uranium mining) do not exceed 0.1% [2].

Therefore, contrary to the very common opinion about the danger of nuclear power facilities and medical procedures. The main factor of radiation risk are homes and workplaces

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where the radon content is always higher than in the outdoor air since people spend 80-90% of their time inside buildings [3].

The model object – *Drosophila melanogaster* is often used as tool for study of prolonged or genetic effects of ionizing radiation. It is extremely important to study the genotoxic, teratogenic and carcinogenic manifestations of radon isotopes to determine the potential risk due to possible exposure to the population.

2 Materials and methods

The high probability of a causal relationship between mutagenesis and carcinogenesis has led to the creation of numerous tests in which the ability to cause gene and chromosomal mutations serves as an indicator of blastogenic activity [4]. The study used several methods to assess the frequency of mutation different types occurrence on the test object - the fruit fly (Drosophila melanogaster). Experiments were carried out on the first and second instars larvae, a genetic line with white eyes [5].

A one mm thick nutrient medium was poured onto the bottom of glass cuvettes prepared according to the standard method [6]. Up to 50 Drosophila larvae of the first and second stages of development were placed in each cell. The experiment used cuvettes with a diameter 24.0±0.2 mm (Fig. 1) and height no more than 3 cm.

There are approximately 40 known isotopes of radon, two of which are ^{222}Rn and ^{220}Rn, are of practical importance. Although both isotopes undergo radioactive decay, the contribution to the total radiation dose from radon-222 is approximately 20 times greater than from radon-220. For model experiments, steel samples of spectrometric sources that had the necessary α-line during decay were selected. The control cuvettes were not irradiated, and the rest were covered with calibration spectrometric sources of alpha radiation with different energy: from 4.8 MeV to 7.7 MeV.

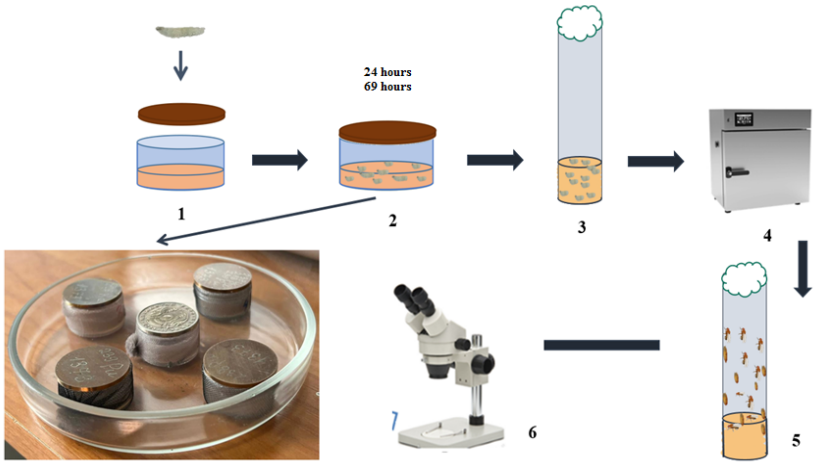

Fig. 1. Diagram of the experiment. Note: 1 – placement of larvae in wells; 2 – 24 and 69 hours for irradiation; 3 – transfer of irradiated larvae to large test tubes; 4 – incubation; 5 – imago and pupae; 6 – visual morphological analysis on MSB-9

In a test system of linked X chromosomes and Basc (Me -5), virgin females were crossed with irradiated wild-type males of the Oregon line. Male drosophila were exposed to UV radiation on a mounted glass installation (Fig. 1) for 24 hours. The source was located above the imago in distance nearly 3 cm for that the entire sample was exposed to alpha radiation. Next, the crossing was carried out according to the scheme (Fig. 2).

Comparison of the results in the experiment and control were performed by the Chi–square method with the amendment of Yates [6].

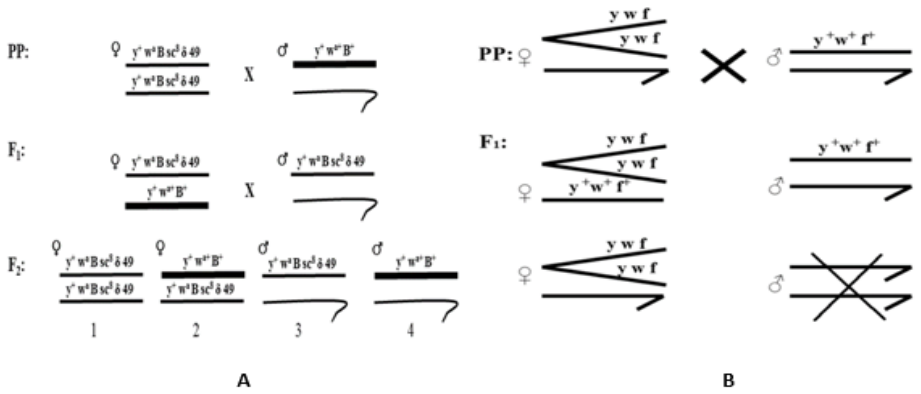

Fig. 2. Schemes of genetic crosses in the Meller-5 (A) test systems and linked X chromosomes (B) with Oregon (OreR) males. Note: morphological markers – gray body (y^+), apricot-colored eyes (w^a), forked bristles (f). The irradiated X chromosome is indicated by a bold line

3 Results and discussion

Visual analysis of the second generation adults (F_2) by Meller-5 test system in showed the induction mutations that reduce male fertility and the appearance of morphoses. The morphoses were identified only in the first generation (F_1 in the future with linked sex chromosomes. Therefore, morphoses were taken into account in the future for a reliable comparison of mutagenicity in different test systems. Morphoses are morphological changes in the appearance of an adult fly, resembling normal structures, but devoid of any functional role. The absence of a certain normal structure or part(s) is a variant of morphosis. Morphosis often looks like an unsuccessful "assembly" of the usual correct elements [7, 8].

