Received: 10 March 2017 / Accepted: 12 April 2017 / Published online: 30 April 2017

УДК 57.049

PROBLEM IN ASSESSING THE EFFECTS OF RADIATION WITH "LOW DOSES". REVIEW

Masaharu Hoshi [1], http://orcid.org/0000–0001–6978–0883
Aisulu Zh. Saimova [2], http//orcid.org/0000-0002-9564-732X

[1] **Hiroshima University, Research Institute for Radiation Biology and Medicine, Hiroshima, Japan.**
[2] **Semey State Medical University, Semey, Kazakhstan**

Abstract

Introduction. The paper presents literature review devoted to the effect of "low doses" of ionizing radiation on health of population and the environment based on the analysis of modern scientific publications. At the moment a lot of research has been done in this area.

Purpose: to review scientific papers on the effect of "low doses" of ionizing radiation on a living organism and the environment.

Materials and methods. To achieve this purpose, we have searched and analysis of scientific publications in the databases: PubMed, Elsevier, ResearchGate, Cyberleninka, Republican scientific and technical library. The following keywords have been define before the start of the search: experimental studies, radiation, low doses. Exclusion criteria included review of publications became summary reports, newspaper articles and personal notifications. During search 1689 literary sources were revealed, 63 from which have been chosen as an analytical material of article.

Results. At the present time, assessing of the influence of "low doses" ionizing radiation have three opposite points of view. Some researchers point to the increased danger of "low doses", others reject any features of their effects and others indicate the existence of radiation hormesis, that is, the positive influence of ionizing radiation.

Conclusions. Despite the abundance of scientific literature this question still opens and requires further study.

Keywords: ionizing radiation, low doses, hormesis.

Резюме

ПРОБЛЕМА В ОЦЕНКЕ ЭФФЕКТОВ ОБЛУЧЕНИЯ «МАЛЫМИ ДОЗАМИ» ИОНИЗИРУЮЩЕГО ИЗЛУЧЕНИЯ. ОБЗОР ЛИТЕРАТУРЫ

Масахару Хоши [1], http://orcid.org/0000–0001–6978–0883
Айсулу Ж. Саимова [2], http://orcid.org/0000-0002-9564-732X

[1] **Университет Хиросима, Научно–исследовательский институт радиационной биологии и медицины, г. Хиросима, Япония;**
[2] **Государственный медицинский университет города Семей, г. Семей, Казахстан**

Введение. В статье представлен обзор литературы, посвященный влиянию «малых доз» ионизирующего излучения на здоровье населения и окружающую среду на основе анализа научных публикаций. На данный момент проведено большое количество исследований в этой области.

Цель: провести анализ научных литературных данных о влияние «малых доз» ионизирующего излучения на живой организм и окружающую среду.

Материалы и методы: для осуществления поставленной цели был выполнен поиск литературы в базах данных: PubMed, Elsevier, ResearchGate, Cyberleninka и Республиканской научно-технической библиотеки. Перед началом поиска были определены следующие ключевые слова: экспериментальное исследование, ионизирующее излучение, малые дозы. Критериями исключения публикаций в обзор были резюме докладов, газетные публикации, личные сообщения. В ходе поиска было обнаружено 1689 литературных источника, из которых 63 были выбраны в качестве аналитического материала статьи.

Результаты. В настоящее время в оценке эффектов влияния ионизирующих излучений в «малых дозах» существуют три противоположные точки зрения. Одни исследователи указывают на повышенную опасность «малых доз», другие отвергают какие-либо особенности их эффектов, третьи утверждают о существовании радиационного гормезиса, то есть позитивного действия ионизирующего излучения.

Выводы. Несмотря на обилие научной литературы, данный вопрос остается открытым и требует дальнейшего исследования этого направления.

Ключевые слова: ионизирующее излучение, малые дозы, гормезис.

Түйіндеме

«ШАҒЫН ДОЗАДАҒЫ» ИОНДАУШЫ СӘУЛЕЛЕНУДІҢ ӘСЕРІН БАҒАЛАУДАҒЫ МӘСЕЛЕЛЕР. ӘДЕБИЕТКЕ ШОЛУ

Масахару Хоши [1], http://orcid.org/0000–0001–6978–0883
Айсулу Ж. Саимова [2], http://orcid.org/0000-0002-9564-732X

[1] Хиросима университеті, Радиациялық биология және медицина ғылыми–зерттеу институты, Хиросима қ., Жапония;
[2] Семей қаласының мемлекеттік медицина университеті, Семей қ., Қазақстан

Кіріспе. Мақалада «шағын дозадағы» иондаушы сәулеленудің әсері туралы әдебиеттік ақпараттары келтірілген. Қазіргі заманғы ғылыми жарияланымдардың талдау негізінде осы мәселе аяғына дейін анықталмағаны анық.

Мақсаты: тірі организмге және қоршаған ортаға «шағын дозадағы» иондаушы сәулеленудің әсері туралы ғылыми ақпараттарды сараптау.

Материалдар мен әдістер: қойылған мақсатқа жету үшін іздестіру келесі деркқорларында жүргізілді: PubMed, Elsevier, ResearchGate, Cyberleninka және Руспубликалық ғылыми-техникалық кітапханасында. Таңдау келесі түйінді сөздер негізінде жүргізілген: эксперименттік зерттеу, иондаушы сәулелену, шағын доза. Әдеби шолу кезінде баяндамалар тұжырымдары, газет мақалалары мен жеке іс ақпараттар қарастырылмаған. Зерттеу барысында 1689 әдебиет көзі, оның 63-і талдамалық мақаланың материалы ретінде таңдап алынды.

Нәтиже. Қазіргі уақытта, «шағын дозада» иондаушы сәуле әсерін бағалауда үш қарама қарсы көз қарас бар. Бір зерттеушілер «шағын дозадағы» иондаушы сәулеленудің әсері қауіпті десе, екіншілері ешқандай әсері жоқ десе, үшіншілері оң әсерінің бар болуы, яғни гормезис туралы айтады.

Қорытынды. Ғылыми әдебиеттердің көптігіне қарамастан, бұл мәселе аяғына дейін анықталмаған және осы бағытта одан әрі зерттеулерді талап етеді.

Түйінді сөздер: иондаушы сәуле, шағын доза, гормезис

Библиографическая ссылка:

Хоши М., Саимова А.Ж. Проблема в оценке эффектов облучения «малыми дозами» ионизирующего излучения. Обзор литературы / / Наука и Здравоохранение. 2017. №2. С. 115-127.

Hoshi M., Saimova A.Zh. Problem in assessing the effects of radiation with "low doses". Review. *Nauka i Zdravookhranenie* [Science & Healthcare]. 2017, 2, pp. 115-127.

Хоши М., Саимова А.Ж. «Шағын дозадағы» иондаушы сәулеленудің әсерін бағалаудағы мәселелер. Әдебиетке шолу // Ғылым және Денсаулық сақтау. 2017. № 2. Б. 115-127.

