On the Issue of Environmental and Economic Consequences of the Chernobyl and Fukushima Daiichi Nuclear Power Plants and Experience of Them Overcoming

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On the Issue of Environmental and Economic Consequences of the Chernobyl and Fukushima Daiichi Nuclear Power Plants and Experience of Them Overcoming

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A retrospective analysis of the situation after the Chernobyl and Fukushima Daiichi disasters and was carried out. The characteristics and character of the population internal exposure doses forming in remote phase of the Chernobyl accident consequences overcoming were found out. The forecast for the expected effects and ways of their overcoming in the future was provided.

Key Words: Chernobyl, Fukushima Daiichi, environmental and economic effects, internal irradiation dose.

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Introduction

Human and the environment security, their protection from natural and man-caused, social and political dangers relates to state and society special importance issues, and their solutions relate to the national and environmental security priorities. Particular attention should be paid to atomic-industrial complex and nuclear power facilities, creating potential radiation threat to the environment with possible occurrence of radiation and environmental hazards.

After the accident with unacceptable nuclear fuel damage at the Chornobyl NPP the world nuclear community, including Ukraine, has been actively and deeply engaged in fundamental issues of improving the of nuclear plants environmental safety in the direction of modernization and developing of new reactor systems projects ass well as developing of scientifically based symptom-oriented instructions on management of beyond-design and severe accidents. Such instructionsis, in fact, the last level of is deeply phased ecological protection of reactor facility.

Unfortunately, the events related to the Chernobyl and Fukushima Daiichi accidents once again found the limited capacity of NPP projects on emergencies prevention and their consequences overcoming, and, above all, the lack of personnel preparedness to manage such radiation accidents.

Materials and Methods

In terms of theory and methodology this study was based on the fundamental provisions of ecology and environment protection, economy of environmental use and agricultural radiology, highlighted in the works of domestic and foreign scholars. The following methods were used in the work: monographic, systemic and structural, factor analysis, abstract and logical research, etc. The materials of scientifi c researches, international materials and reports and other literary sources on the issues investigated have been used as an information base. Retrospective analysis of sources and state of radioactive ecosystems contamination was conducted.

The internal radiation exposure measuring was conducted using the human radiation counter (LVL) during 2011-2016 years. In order to clarify the characteristics and nature of the population individual internal exposure doses formation the entire array of data has been considered as a statistical set of random variables. The hypothesis of the distribution type was checked by the Pearson consistency criteria.

Results and Discussion

Scientists estimate that the nature of the Fukushima Daiichi and the Chernobyl nuclear incidents are of the same class, i.e. in both cases the shell of the reactor has been destroyed and radioactive isotopes have been released.

According to the IAEA [1], as a result of the Chernobyl incident $14*10^{18}$Bk of radioactivity (about 380 mln Ci) has been released into the air. According to various estimates, the radioactive substances emission period lasted for 10-15 days. Fission and activation products were radioactive isotopes of nearly 200 varieties with different volatility degrees (from inert gases isotopes such as xenon and krypton to plutonium and americium isotopes) and different half-life period: from 20.8 hours for ^{133}I to 376,000 years for ^{242}Ru. Radioactive fallout deposition has taken place not only on the adjacent territories of Ukraine, Belarus and Russia, but almost throughout Europe, especially in the mountainous regions of Scandinavia, the Alps and the Balkans. The Chernobyl accident was the unprecedented tragedy by population exposure doses. The collective effective dose of the population of Ukraine, Belarus and Russia contaminated territories makes 160 thousand. man-sieverts; the global is another extra 135 thousand. man-sieverts. The accident consequences liquidators have received 61 ths. man-sieverts. In 1986 acute radiation sickness was diagnosed for 237 patients, and in 1989 the diagnosis was retrospectively confirmed for another 134 people. The Chernobyl Forum 2006 materials indicates the number of deaths due to radiation as 28 people. Two more people died from injuries received in the accident on the 4th unit and one from a heart attack. Another 42 patients died during the 1987-2012. Those lost lives, unfortunately, are not the only ones in Chernobyl martyrology. Medical statistics recorded an increased frequency of leukemia, thyroid cancer and breast cancer, mortality from cardiovascular diseases, adverse demographic trends on the radioactively contaminated areas. 600 thousand people of military and civilian personnel who worked on the accident consequences elimination received different irradiation doses [2].