The most common morphoses found in *Drosophila* imagoes after irradiation of larvae in F_0 and in descendants in the first and second generations (Fig. 3).

This is a bubble on the wing and a violation of the tergite pattern; curled wings; changing the shape of the wings; black spots on the wings; missing one wing; discoloration of the chest and legs, or "glazing"; black spots on the body (melanoma) a bubble on the right wing and a violation of the tergite

Analysis of adults with morphoses showed that the latter have virtually no effect on the vital activity of flies: they do not reduce survival, the ability to mate and produce generations. The manifestation of morphoses was observed up to F_4 in isolated cases.

Morphoses can occur under the influence of various environmental stress factors, such as temperature shock and gamma irradiation [9, 10]. In our experiments, alpha irradiation demonstrated genotoxic effects through the formation of various morphoses with probability ($p \leq 0.01$) compared to control.

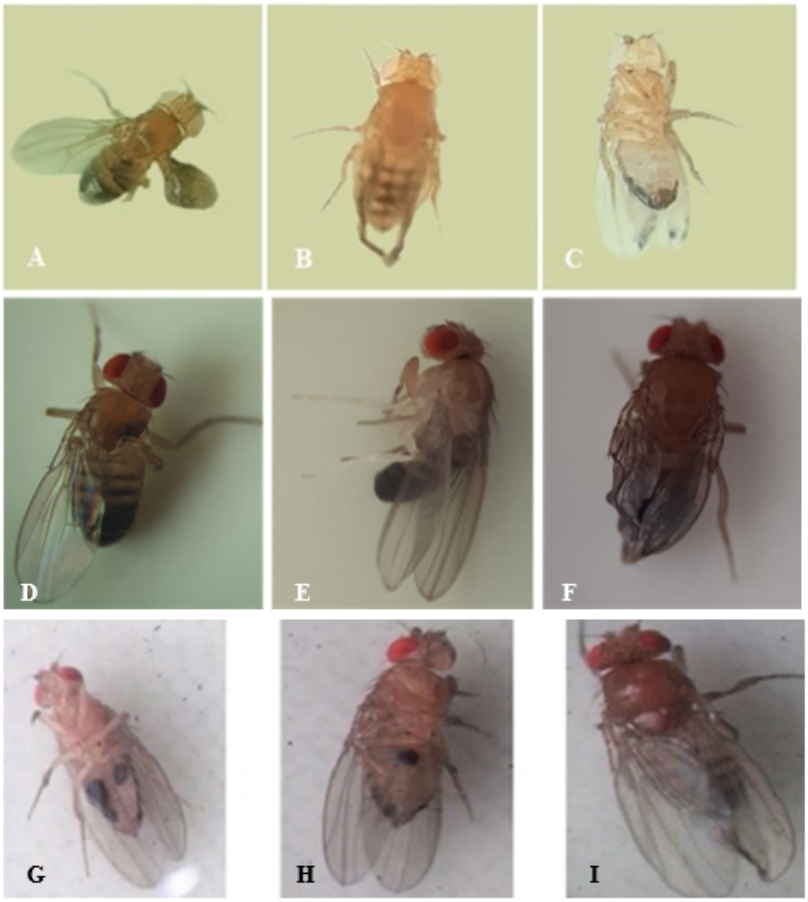

Fig. 3. External morphoses. Note: A-C – imago emerging larvae of the white genetic line subjected to alpha irradiation; D-F – in the second generation of irradiated OreR males in the Meller-5 test system; G-I – F1 in a short-term test of linked X-chromosomes.

4 Conclusion

Alpha particles create a large number of ions along their short path, that is, they cause a large linear ionization density. This provides a pronounced biological relative efficiency, 10 times greater than exposed to X-ray and gamma radiation. Therefore, α-particles can cause severe consequences if they enter the human body directly. Thus, the connection of radon with human lung cancer has been proven and statistically justified [8] but the question of the involvement of radon isotopes in the development of other types of oncological diseases, such as, stomach, skin cancer, central nervous system etc. remains open. The collected statistics on human oncology are insufficient for the association of neoplasms with radon and the alpha radiation generated by it and its DDP. Only human skin cancer data show a weak association with radon [4].

In our case, male imagoes and larvae were treated with alpha particles with high energy but low penetrating power. Despite this, the thickness of the integuments of the imago and larvae is commensurate with the limit of penetration of alpha particles into the body, which allows the latter to reach the gonads of the insect and generate the appearance of morphoses in descendants. Pronounced teratogenic properties associated with alpha radiation were

observed, which manifested themselves in the form of morphoses: a violation of the shape of the wings, the absence of a wing or leg, abdominal deformity, blisters on the wings. All this confirms the genetic predisposition and demonstrates the genetic signs of the all-part ($p \leq 0.01$).

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