Introduction

Our Republic has the areas where functioning nuclear power plants, uranium mining provinces, as well as the territories former Semipalatinsk nuclear test site. Therefore, the notion of the definition of "low doses" is very important for the implementation of environmental monitoring and protection of civic health near the located to them.

Aim: to review scientific papers on the effect of "low doses" of ionizing radiation on a living organism and the environment.

Materials and methods

To achieve this purpose, we have searched and analysis of scientific publications in the databases: PubMed, Elsevier, ResearchGate, Cyberleninka, Republican scientific and technical library. The following keywords have been define before the start of the search: experimental studies, radiation, low doses. Exclusion criteria included review of publications became summary reports, newspaper articles and personal notifications. During search 1689 literary sources were revealed, 63 from which have been chosen as an analytical material of article.

Results and discussion

Nuclear power plants comparison with other types of energy have huge energy potential for the economy of any country, but in case of accidents on them, the consequences and damage to the health of the population of the adjacent to the areas practically impossible to fill [1].

Based on the history of radiation exposure to a living organism, we know that significant effects occurred due to [13]: nuclear weapon tests (Semipalatinsk nuclear test site, Nevada Nuclear Test Site, Alamogordo test range, Pacific Proving Grounds and others); accidents at nuclear power plants (Chernobyl, Fukushima, Three Mile Island, Windscale); emissions of radioactive substances from industries working with the processing of nuclear products; dispersion of radioactive substances.

As a result, due to neutron activation of chemical elements, beta and gamma-emitting radionuclides in the soil composition is develop [14].

Gamma radiation affects internal tissues, when the source of radiation is outside the body, in this case, irradiation is considered to be external. Beta-irradiation affects internal organs only when the source of radiation enters the body (by inhalation of neutron-activated soil dust, contaminated water and products), thereby leading to internal irradiation [14, 24].

After the nuclear accidents at the Chernobyl nuclear power plant, and then at Fukushima, radiobiologists have the question of how to diagnose the biological consequences of "low doses" [31].

In radiobiology, the concept of "low doses" is associated with the dose at which the effects under investigation begin to appear [4, 17]. For all this, the upper limit of "low doses" is determined in different ways, depending on the evaluation criterion. When studying the effect of ionizing radiation on organisms, "low doses" are those that do not cause noticeable disturbances in vital activity. Based on this, some authors suggest to count for "low doses" of a person in the range up to 200mGy and 500mGy for mammals [5, 17, 36].

Along with this, there are also microdosimetric studies, according to which a dose can be considered low when the critical target receives on average no more than one radiation event. Therefore, all biological effects and the effects of ionizing irradiation on a living organism are divided into deterministic and stochastic [12].

Deterministic effects, which manifest themselves in the form of obvious pathology, with significant radiation doses. The peculiarity of such effects is that they assume the presence of a certain minimum threshold, below which the effect is absent, and above - depends on the dose received. Stochastic effects do not have a dose threshold, that is theoretically possible with a "low dose" of irradiation, and the probability of occurrence is less, the lower the dose.

At the present time, in assessing the effects of the effects of ionizing radiation in "low doses", there are three opposite points of view. Some researchers point to the increased danger of "low doses," others reject any features of their effects, while others indicate the existence of radiation hormesis, that is, the positive action of ionizing irradiation [2].

The absence of peculiarities in the effect of radiation in "low doses" is evidenced by the recognition of a linear no-threshold concept as the basis for the normalization of the radiation factor [32, 44, 45, 54, 55] Regions with increased of natural background radiation have not been detected changes in the health of the local population.

On the positive effect of radiation in small doses and radiation hormesis began to speak at the beginning of the development of radiobiology. Many researchers observed the stimulation of various life processes. A detailed review of such works relating to this and subsequent periods is given by the convinced follower of the ideas of radiation hormesis in Russia – A. Kuzin [6, 7].

After nuclear accidents, environmental pollution occurs. As a result, radioactive particles enter the body, which in turn leads to beta radiation. As a result of the accident at the Chernobyl nuclear power plant, the vast adjoining territories were contaminated with radioactive fallout. Studies on the evaluation of humoral immunity have determined that soil contamination has a strong correlation with the individual dose of 137Cs [50], 25 years after the accident at the Chernobyl NPP, the doses of internal exposure to residents living in contaminated areas of northern Ukraine are limited but still associated with pollution Soil 137Cs. In addition, the cause of internal exposure is the consumption of local products [60].

In 2011, the Fukushima nuclear power plant accident in Japan caused by an earthquake measuring 9.0 magnitude after the tsunami was a reminder that even modern systems are vulnerable to natural disasters [20]. Given that the magnitude of environmental pollution accident at the Fukushima nuclear power plant second after the Chernobyl nuclear power plant, scientists from Japan, reacted sharply and began to study the effect of "low doses" of radiation on the ecosystem. Atsuki Hiyama [22-25] and colleagues studied blue butterflies, permanent inhabitants of the Fukushima Prefecture and concluded that "low doses" significantly affect the genetic apparatus, which manifests itself in the form of changes in pattern and color, as well as the shape of the wings, the size of the chest, abdome. The first generation extended the process of pupation, the frequency of abnormalities showed a high inverse correlation with the distance of the collection sites from the Fukushima nuclear power plant. A decrease in survival was also observed. Based on these data, it is impossible to estimate the effect of low doses on the human body, since the cells of the wings of these butterflies are more stable than human cells to short-term high doses of radiation. But we must also take into account that larvae and pupae are more vulnerable to long-term low radiation doses.

At the moment, scientifically, no one can provide convincing data that the long-term impact of "low doses" on the population living in the Fukushima area is safe for people’s health.

In 1920, Herman Joseph Muller [40, 41] found serious consequences after exposure to ionizing radiation in the descendants of irradiated parents. In his experiment, he irradiated - Drosophila - with X-rays and found developmental defects and other disturbances in the following generations. Based on this, he came to the conclusion that a "low dose" of irradiation and even a natural radiation with increasing range of norms can lead to induction of cancer and various mutations. His work was awarded the Nobel Prize in Medicine in 1946. In 1950, he warned that radioactive contamination of the lower atmosphere adversely affects the human gene pool.

Later Anne Graupner [21, 47] with a group of scientists conducted an experimental study in mice and found that radiation in "low doses" causes genotoxic effects. Radiation damage to DNA is more complex than endogenous, which in turn can lead to an irreversible reorganization of the DNA apparatus.

In 2001, SCEAR [59] presented a report about the health of the survivors of the atomic bombing of Hiroshima and Nagasaki. There, data were presented that the descendants of the surviving mutations in the genetic apparatus were not found.

Later, Inge Schmitz-Feuerhake [40] and co-authors analyzed the scientific papers on the effect of "low doses" of radiation on the genetic apparatus and concluded that the hereditary defects found were at doses from 1 mSv to 10 mSv.

Radioactive fallout from nuclear explosions has affected the population around the world to some extent. After the Chernobyl nuclear power plant accident in 1986, the inhabitants of Sweden suffered from 137Cs exposure, after five years, cancer growth was observed [35], in Belarus [29, 61], Russia [29, 39] and Ukraine [28], the incidence of thyroid cancer increased sharply in children. Based on these data, a screening of the incidence of thyroid cancer in Fukushima was carried out, which also showed a high growth of this nosology [48, 50].