Large areas are the lost for a long time for normal economic activity. Dozens of settlements were depopulated and turned into wasteland. Tremendous resources have been spent and being spent still on the accidents consequences overcoming.

Both radiation accident was given the 7th grade on the INES scale. However, the radionuclide composition of Chernobyl emissions was slightly more diverse.

Amount of radioactive ^{131}I ejected in the accident at the Fukushima Daiichi NPP compared with that in Chornobyl does not exceed its one-third, the amount of ^{137}Cs — its quarter, and strontium and plutonium release is of “very small amount”. At the Fukushima Daiichi accident, unlike Chernobyl, radioactive substances spread in the air surface layer and did not reach the ten kilometer height. Therefore they fell at about the 500th km from the NPP. However, the density of the Japan territory contamination in the accident area was higher than in Chernobyl zone. According to official reports, nobody died in an accident, although an information about missing persons lacked in the first days. Obviously, this is because it was difficult to distinguish the victims of natural disasters or man-made disaster after the earthquake and tsunami.

As for the total emission of radioactivity, the joint assessment did not exist originally. According to initial estimates, published with reference to the IRSN, emissions was about 5 mln. Ci [3]. There were other points of view that emissions exceeded the lower limit of Chernobyl emissions estimates and were 60 million Ci [4] caught mainly in the atmosphere and the ocean. Traces of the most radioactively toxic plutonium isotopes (^{238}Pu, ^{239}Pu and ^{240}Pu) have been found only in the soil around NPP [5]. However, the first evaluation could not be accurate because the radioactivity emissions had temporal dynamics. In an official report of independent commission investigating the Fukushima Daiichi accident in Japan parliament found that radioactivity emissions in an equivalent to ^{131}I was "approximately 1/6 from Chernobyl emissions" [6]. The NISA estimates the amount of ^{137}Cs that was released into the atmosphere as equal to 168 Hiroshimas [7]. According to estimates of European scientists, the number of the accident victims may not be limited to the number of people evacuated from the NPP area. According to the ECRR, the number of victims could reach about 420 thousands people for over 50 years [8], and the consequences could be more severe than for Chornobyl. It should be noted that these projections are modeling results and cannot take into account the complexity of the situation and the influence of countervailing factors. Real health consequences will become apparent in the future. In Fukushima Prefecture, following the example Chornobyl, an examination of several million people with dose restoration, clinical and laboratory examination and thyroid gland ultrasound examination were conducted.

Both of these accidents can be called forest-agrarian on a number of characteristics:

1. 70% of the population living in the affected areas are rural residents and agricultural production is the main economic focus of accidents regions. And more

than half of contaminated areas is occupied by forest stands in both cases;

2. Agricultural products received in the radioactively contaminated lands is a major, and perhaps the dominant source of human exposure;

3. As a result of specific “rural” diet type irradiation doses of rural residents significantly exceed those of urban residents;

4. Minimizing the accident consequences in the agricultural sector on the radioactively contaminated areas is a major element of the population radiation safety system and an important factors influencing the agricultural sector.

Despite the vast geographical landscape, technical, social differences between the countries (Table. 1), the formation of the Fukushima Daiichi NPP exclusion zone is largely similar to the processes that took place in the Chernobyl zone in 1986.

Before the Fukushima NPP accident Fukushima Prefecture had been famous for the high level of organic (ecological) farming and had international fame in the area of eco-tourism [9]. The same could be said of the zone of radioactive contamination after ChNPP accident. Chernobyl area had been known for its recreational opportunities before the accident. It was a famous place for recreation, wild mushrooms and berries harvesting, fishing and hunting.

Self-sufficiency of own products for people of the region affected by the accident in Japan is 70% (compared to the rural population of Ukrainian Polissya providing itself with food almost completely).

