

полисахаридов у бактерий-симбионтов растений люцерны, собранных в 10-км зоне ЧАЭС связан с высокой эффективностью действия хронического облучения на генетический аппарат клетки, контролирующей ее метаболические процессы. Микродозиметрический анализ полученных данных показывает, что в основе высокой эффективности действия хронического облучения растения лежат глубокие и фундаментальные радиобиологические процессы.

Работа выполнена в рамках международного сотрудничества между НИЛ экологического мониторинга, МЭУ, Минск, Беларусь и Laboratoire des Polysaccharides Microbiens et Vegetaux (LPMV) IUT d'Amiens при финансовой поддержке Правительства Франции.

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Genetic efficiency of low-dose chronic irradiation in mammals and fish

R. Goncharova, N. Ryabokon, I. Smolich, A. Slukvin

*Institute of Genetics and Cytology,
National Academy of Sciences of Belarus,
Minsk, Republic of Belarus*

The problem of biological effects of low-dose chronic irradiation is central radiobiological problem and seems to be very important for human monitoring and risk assessment.

Since 1986 we are engaged in studying genetic effects of low-dose chronic irradiation in natural populations of small mammals (bank vole – *Clethrionomys glareolus*) inhabiting radiocontaminated monitoring sites, in laboratory hybrid mice *CBA×C57Bl/6j*, exposed to chronic irradiation at radiocontaminated sites, as well as in pond carp (*Cyprinus carpio*) reared in fish farms in areas contaminated due to the Chernobyl accident. The mean ground depositions in monitoring

sites were 8–2330 kBq/m² and the mean bottom depositions in ponds were 52–3235 Bq/kg for ¹³⁷Cs.

We used conventional cytogenetics and genetics tests [1–3] and the following approaches in studying on genetic effects of low-dose chronic irradiation:

Radiation exposures from external γ - and internal α -, β -, γ -irradiation from incorporated radionuclides were estimated for each specimen tested.

Regression analysis of dose-effect relationships based on comparison of individual genetic end-points with individual absorbed doses was carried out.

We observed statistically significant changes in the frequencies of genetic end-points, which have been studied in somatic and germ cells, as well as in embryos of irradiated mammals and fish (Table). So, the frequencies of chromosome aberrations in bank vole populations had up to 7-fold increase in comparison with background and pre-accident levels. It is of great importance to emphasize high radio-sensitivity of fertilized eggs (zygotes) and pond carp embryos produced by chronically irradiated parents [1–3].

Regression analysis allowed us to reveal dependence of the studied parameters' frequencies on radiation exposure namely on the concentrations of basic dose forming radionuclides, absorbed dose rate and whole body absorbed dose. In most cases, dose-effect relationships were better approximated by non-linear functions [3].

Thus, we found genetic effects of chronic irradiation in the range of extremely low doses, from close to background and up to 10 cGy. The observed effects are not expected from high dose experiments known from scientific literature. Therefore comparative analysis of genetic efficiency of low dose chronic irradiation and higher doses of acute irradiation was carried out.

For this purpose linear regression models of dose-effect curves were used for micronucleated erythrocytes in bone marrow of bank voles exposed to chronically irradiation in radiocontaminated sites in natural environment (2.4 and 41.2 microGy/day, 0.04 and 0.68 cGy for populations) and to acute gamma-irradiation in laboratory conditions (¹³⁷Cs sources, 5.4 R/min, 10–100 cGy).

Comparison of genetic efficiency was made by three approaches: extrapolation, regression line slopes and doubling doses.

When we applied extrapolation method, we found that the doses of acute irradiation should be much more higher, about 13.1 and 20.9 cGy, than doses of chronic irradiation (0.04 and 0.68 cGy) in order to induce the mutation frequencies, which were observed in chronically irradiated populations.

As known, regression line slope or coefficient 'b' in linear dose-effect equation means the induced mutation rate per unit dose. When we compared the regression line slopes, we revealed that the slope values for chronic exposure exceeded slopes for acute irradiation.

We found also that the doubling doses of chronic low-LET exposure varied from 0.1 to approximately 2 cGy. This time the doubling doses of acute irradiation were in the range of 5–20 cGy.

The above facts indicate higher efficiency of low dose chronic irradiation in comparison with the higher doses of acute one.

Are there other data about a higher efficiency of small doses? Yes. One of them, the most important, is the data of Radiation Effect Research Foundation. They published that The Excessive Relative Risk for cancer mortality in people per Sv was the highest in the lowest dose category, namely from 5 mSv to 20 mSv [4].