A lot of different researches of the SNTS have been carried out, the definition of the radioactivity of the environment [33, 34, 53, 56], and the health status of the population living near the regions. For example, an analysis of radiation risk among the Semipalatinsk historical cohort was conducted in relation to mortality from cardiovascular diseases. A significant high risk was found in people living in the landfill area than among those who lived in the villages of comparison [26]. A biomarker of leukemia for a given cohort was determined [62]. A study was conducted on the evaluation of polymorphisms of genes that have a potential relationship with thyroid cancer [19], and a dose-effect relationship was also established [63].

R. Rozenson [11] investigated the relationship between the irradiated population between radiation-induced changes in the immune status and allergic reactions. The author established that a number of individuals irradiated at a dose of more than 1000 mSv had a decrease in immunoregulatory subpopulations with a predominant deficiency of T suppressors with a simultaneous increase in immunoglobulin of class E, which in turn led to the formation of respiratory allergies and allergic dermatoses.

Kenji Iwata [41] and co-authors conducted studies on the prevalence of skin cancer in people living near the SNTS. According to their data, even many years after the closure of the polygon, "low doses" may be the cause of the development of this pathology.

According to the long-term results of scientists, the health of the exposed population living in the territories near the Semipalatinsk test site shows an increase in morbidity and mortality rates, a combination of multiple somatic pathology and psycho-organic disorders [15].

When assessing the hazard of radiation exposure, it is necessary to take into account the accompanying chemical factors, that is, regional features. For the first time, N. Chayzhunusova [16], in her studies, found that the assessment of the risk of radiation exposure should be carried out taking into account the concomitant effects of modifying chemical factors. According to the results of studies, the dose of ionizing radiation on the population of the Maiskyi and Lebyazhye districts was about 3 sZv. Along with this, in the territory of the Maisky district, there was a marked increase in the content of pesticides and mineral fertilizers. As a result, based on the obtained data, the author comes to the conclusion that the combined effect of ionizing radiation and chemical agents leads to a substantial reduction in the thresholds for the main effects of ionizing radiation. This is due to the fact that there was an excess of cancer, as well as congenital malformations in the Maiskyi district where there was a combined radiation - chemical effect. In the Lebyazhye district, where the dose was almost the same as in Maysky, but without pesticide exposure, no such effects were found

The exposed population of different continents complained the following similar symptoms: general weakness, fatigue, reduced efficiency. These symptoms have not a general diagnosis. In Japan after the atomic bombing of Hiroshima this syndrome is called "Genbaku Burabura Byo" (the impact of the atomic bomb) [37], in America among veterans who fought in the Persian Gulf, this syndrome is called "Gulf war syndrome" [27]. The liquidators of the Chernobyl nuclear power plant presented all these symptoms in the form of a psychoorganic syndrome. Therefore, they have been treated annually since 1990 to the present [9, 43].

It is believed that the nervous system is considered relatively resistant to ionizing radiation [3], but it should be noted that the experimental work of Achanta Pragathi and colleagues shows that ionizing radiation contributes to worsening of associative memories [18].

In Ukraine, the adolescents were examined for determining suicidal tendencies and the presence of depression. In the study group were children who were 6 years of age, in the womb and born 45 weeks after the accident. They have identified psychological problems associated with inadequate environmental assessment [30]. Mental health problems have been observed in many residents of the Fukushima prefecture [50].

To date, there is no single scientific justification for the pathogenesis of diseases of people living in environmentally unfavorable conditions. Very often, changes from the nervous system are treated as functional. The reported complaints of general weakness, fatigue, headaches, dizziness, decreased performance [38, 42] interpreted by some specialists as a desire to receive benefits or as a manifestation of radiophobia [10, 16].

Unfortunately, there is no specific data indicating that "low doses" of ionizing radiation may or may not be, one of the causes of "chronic fatigue" of the population. As, basically presented complaints are treated as the desire to receive benefits or psychological violations.

Thus, analysis of literature data suggests that in assessing the effects of irradiation with "low doses", there are three categories of researchers who hold different views. Existing judgments create the problem of "low doses", the study of which is relevant.

Литература.

1. *Аскарова У.Б.* Радиационная обстановка в Казахстане и здоровье населения // Austrian Journal of Technical and Natural Sciences. 2014. №5-6. С. 3-5.

2. *Богданов И.М., Сорокина М.А., Маслюк А.И.* Проблема оценки эффектов воздействия «малых» доз ионизирующего излучения // Бюллетень сибирской медицины, 2005. № 2. С.145-151.

3. *Гуськова А.К., Шакирова И.Н.* Реакция нервной системы на повреждающее ионизирующее облучение. Обзор // Журнал невропатологии и психиатрии. 1989. №2. С.138-142.

4. *Ельтокова М.Х.* Оценка радиобиологического эффекта хрусталика у лиц, подвергшихся воздействию малых доз ионизирующего излучения: дис. ... д-ра философии (PhD). Астана, 2014. 351 с.

5. *Котеров А.Н.* От очень малых доз до очень больших доз радиации: данные по установлению диапазонов и их экспериментально – эпидемиологическое обоснование // Мед. радиология и радиац. безопасность. 2013. Т. 58, №2. С. 5–21.

6. *Кузин А.М.* Идеи радиационного гормезиса в атомном веке. М.: Наука, 1995. 198 с.

7. *Кузин А.М.* Природный радиоактивный фон и его значение для биосферы Земли. М.: Наука, 1991. 158с.

8. *Лахин А.В., Тарантул В.З., Генинг Л.В.* Индуцированный марганцем некорректный синтез днк как возможная причина манганизма // Молекулярная генетика, микробиология и вирусология. 2014. №1, С. 15-21. http://surgeryzone.net/info/informaciya-po-onkologii/luchevaya-terapiya.html (Дата обращения: 02.07.2015)

9. *Лысенко Е.В.* Возможности доклинической диагностики состояния периферической нервной системы у ликвидаторов последствий аварии на Чернобыльской АЭС. Вестник новых медицинских технологий. 2007. Т.XIV, №4. С.168-171.

10. *Мулдагалиев Т.Ж., Белихина Т.И., Жазыкбаева Л.К., Токанов А.М.* Распространенность психических расстройств среди экспонированного населения Бородулихинского района ВКО и их потомков в отдаленные сроки после радиационного воздействия // Наука и здравоохранение. 2012. №4. С. 25-28.

11. *Розенсон Р.И.* Особенности иммунопатогенеза респираторных аллергозов у населения региона, подвергавшегося выпадению локальных радиоактивных осадков: дис. …д-ра мед. наук. СПб, 1997. 340 с.

12. *Сафонова В.Ю., Сафонова В.А.* Биологическое влияние малых доз радиации, аспекты безопасности // «Известия Оренбурского государственного аграрного университета». 2011. №31-1. Т.3. С. 308-310.