Average import tariffs on agricultural products by agreements within the WTO for Ukraine and in Japan appears to be equally low, about 12% and 29% respectively. Only 10% of agricultural products have high rates in Japan (rice - 490%, butter - 330%, milk - 200% sugar - 45%). On the other hand, the average rates for the remaining goods (90%) is relatively low, for example, only 3% for most vegetables [10].

Table 1 Comparison of agricultural and socio-economic indicators of Ukraine and Japan

	Japan	Ukraine
Area	78 thousand. κm^2 66% of the area is under forests, mostly in the mountains; 6 mln. hectares are sown	603 thousand. κm^2 38% of the area is under forests; 25-28 mln. hectares are sown
The sown areas structure, %		
grains and legumes	54,5 (mainly rice)	56,6
vegetables	27,2	7,3
forage grass	11,6	8,6
industrial crops	6,7	27,5
Animal Husbandry	pigs, cattle, poultry, sericulture, fishery.	pigs, cattle, sheep, poultry.
Population, mln. people.	128	45,59
GDP (nominal) per capita, USD. USA	42,500	3,867
Soils	podzolic and meadow marsh in the north; brown forest in the south; yellow soils and red in the tropics and subtropics.	sod-podzolic, boggy black and gray forest soils in Polissia; gray and dark gray forest soils, black and meadow-steppe soils in the Forest Steppe; southern ordinary black, dark brown and brown solonetsous soils in Steppe.

Because of the tropical climate of milk production is insignificant. Although the demand for livestock products is growing rapidly. A dairy cattle breeding in Ukraine is quite developed.

The inhabitants of contaminated areas in Ukraine receive up to 95% of ionizing radiation dose due to incorporated radionuclides entering the body with food [11]. For this population the main criterion for deciding whether or not to use food obtained in the region, are acceptable levels of radionuclide content in foods (Tab. 2). When making standards a certain balance between benefit and harm from their use (radiological, economic, social and psychological) is's been taken into account in each State.

Table 2 ^{137}Cs acceptable levels in food products and drinking water in Ukraine and Japan Bq/kg, Bq/l

Food product	Ukraine	Japan
Grain food, cereals	50	100
Bread and bakery products	20	100
Potatoes	60	100
Vegetables (leaves, herbs, roots)	40	100
Fruits	70	100
Meat and meat products	200	100
Fish and fish products	150	100
Milk	100	50
Water	2	10
Fresh growing wild berries and mushrooms	500	100
Dried growing wild berries and mushrooms	2500	100
Special baby foods	40	50

The data shows that Japan has tighter ^{137}Cs concentration acceptable level for fish and seafood. At the same time, ^{137}Cs acceptable levels in vegetables is higher here than in Ukraine. There are no acceptable levels of ^{90}Sr foodstuffs contamination in Japan because of the lack of this radionuclide in radioactive fallout after the accident at the Fukushima Daiichi NPP.

During 2011–2016 scientists of Laboratory of Agricultural and forest ecosystems Radiology of Institute of Agroecology and Environmental Management of NAAS using human radiation counter (LVL) examined more than 15,800 residents of about 170 settlements in 17 districts of Kyiv, Zhytomyr and Chernihiv regions belonging to the second and third radioactive contamination zones. According to examination of Ukrainian Polissya residents in remote period after the Chernobyl accident significant differences in dose rates structure determining depending on