It is evident that new experimental and epidemiological data reject the hypothesis of a low biological efficiency of low doses especially delivered in chronic irradiation.

What are the reasons of this phenomenon, which might be considered as universal? It may be

ineffective repair system at low-dose irradiation, genomic instability, bystander response, etc.

Table

Genetic effects of low-dose chronic irradiation in wildlife bank vole (*Clethrionomys glareolus*), pond carp (*Cyprinus carpio*) and laboratory mice *CBA*×*C57Bl/6j*

Irradiated animals	Dose rate from internal irradiat.	Total dose rate	Total whole body dose	Genetic effects in		
				somatic cells	germ cells	embryos
Bankvole						
♂♂ + ♀♀ parents and F ₁ - F ₂₂ , exposed during life	0.01-227 mGy/day	2-730 mGy/day	0.02-7.3 cGy	Chromosome aberrations and Polyploid cells in bone marrow Micronucleated polychromatic erythrocytes in bone marrow Micronucleated erythrocytes in peripheral blood	Abnormal sperm heads	Pre- and post-implantation embryonal lethality
Pondcarp						
♂♂ + ♀♀ parents, exposed during 3-5 years	0.1-1.5 mGy/day for zygotes	1.0-5.4 mGy/day for zygotes	-	-	Fertilization Quantity of pre-larvae and larvae Larvae survival	Malformations Chromosome aberrations Mitotic index
♂♂ + ♀♀ parents and F ₁ , exposed during life	0.1-0.9 mGy/day	1.0-6.0 mGy/day	0.008-0.09 cGy	Effects in F ₁ (fry): malformations	-	-
Laboratory mice						
♂♂ exposed during 133 days	0.02-3 mGy/day	3-144 mGy/day	0.04-1.9 cGy	Chromosome aberrations and Polyploid cells in bone marrow	Reciprocal trans-locations in spermatocytes Abnormal sperm heads	-

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Полигены и малые дозы радиации в исследованиях на карпе

Гончарова Р.И., Слуквин А.М., Аношенко Б.Ю.

*Институт генетики и цитологии Национальной Академии
Наук Беларуси, Минск, Беларусь*

THE STUDY ON POLYGENES AND LOW RADIATION DOSES IN CARP EXPERIMENTS. The study on morphometric traits under the revealed fish death conditions by using cluster analysis has detected relative pair indices acceptable for further analysis. These indices do not depend on the season of carrying out investigations, fish quantity and size, do not correlate with each other and thus, may be used for performing subsequent task of studying the influence of low-dose chromosomal ionizing radiation on morphometric indices in fish.

Изучение полигенов является весьма сложной задачей и до настоящего времени не существует прямых методов оценки их мутабельности. Все известные методы оценки мутабельности являются косвенными и основаны на использовании средних значений количественных признаков и их варианты. Такой же методический подход применен нами для изучения возможного влияния малых доз радиации на полигены, ответственные за количественные признаки у прудового карпа (*Cyprinus carpio* L.). Этот объект является модельным в генетике и радиобиологии рыб, и у него хорошо изучены закономерности наследования многих количественных признаков [1,2].

Работа выполнена на базе рыбхоза "Белое" Житковичского района Гомельской области. Морфометрический анализ (пластических и меристических признаков) проводился на живых особях молоди карпа трижды за период выращивания в 6-ти опытных, загрязненных радионуклидами (концентрация ^{137}Cs в донных отложениях от 801.1 до 3235.4 Бк/кг) и 4-х контрольных, или условно "чистых" выростных прудах (51.6–136.8 Бк/кг). Пруды имели единый источник водоснабжения и были одинаковы по площади (по 10 гектар каждый).

В воде опытных и контрольных прудов превышение ПДК по содержанию пестицидов, СПАВ, тяжелых металлов не обнаружено.

Плотность посадки личинок и в опытные, и в контрольные пруды была одинаковой и составляла 150 тыс.шт. на гектар.

Сбор и анализ материала в популяциях молоди карпа осуществлялся по неполной схеме измерений пластических и меристических признаков для отряда Карповых (*Cypriniformes*) [3]. У всех рыб измеряли общую длину тела – L (мм), длину тела до конца чешуйного покрова – l (мм), высоту тела – H (мм), толщину тела – B (мм), а также определяли вес тела – P (мг).