13. *Степаненко В.Ф.* Разработка и применение методов индивидуальной ретроспективной дозиметрии населения для оценки последствий крупномасштабных

радиационных аварий: дис. …д-ра мед. наук. Обнинск. 2009. 290 с.

14. *Степаненко В.Ф., Рахыпбеков Т.К., Каприн А.Д. с соавт.* Облучение экспериментальных животных активированной нейтронами радиоактивной пылью: разработка и реализация метода – первые результаты международного многоцентрового исследования // Радиация и риск. 2016. Т.25. №4. С. 111-125. DOI: 10.21870/0131-3878-2016-25-4-111-125.

15. *Токанов А.М., Кангожирова О.Г., Гайнулина Р.С.* Неврологические нарушения среди лиц, проживающих на территориях, прилегающих к Семипалатинскому испытательному ядерному полигону в отдаленные сроки после облучения // Вестник КазНМУ, 2014. № 3(1). С. 172-176.

16. *Чайжунусова Н.Ж.* Иммунные, генетические эффекты и онкозаболеваемость населения в условиях комбинированного действия вредных факторов окружающей среды (в регионе распространения локальных радиоактивных осадков): дис. …д-ра мед. наук., Алма-Ата. 1993. 347 с.

17. *Ярмоненко С.П., Вайсон А.А.* Радиобиология человека и животных. – М.: Высшая школа, 2004. 549 с.

18. *Achanta, Pragathi; Fuss, Martin; Martinez Jr., Joe L.* Ionizing radiation impairs the formation of trace fear memories and reduces hippocampal neurogenesis // Behavioral Neuroscience, Vol 123(5), Oct. 2009, P. 1036-1045.

19. *Alice J. Sigurdson, Charles E. Land, Parveen Bhatti, Marbin Pineda, Alina Brenner, Zhanat Carr, Boris I. Gusev, Zhaxibay Zhumadilov, Steven L. Simon, Andre Bouville, Joni L. Rutter, Elaine Ron, and Jeffery P. Struewing* Thyroid nodules, polymorphic variants in DNA repair and RET-related genes, and interaction with ionizing radiation exposure from nuclear tests in Kazakhstan // Radiat Res. 2009 January; 171(1): P. 77–88. doi:10.1667/RR1327.1.

20. *Amina Aitsi-Selmi, Virginia Murray* The Chernobyl Disaster and Beyond: Implications of the Sendai Framework for Disaster Risk Reduction 2015–2030 // PLoS Med. 2016 Apr; 13(4): e1002017. doi:10.1371/journal.pmed.1002017

21. *Anne Graupner, Dag M. Eide, Christine Instanes et al.* Gamma radiation at a human relevant low dose rate is genotoxic in mice // Scientific reports. 2016; 6: 32977. doi:10.1038/srep32977

22. *Atsuki Hiyama, Chiyo Nohara, Seira Kinjo et al.* The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly // Scientific reports. 2012; 2: 570. doi:10.1038/srep00570

23. *Atsuki Hiyama, Chiyo Nohara, Wataru Taira et al.* The Fukushima nuclear accident and the pale grass blue butterfly: evaluating biological effects of long-term low-dose exposures // BMC evolutionary biology. 2013; 13: 168. doi:10.1186/1471-2148-13-168

24. *Atsuki Hiyama, Wataru Taira, Chiyo Nohara et al.* Spatiotemporal abnormality dynamics of the pale grass blue butterfly: three years of monitoring (2011-2013) after the Fukushima nuclear accident // BMC evolutionary biology. 2015. Feb 10;15:15. doi: 10.1186/s12862-015-0297-1.

25. *Atsuki Hiyama, Wataru Taira, Joji M. Otaki.* Color-Pattern Evolution in Response to Environmental Stress in Butterflies // Frontiers in genetics. 2012; 3: 15. doi:10.3389/fgene.2012.00015

26. *Bernd Grosche, Daniel T. Lackland, Charles E. Land, Steven L. Simon, Kazbek N. Apsalikov, Ludmilla M. Pivina, Susanne Bauere, and Boris I. Gusev.* Mortality from Cardiovascular Diseases in the Semipalatinsk Historical Cohort, 1960–1999, and its Relationship to Radiation Exposure // Radiat Res. 2011. November; 176(5): 660–669.

27. *Bertell R.* Testimony at Unites States Senate Committee on Veterans' Affairs. 1998. http://www.ccnr.org/rosalie_testimony.html.

28. *Brenner A.V., Tronko M.D., Hatch M. et al.* I-131 dose response for incident thyroid cancers in Ukraine related to the Chornobyl accident // Environ Health Perspect. 2011;119:933–9. doi:10.1289/ehp.1002674

29. *Cardis E., Kesminiene A., Ivanov V. et al.* Risk of thyroid cancer after exposure to ^{131}I in childhood // J Natl Cancer Inst. 2005;97:724–32. doi:10.1093/jnci/dji129

30. *Contis G., Foley T.P. Jr. Depression,* suicide ideation, and thyroid tumors among ukrainian adolescents exposed as children to Chernobyl radiation // Journal of clinical medicine research. 2015. May; 7(5): 332-8. doi: 10.14740/jocmr2018w.

31. *Daria Handkiewicz-Junak, Michal Swierniak, Dagmara Rusinek et al.* Gene signature of the post-Chernobyl papillary thyroid cancer // European Journal of Nuclear Medicine and Molecular Imaging. 2016; 43: 1267–1277. doi:10.1007/s00259-015-3303-3

32. *Edward J., Calabrese L., Baldwin A.* Radiation Hormesis and Cancer // Human and Ecological Risk Assesment. 2002. V. 8. № 2. P. 327–353.

33. *Evseeva T., Belykh E., Geras'kin S., Majstrenko T.* Estimation of radioactive contamination of soils from the "Balapan" and the "Experimental field" technical areas of the Semipalatinsk nuclear test site // Journal of Environmental Radioactivity**.** Vol. 109, July 2012, P.52–59.

34. *Evseeva T.I., Geras'kin S.A., Maĭstrenko T.A., Belykh E.S.* Assessment of soil degradation in regions of nuclear power explosions at Semipalatinsk Nuclear Test Site // Radiats Biol Radioecol. 2011. Mar-Apr; 51(2): 264-72.

35. *Hassan Alinaghizadeh, Robert Wålinder, Eva Vingård, and Martin Tondel* Total cancer incidence in relation to ^{137}Cs fallout in the most contaminated counties in Sweden after the Chernobyl nuclear power plant accident: a register-based study // BMJ Open. 2016; 6(12): e011924. doi: 10.1136/bmjopen-2016-011924

36. *Hayes D.P.* Non – problematic risk from low – dose radiation – in DNA damage clusters // Dose Response. 2008. Vol.6. P. 30-52.

37. *Hida S.* Internal exposure. (Fuso-sya) 2010. https://www.afsc.org/document/shuntaro-hida-japan.

38. *Hirabayashi K, Kawano N, Ohtaki M et al.* Health status of radiation exposed residents living near the Semipalatinsk Nuclear Test Site based on health assessment by interview // Hiroshima Journal of Medical Scitnce. 2008. Mar; 57(1). 27-35.