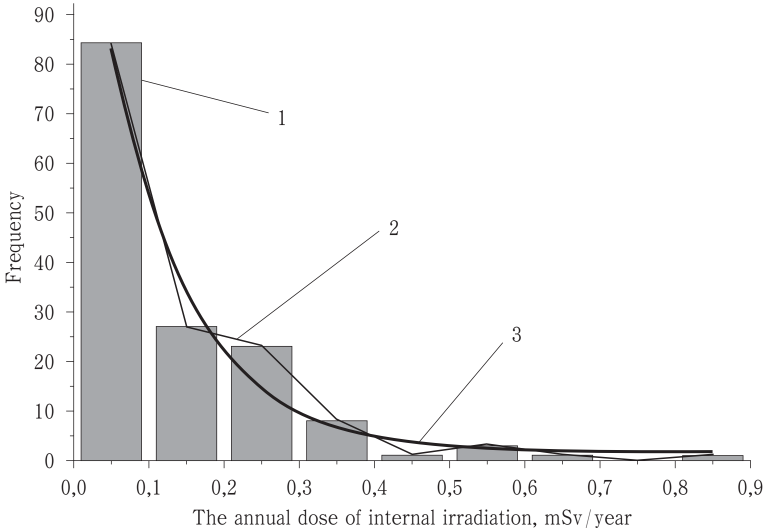

Fig. 1. Graphical interpretation of the internal exposure doses distribution law for the population of Narodychi district, Zhytomyr region:

1 — distribution histogram; 2 — experimental curve; 3 — the exponential distribution law

territorial characteristics were found [12].

In particular, it was found that for the population of distant and relatively small settlements internal exposure doses exponential distribution is inherent. The exponential distribution of experimental data (Fig. 1) shows the ability of such sets to stability in certain conditions. In this case, it might be the economic situation in the region, the population diet features, the radionuclide contamination level of food etc. It is noteworthy that since the 1996 rehabilitation activities in areas affected by the Chernobyl accident, hardly carried out. The local population does not follow the radiation hygiene and security rules for various reasons. Therefore we can assume that the ^{137}Cs and ^{90}Sr specific activity decrease in local origin foods as the main source of internal radiation exposure occurs mainly due to radionuclides physical decay, which are known to be also described exponentially over time. There are reasons to expect the exponential distribution law of individual internal exposure dose of the population in regions affected by the Chernobyl accident in remote period to be typical for many settlements.

For population of relatively large settlements or those located far from major cities, the distribution of internal exposure doses is approximated by normal or lognormal distribution. For instance, the hypothesis are accepted for Gaussian distribution in Borodyanka district (with a probability of 0.39 for Gaussian distribution and 0.11 for log-normal distribution) (Fig. 2). In other words, the probability of Gaussian distribution is three times higher than the log-normal one, but the features of log-normal distribution are still present, indicating the statistical set development ability.

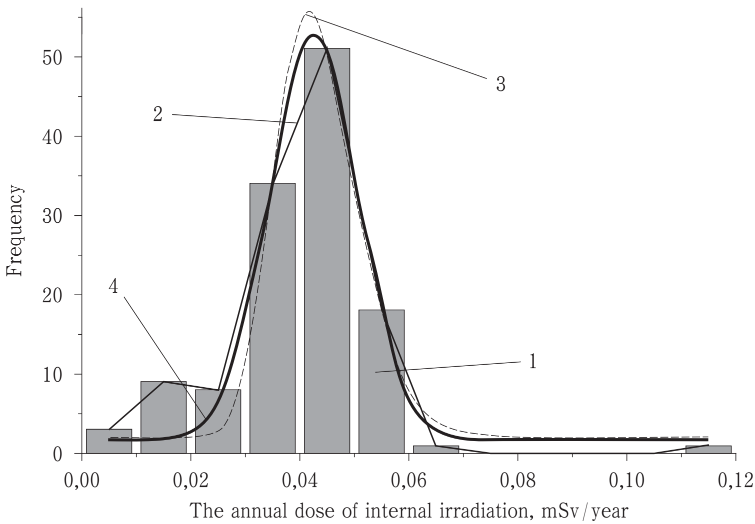

Fig. 2. Graphical interpretation of the internal exposure doses distribution law for the population of Borodyanka district, Kyiv region:

1 — distribution histogram; 2 — experimental curve; 3, 4 — log-normal and normal distribution laws, respectively

We know that statistical sets with normal distribution (Gaussian) are formed as a result of a rather large number of independent (or with little dependence) random variables, subordinated to any distribution law, none of which is dominant. So, it can be assumed that none of the current factors (such as food) does not prevail in the formation of population internal exposure doses in Borodyanka district, Kyiv region. It should be noted that so far in the regions affected by the Chernobyl accident slightly different internal exposure doses distribution pattern was observed, i.e. log-normal [13]. We know that this kind of distribution is formed by multiplicative principle. In other words, unlike a normal distribution among the factors that contributed to the formation of the set, there were those that substantially predominate over others (in particular, it might be some food — growing wild mushrooms, berries, milk), which provided statistical set's ability to change its number.