39. *Ivanov V.K., Kashcheev V.V., Chekin S.Y. et al.* Radiation-epidemiological studies of thyroid cancer incidence in Russia after the Chernobyl accident (estimation of radiation risks, 1991–2008 follow-up period) // Radiat Prot Dosimetry. 2012; 151: 489–99.doi:10.1093/rpd/ncs019

40. *Inge Schmitz - Feuerhake, Christopher Busby, and Sebastian Pflugbeil*. Genetic radiation risks: a neglected topic in the low dose debate // Environmental health and toxicology. 2016; 31: e2016001. doi:10.5620/eht.e2016001

41. *Iwata K., Takamura N., Nakashima M., Alipov G., Mine M., Matsumoto N., Yoshiura K., Prouglo Y., Sekine I., Katayama I., Yamashita S.* Loss of heterozygosity on chromosome 9q22.3 in microdissected basal cell carcinomas around the Semipalatinsk Nuclear Testing Site, Kazakhstan. Human pathology. 2004. Apr;35(4):460-464.

42. *Kawano N., Hirabayashi K., Matsuo M. et al.* Human suffering effects of nuclear tests at Semipalatinsk, Kazakhstan: established on the basis of questionnaire surveys. Journal of radiation research. 2006. Feb;47 Suppl A:A209-17.

43. *Krasnov V., Kryukov V., Samedova E., Emelianova I., and Ryzhova I.* Early Aging in Chernobyl Clean-Up Workers: Long-Term Study // *BioMed research international.* 2015; 2015: 948473. doi: 10.1155/2015/948473

44. *Lackey T.* Ionizing radiation promotes protozoan reproduction // Radiat. Res. 1986. V. 108. P. 215–221.

45. *Lackey T.* Physiological benefits from low levels of ionizing radiation // Health Phys. 1982. V. 43. P. 771–789.

46. *Land C.E., Zhumadilov Z., Gusev B. I. et al.* Ultrasound-Detected Thyroid Nodule Prevalence and Radiation Dose from Fallout // Radiation Research Society. 2008 Apr; 169(4): 373–383. doi: 10.1667/RR1063.1

47. *Lomax M.E., Folkes L.K., O'Neill P.* Biological consequences of radiation-induced DNA damage: relevance to radiotherapy. Clinical oncology (Royal College of Radiologists (Great Britain)). 2013 Oct;25(10):578-85. doi: 10.1016/j.clon.2013.06.007.

48. *Norisato Mitsutake, Toshihiko Fukushima, Michiko Matsuse et al.* $BRAF^{V600E}$ mutation is highly prevalent in thyroid carcinomas in the young population in Fukushima: a different oncogenic profile from Chernobyl // Scientific reports. 2015. Nov 20 ;5 :16976. doi: 10.1038/srep16976.

49. *Maeda M., Yabe H., Yasumura S., Abe M.* What about the mental health of adults? // Fukushima journal of medical science. 2014;60(2):209-10. doi: 10.5387/fms.2014-24.

50. *McMahon D.M., Vdovenko V.Y., Karmaus W.* et al. Effects of long-term low-level radiation exposure after the Chernobyl catastrophe on

immunoglobulins in children residing in contaminated areas: prospective and cross-sectional studies. Environmental health. 2014 May 10;13(1):36. doi: 10.1186/1476-069X-13-36.

51. *Muller H.J.* Radiation damage to the genetic material // American scientist. 1950;38(1):33–59.

52. *Mykola D. Tronko, Vladimir A. Saenko, Victor M. Shpak, Tetiana I. Bogdanova, Shinichi Suzuki and Shunichi Yamashita.* Age Distribution of Childhood Thyroid Cancer Patients in Ukraine After Chernobyl and in Fukushima After the TEPCO-Fukushima Daiichi NPP Accident // *Thyroid.* 2014 Oct 1; 24(10): 1547–1548. doi:10.1089/thy.2014.0198

53. *Norisato Mitsutake, Toshihiko Fukushima, Michiko Matsuse et al.* BRAF^{V600E} mutation is highly prevalent in thyroid carcinomas in the young population in Fukushima: a different oncogenic profile from Chernobyl // Scientific reports. 2015. Nov 20; 5 :16976. doi: 10.1038/srep16976.

54. *Pohl-Ruling J., Fischer P., Haas O. et al.* Effect of low dose acute X-irradiation on the frequencies of chromosomal aberrations in peripheral lymphocytes in vitro // Mutat. Res. 1983. V. 100. № 2. P. 71–82.

55. *Schneider A.B., Ron E., Lubin J. et al.* Dose-response relationships for radiation-induced thyroid cancer and thyroid nodules: evidence for the prolonged effects of radiation on the thyroid // J. Clin. Endocrinol. Metab. 1993. V. 77(2). P. 362–369.

56. *Taira Y., Hayashida N., Brahmanandhan G.M., Nagayama Y., Yamashita S., Takahashi J., Gutevitc A., Kazlovsky A., Urazalin M., Takamura N.* Current concentration of artificial radionuclides and estimated radiation doses from 137Cs around the Chernobyl Nuclear Power Plant, the Semipalatinsk Nuclear Testing Site, and in Nagasaki // Journal of Radiation Research. 2011; 52(1):88-95. Epub 2010 Dec 24.

57. *Tetsuji Imanaka, Masayoshi Yamamoto, Kenta Kawai, Aya Sakaguchi, Masaharu Hoshi, Nailya Chaizhunusova, Kazbek Apsalikov.* Reconstruction of local fallout composition and gamma-ray exposure in a village contaminated by the first USSR nuclear test in the Semipalatinsk nuclear test site in Kazakhstan // *Radiation and Environmental Biophysics November*. 2010, Volume 49, Issue 4, pp 673–684

58. *Timothy A.* Mousseau and Anders P. Møller. Genetic and Ecological Studies of Animals in Chernobyl and Fukushima // Journal of Heredity 2014:105(5):704–709. doi:10.1093/jhered/esu040

59. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) UNSCEAR 2001 report: hereditary effects of radiation. http://www.unscear.org/unscear/en/publications/2001.html.

60. *Yuko Kimura, Yuka Okubo, Naomi Hayashida et al.* Evaluation of the Relationship between Current Internal ^{137}Cs Exposure in Residents and Soil Contamination West of Chernobyl in Northern Ukraine // PLoS One. 2015; 10(9):e0139007.doi:10.1371/journal.pone.0139007

61. *Zablotska L.B., Ron E., Rozhko A.V. et al.* Thyroid cancer risk in Belarus among children and adolescents exposed to radioiodine after the Chornobyl accident // Br J Cancer. 2011;104:181–7. doi:10.1038/sj.bjc.6605967

62. *Zharlyganova D., Harada H., Harada Y., Shinkarev S., Zhumadilov Z., Zhunusova A., Tchaizhunusova N.J., Apsalikov K.N., Kemaikin V., Zhumadilov K., Kawano N., Kimura A., Hoshi M.* High frequency of AML1/RUNX1 point mutations in radiation-associated myelodysplastic syndrome around Semipalatinsk nuclear test site // Journal of Radiation Research. 2008 Sep;49(5):549-55. Epub 2008 Aug 23.

63. *Zhumadilov Z.* Thyroid nodules in the population living around Semipalatinsk nuclear test site: possible implications for dose-response relationships study // Journal of radiation research. 2006 Feb;47 Suppl A:A183-7.

References:

1. Askarova U.B. Radiatsionnaya obstanovka v Kazakhstane i zdorov'e naseleniya [Radiation situation in Kazakhstan and health of the population]. *Austrian Journal of Technical and Natural Sciences.* 2014, №5-6, pp. 3-5.

2. Bogdanov I.M., Sorokina M.A., Maslyuk A.I. Problema otsenki effektov vozdeistviya «malykh» doz ioniziruyushchego izlucheniya [The problem of evaluating low dose ionizing radiation effects]. *Byulleten' sibirskoi meditsiny* [Bulletin of Siberian Medicine], 2005. №2, pp.145-151.

3. Gus'kova A.K., Shakirova I.N. Reaktsiya nervnoi sistemy na povrezhdayushchee

ioniziruyushchee obluchenie. obzor [Reaction of the nervous system to damaging ionizing radiation: Review]. *Zhurnal nevropatologii i psikhiatrii* [Journal of Neuropathology and Psychiatry]. 1989. №2. pp.138-142.

4. El'tokova M. Kh. *Otsenka radiobiologicheskogo effekta khrustalika u lits, podvergshikhsya vozdeistviyu malykh doz ioniziruyushchego izlucheniya (dokt.dis (PhD)* [Evaluation of the radiobiological effect of the lens in persons exposed to low doses of ionizing radiation. Dokt.Dis (PhD)]. Astana, 2014, 351 p.

5. Koterov A.N. Ot ochen' malykh doz do ochen' bol'shikh doz radiatsii: dannye po ustanovleniyu diapazonov i ikh eksperimental'no – epidemiologicheskoe obosnovanie [From very low doses to very large doses of radiation: data on the establishment of ranges and their experimental - epidemiological substantiation]. *Med. radiologiya i radiats. Bezopasnost'* [Med. Radiology and radiation. security]. 2013. T.58, №2. P. 5–21.

6. Kuzin A.M*. Idei radiatsionnogo gormezisa v atomnom veke* [Ideas of radiation hormesis in the atomic century]. M.:Nauka, 1995. 198 p.

7. Kuzin A.M. *Prirodnyi radioaktivnyi fon i ego znachenie dlya biosfery Zemli* [Natural radioactive background and its significance for the Earth's biosphere]. M.:Nauka, 1991. 158 p.

8. Lakhin A.V., Tarantul V.Z., Gening L.V. Indutsirovannyi margantsem nekorrektnyi sintez dnk kak vozmozhnaya prichina manganizma [Induced manganese incorrect synthesis of DNA as a possible cause of manganism]. *Molekulyarnaya genetika, mikrobiologiya i virusologiya* [Molecular genetics, microbiology and virology]. 2014, №1, pp. 15-21. http://surgeryzone.net/info/informaciya-po-onkologii/luchevaya-terapiya.html

9. Lysenko E.V. Vozmozhnosti doklinicheskoi diagnostiki sostoyaniya perifericheskoi nervnoi sistemy u likvidatorov posledstvii avarii na Chernobyl'skoi AES [Possibilities of preclinical diagnostics of the peripheral nervous system in the liquidators of the consequences of the Chernobyl accident]. *Vestnik novykh meditsinskikh tekhnologii* [Herald of new medical technologies]. 2007, T.XIV, №4, pp. 168-171.

10. Muldagaliev T.Zh., Belikhina T.I., Zhazykbaeva L.K., Tokanov A.M. Rasprostranennost' psikhicheskikh rasstroistv sredi eksponirovannogo naseleniya Borodulikhinskogo raiona VKO i ikh potomkov v otdalennye sroki posle radiatsionnogo vozdeistviya [The prevalence of mental disorders among the exposed population of Borodulikha district of East Kazakhstan area and their descendants in the long term after the radiation exposure]. Nauka i zdravookhranenie [Science & Health Care], 2012. № 4. pp. 25-28.

11. Rozenson R.I. Osobennosti immunopatogeneza respiratornykh allergozov u naseleniya regiona, podvergavshegosya vypadeniyu lokal'nykh radioaktivnykh osadkov: *(dokt.dis.)* [Features of immunopathogenesis of respiratory allergoses in the population of the region subjected to loss of local radioactive fallout: Dokt.Dis]. SPb, 1997, 340 p.

12. Safonova V.Yu., Safonova V.A. Biologicheskoe vliyanie malykh doz radiatsii, aspekty bezopasnosti [Biological impact of low doses radiation, safety aspects]. *Izvestiya Orenburskogo gosudarstvennogo agrarnogo universiteta* [Proceedings of the Orenburg State Agrarian University]. 2011, № 31-1, T.3. pp.308-310.

13. Stepanenko V.F. *Razrabotka i primenenie metodov individual'noi retrospektivnoi dozimetrii naseleniya dlya otsenki posledstvii krupnomasshtabnykh radiatsionnykh avarii: (dokt.dis.)* [Development and application of methods for individual retrospective dosimetry of the population to assess the consequences of large-scale radiation accidents: Dokt. Dis]. Obninsk, 2009, 29 p.

14. Stepanenko V.F., Rakhypbekov T.K., Kaprin A.D. s soavt. Obluchenie eksperimental'nykh zhivotnykh aktivirovannoi neitronami radioaktivnoi pyl'yu: razrabotka i realizatsiya metoda – pervye rezul'taty mezhdunarodnogo mnogotsentrovogo issledovaniya [Irradiation of experimental animals with neutron-activated radioactive dust: the development and implementation of the method are the first results of an international multicenter study]. *Radiatsiya i risk* [Journal «Radiation and Risk»]. 2016, Tom 25. № 4, DOI: 10.21870/0131-3878-2016-25-4-111-125

15. Tokanov A.M., Kangozhirova O.G., Gainulina R.S. Nevrologicheskie narusheniya sredi lits, prozhivayushchikh na territoriyakh,

prilegayushchikh k Semipalatinskomu ispytatel'nomu yadernomu poligonu v otdalennye sroki posle oblucheniya [Neurologic violations among the persons living in territories, adjacent to the Semipalatinsk proving nuclear ground in the remote terms after radiation]. *Vestnik KazNMU* [*Vestnik KazNMU*], 2014. № 3(1). pp. 172-176.

16. Chaizhunussova N.Zh.. *Immunnye, geneticheskie effekty i onkozabolevaemost' naseleniya v usloviyakh kombinirovannogo deistviya vrednykh faktorov okruzhayushchei sredy (v regione rasprostraneniya lokal'nykh radioaktivnykh osadkov): (doct. diss.)* [Immune, genetic effects and oncological morbidity of the population in conditions of combined action of harmful environmental factors (in the region of local radioactive fallout): Doct. Diss.]., Alma-Ata. 1993. 347 p.