Thereby the irradiation forming feature been detected is the dependence of internal exposure dose not only on the surface contamination level, but also on the local diet characteristics, and, therefore, on the social and economic characteristics of the region/settlement and even certain family. These circumstances cause the need for further in-depth research.

Radiation accidents cause the serious losses the economy. Accidents have particularly noticeable violated the normal human activity, the environment and agricultural production:

— agricultural and industrial facilities have suffered significant losses;

— forestry and water economy have suffered;

— significant expenditures focused on the evacuation and the accommodation construction for evacuated people;

— considerable resources aimed at the population protecting from radiation exposure directly;

— huge amounts of money focused on production restoring and environment decontamination, social support, compensation of material damage for the population and enterprises, etc.

According to the analysis contained in the National Report of Ukraine "Twenty-five Years after Chornobyl Accident: Safety for the Future" [14], the total value of damage and losses for Ukraine is 198.4 billion US dollars. According to the report, these losses are not exhaustive, since it is impossible to estimate the loss of health, disability and income in the current and future generations affected, future expenditure on the contaminated areas and water rehabilitation, the cost of radioactive waste disposal, object "Shelter" transformation into an environmentally safe system. So with that in mind, the experts believe that overall economic losses of Ukraine Chernobyl disaster reach 232 billion US dollars. Regarding the accident at the Fukushima Daiichi NPP, according to preliminary estimates (for the autumn 2011period) it required about 74 billion US dollars to overcome the consequences of the accident [15]. A more thorough job had been held a year later by TEPCO company. It was found that necessary sum has almost doubled — to 137 billion dollars [16].

Total economic losses have several components:

— Direct losses (loss of infrastructure, housing, machinery and equipment, losses associated with the relocation of victims).

— Direct costs (social protection of victims, research, radiation monitoring, ecological environmental sanitation, etc.).

— Indirect costs (loss of production reducing, unused agricultural and forest land).

In the context of reducing the economic losses associated with the radioactively contaminated agricultural land withdrawal and the shortfall in revenue due to reducing agricultural production, there is an acute need for economic and social use of the affected areas and their partial/complete return to agricultural use.

The process is slightly complicated by a number of reasons, the main ones are:

— natural transformation of the abandoned agricultural land with time (afforestation, logging, degradation of soil fertility, etc.);

— after evacuation of population the infrastructure in these areas was broken (buildings, roads, electricity, drainage systems, etc.).;

— community worries of attempts to use contaminated areas for the any consumer products manufacturing [17].

In terms of radiation situation prevailing in the territories contaminated with radionuclides at the present time, minimization of radionuclides intake into the human body with food is the main criterion for the return agricultural lands into use. Therefore, rehabilitation activities should be directed primarily on the production of food with a minimum radionuclides content.

Conclusions

In both cases, the number one task for the governments of Ukraine and Japan is to preserve the health of population of the affected areas and to provide residents with the ecologically safe food. It is extremely necessary to pay greater attention of doctors to patients who received higher or lower dose since long-term effects of radiation are not well understood yet and this is a potential danger for future generations of Ukrainians and Japanese.

Radiation monitoring of settlements residents allows us to assert that in remote period after the ChNPP accident the nature of the internal exposure dose forming changed somewhat. In previous studies for prevailing majority of settlements logarithmically normal distribution was typical, but now some data sets show signs of exponential and normal distribution types. This distribution indicates a stabilization of conditions that affect the formation of values in the case of the first type of distribution (diet, radioactive contamination levels, social and economic situation, etc.) and the lack the prevailing reasons (their balancing) of data sets forming in the case of the second type of distribution.

Considering the similarity of the nuclear incidents it is advisable to intensify co-operation of relevant scientific institutions of Ukraine and Japan to promote more effective disaster management.

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