17. Yarmonenko S.P., Vaison A.A. *Radiobiologiya cheloveka i zhivotnykh* [Radiobiology of humans and animals]. M.: Vysshaya shkola [High school], 2004. 549 p.

18. Achanta Pragathi, Fuss Martin, Martinez Jr., Joe L. Ionizing radiation impairs the formation of trace fear memories and reduces hippocampal neurogenesis. *Behavioral Neuroscience,* Vol 123(5), Oct 2009, pp. 1036-1045.

19. Alice J. Sigurdson, Charles E. Land, Parveen Bhatti, Marbin Pineda, Alina Brenner, Zhanat Carr, Boris I. Gusev, Zhaxibay Zhumadilov, Steven L. Simon, Andre Bouville, Joni L. Rutter, Elaine Ron, and Jeffery P. Struewing. Thyroid nodules, polymorphic variants in DNA repair and RET-related genes, and interaction with ionizing radiation exposure from nuclear tests in Kazakhstan. *Radiat Res*. 2009, January; 171(1): 77–88. doi:10.1667/RR1327.1.

20. Amina Aitsi-Selmi, Virginia Murray. The Chernobyl Disaster and Beyond: Implications of the Sendai Framework for Disaster Risk Reduction 2015–2030. *PLoS Med.* 2016, Apr; 13(4): e1002017. doi:10.1371/journal.pmed.1002017

21. Anne Graupner, Dag M. Eide, Christine Instanes et al. Gamma radiation at a human relevant low dose rate is genotoxic in mice. *Scientific reports*. 2016, 6: 32977. doi:10.1038/srep32977

22. Atsuki Hiyama, Chiyo Nohara, Seira Kinjo et al. The biological impacts of the Fukushima nuclear accident on the pale grass blue butterfly. *Scientific reports*. 2012, 2: 570. doi:10.1038/srep00570

23. Atsuki Hiyama, Chiyo Nohara, Wataru Taira et al. The Fukushima nuclear accident and the pale grass blue butterfly: evaluating biological effects of long-term low-dose exposures. *BMC evolutionary biology.* 2013, 13: 168. doi:10.1186/1471-2148-13-168

24. Atsuki Hiyama, Wataru Taira, Chiyo Nohara et al. Spatiotemporal abnormality dynamics of the pale grass blue butterfly: three years of monitoring (2011-2013) after the Fukushima nuclear accident. *BMC evolutionary biology.* 2015, Feb 10;15:15. doi: 10.1186/s12862-015-0297-1.

25. Atsuki Hiyama, Wataru Taira, Joji M. Otaki. Color-Pattern Evolution in Response to Environmental Stress in Butterflies. *Frontiers in genetics.* 2012, 3: 15. doi: 10.3389/fgene.2012.00015

26. Bernd Grosche, Daniel T. Lackland, Charles E. Land, Steven L. Simon, Kazbek N. Apsalikov, Ludmilla M. Pivina, Susanne Bauere, and Boris I. Gusev. Mortality from Cardiovascular Diseases in the Semipalatinsk Historical Cohort, 1960–1999, and its Relationship to Radiation Exposure. *Radiat Res.* 2011 November; 176(5): 660–669.

27. Bertell R. *Testimony at Unites States Senate Committee on Veterans' Affairs*. 1998. http://www.ccnr.org/rosalie_testimony.html.

28. Brenner A.V., Tronko M.D., Hatch M. et al. I-131 dose response for incident thyroid cancers in Ukraine related to the Chornobyl accident. *Environ Health Perspect.* 2011; 119:933–9. doi:10.1289/ehp.1002674

29. Cardis E., Kesminiene A., Ivanov V. et al. Risk of thyroid cancer after exposure to ^{131}I in childhood. *J Natl Cancer Inst.* 2005; 97: 724–32. doi:10.1093/jnci/dji129

30. Contis G., Foley T.P. Jr. Depression, suicide ideation, and thyroid tumors among ukrainian adolescents exposed as children to Chernobyl radiation. *Journal of clinical medicine research.* 2015, May; 7(5): 332-8. doi: 10.14740/jocmr2018w.

31. Daria Handkiewicz-Junak, Michal Swierniak, Dagmara Rusinek et al. Gene signature of the post-Chernobyl papillary thyroid cancer. *European Journal of Nuclear Medicine*

and Molecular Imaging. 2016, 43: 1267–1277. doi:10.1007/s00259-015-3303-3

32. Edward J., Calabrese L., Baldwin A. Radiation Hormesis and Cancer. *Human and Ecological Risk Assesment.* 2002. V. 8. № 2. P. 327–353.

33. Evseeva T., Belykh E., Geras'kin S., Majstrenko T. Estimation of radioactive contamination of soils from the "Balapan" and the "Experimental field" technical areas of the Semipalatinsk nuclear test site. *Journal of Environmental Radioactivity***.** 2012, July, Vol. 109, pp. 52–59.

34. Evseeva T.I., Geras'kin S.A., Maĭstrenko T.A., Belykh E.S. Assessment of soil degradation in regions of nuclear power explosions at Semipalatinsk Nuclear Test Site. *Radiats Biol Radioecol.* 2011, Mar-Apr; 51(2): 264-72.

35. Hassan Alinaghizadeh, Robert Wålinder, Eva Vingård, and Martin Tondel. Total cancer incidence in relation to ^{137}Cs fallout in the most contaminated counties in Sweden after the Chernobyl nuclear power plant accident: a register-based study. *BMJ Open.* 2016; 6(12): e011924. doi: 10.1136/bmjopen-2016-011924

36. Hayes D.P. Non – problematic risk from low – dose radiation – in DNA damage clusters. *Dose Response.* 2008. Vol.6. pp. 30-52.

37. Hida S. Internal exposure. (Fuso-sya) 2010. https://www.afsc.org/document/shuntaro-hida-japan.

38. Hirabayashi K., Kawano N., Ohtaki M. et al. Health status of radiation exposed residents living near the Semipalatinsk Nuclear Test Site based on health assessment by interview. *Hiroshima Journal of Medical Scitnce.* 2008, Mar; 57(1): pp. 27-35.

39. Ivanov V.K., Kashcheev V.V., Chekin S.Y. et al. Radiation-epidemiological studies of thyroid cancer incidence in Russia after the Chernobyl accident (estimation of radiation risks, 1991–2008 follow-up period). *Radiat Prot Dosimetry.* 2012; 151: pp. 489–99.doi:10.1093/rpd/ncs019

40. Inge Schmitz-Feuerhake, Christopher Busby, and Sebastian Pflugbeil. Genetic radiation risks: a neglected topic in the low dose debate. *Environmental health and toxicology.* 2016, 31: e2016001. doi:10.5620/eht.e2016001

41. Iwata K., Takamura N., Nakashima M., Alipov G., Mine M., Matsumoto N., Yoshiura K., Prouglo Y., Sekine I., Katayama I., Yamashita S. Loss of heterozygosity on chromosome 9q22.3 in microdissected basal cell carcinomas around the Semipalatinsk Nuclear Testing Site, Kazakhstan. *Human pathology.* 2004, Apr; Vol 35, Issue 4, 35(4): 460-464.

42. Kawano N., Hirabayashi K., Matsuo M. et al. Human suffering effects of nuclear tests at Semipalatinsk, Kazakhstan: established on the basis of questionnaire surveys. *Journal of radiation research.* 2006, Feb; 47 Suppl A:A209-17.

43. Krasnov V., Kryukov V., Samedova E., Emelianova I., and Ryzhova I.. Early Aging in Chernobyl Clean-Up Workers: Long-Term Study. *BioMed research international.* 2015, 948473. doi: 10.1155/2015/948473

44. Lackey T. Ionizing radiation promotes protozoan reproduction. *Radiat. Res.* 1986. V. 108. pp. 215–221.

45. Lackey T. Physiological benefits from low levels of ionizing radiation. *Health Phys.* 1982. V. 43. pp. 771–789.

46. Land C. E., Zhumadilov Z., Gusev B. I. et al. Ultrasound-Detected Thyroid Nodule Prevalence and Radiation Dose from Fallout. *Radiation Research Society.* 2008, Apr; 169(4): 373–383. doi: 10.1667/RR1063.1

47. Lomax M.E., Folkes L.K., O'Neill P. Biological consequences of radiation-induced DNA damage: relevance to radiotherapy. *Clinical oncology (Royal College of Radiologists (Great Britain))*. 2013, Oct; 25(10): 578-85. doi: 10.1016/j.clon.2013.06.007.

48. Norisato Mitsutake, Toshihiko Fukushima, Michiko Matsuse et al. BRAF^{V600E} mutation is highly prevalent in thyroid carcinomas in the young population in Fukushima: a different oncogenic profile from Chernobyl. *Scientific reports.* 2015, Nov 20; 5 :16976. doi: 10.1038/srep16976.

49. Maeda M., Yabe H., Yasumura S., Abe M. What about the mental health of adults? *Fukushima journal of medical science.* 2014; 60(2): 209-10. doi: 10.5387/fms.2014-24.

50. McMahon D.M., Vdovenko V.Y., Karmaus W. et al. Effects of long-term low-level radiation exposure after the Chernobyl catastrophe on immunoglobulins in children residing in contaminated areas: prospective and cross-sectional studies. *Environmental health.* 2014, May 10;13(1):36. doi: 10.1186/1476-069X-13-36.

51. Muller H.J. Radiation damage to the genetic material. *American scientist.* 1950;38(1):33–59.

52. Mykola D. Tronko, Vladimir A. Saenko, Victor M. Shpak, Tetiana I. Bogdanova, Shinichi Suzuki and Shunichi Yamashita. Age Distribution of Childhood Thyroid Cancer Patients in Ukraine After Chernobyl and in Fukushima After the TEPCO-Fukushima Daiichi NPP Accident. *Thyroid.* 2014, Oct 1; 24(10): 1547–1548. doi:10.1089/thy.2014.0198

53. Norisato Mitsutake, Toshihiko Fukushima, Michiko Matsuse et al. $BRAF^{V600E}$ mutation is highly prevalent in thyroid carcinomas in the young population in Fukushima: a different oncogenic profile from Chernobyl. *Scientific reports.* 2015, Nov 20; 5: 16976. doi: 10.1038/srep16976.

54. Pohl-Ruling J., Fischer P., Haas O. et al. Effect of low dose acute X-irradiation on the frequencies of chromosomal aberrations in peripheral lymphocytes in vitro. *Mutat. Res.* 1983. V. 100. № 2. pp. 71–82.

55. Schneider A.B., Ron E., Lubin J. et al. Dose-response relationships for radiation-induced thyroid cancer and thyroid nodules: evidence for the prolonged effects of radiation on the thyroid. *J. Clin. Endocrinol. Metab.* 1993. V. 77(2). pp. 362–369.

56. Taira Y., Hayashida N., Brahmanandhan G.M., Nagayama Y., Yamashita S., Takahashi J., Gutevitc A., Kazlovsky A., Urazalin M., Takamura N. Current concentration of artificial radionuclides and estimated radiation doses from 137Cs around the Chernobyl Nuclear Power Plant, the Semipalatinsk Nuclear Testing Site, and in Nagasaki. *Journal of Radiation Research.* 2011, 52(1):88-95. E-pub. 2010 Dec 24.

57. Tetsuji Imanaka, Masayoshi Yamamoto, Kenta Kawai, Aya Sakaguchi, Masaharu Hoshi, Nailya Chaizhunusova, Kazbek Apsalikov. Reconstruction of local fallout composition and gamma-ray exposure in a village contaminated by the first USSR nuclear test in the Semipalatinsk nuclear test site in Kazakhstan. *Radiation and Environmental Biophysics November*. 2010, Volume 49, Issue 4, pp 673–684

58. Timothy A. Mousseau and Anders P. Møller. Genetic and Ecological Studies of Animals in Chernobyl and Fukushima. *Journal of Heredity* 2014:105(5):704–709. doi:10.1093/jhered/esu040

59. United Nations Scientific Committee on the Effects of Atomic Radiation (UNSCEAR) UNSCEAR 2001 report: hereditary effects of radiation. http://www.unscear.org/unscear/en/publications/2001.html.

60. Yuko Kimura, Yuka Okubo, Naomi Hayashida et al. Evaluation of the Relationship between Current Internal ^{137}Cs Exposure in Residents and Soil Contamination West of Chernobyl in Northern Ukraine. *PLoS One.* 2015, 10(9):e0139007.doi:10.1371/journal.pone.0139007

61. Zablotska L.B., Ron E., Rozhko A.V. et al. Thyroid cancer risk in Belarus among children and adolescents exposed to radioiodine after the Chornobyl accident. *Br J Cancer.* 2011;104:181–7. doi:10.1038/sj.bjc.6605967

62. Zharlyganova D., Harada H., Harada Y., Shinkarev S., Zhumadilov Z., Zhunusova A., Tchaizhunusova N.J., Apsalikov K.N., Kemaikin V., Zhumadilov K., Kawano N., Kimura A., Hoshi M. High frequency of AML1/RUNX1 point mutations in radiation-associated myelodysplastic syndrome around Semipalatinsk nuclear test site. *Journal of Radiation Research.* 2008 Sep; 49(5): 549-55. E-pub.

63. Zhumadilov Z. Thyroid nodules in the population living around Semipalatinsk nuclear test site: possible implications for dose-response relationships study. *Journal of radiation research.* 2006, Feb; 47, Suppl A:A183-7.

Контактная информация:

Саимова Айсулу Жумабаевна – Phd-докторант по специальности «Медицина». Государственный Медицинский университет города Семей.

Почтовый адрес: Республика Казахстан, 071400 г. Семей, ул. Абая 103.

E-mail: aisulu626@gmail.com

Телефон: 7 777 7499946