Application of Radiation Risks in Assessment of STS Radioactive Contamination Effect to Population

S. Baranov, S. Spiridonov, M. Mukusheva

Abstract—For estimation and prognoses of negative consequences of influence of the nuclear weapon tests for population, living in region of Semipalatinsk Test Site, acceptance of probabilistic methods is necessary including the methods of risk calculations intensively developing now. Use as rate of radiation risks, allows to consider spatial indefinite radiation dose and to define probability of negative effects for the person.

Keywords— Semipalatinsk Test Site, radionuclides, radioactive contamination, geographic informational system (GIS), radiation risks, intervention level.

I. INTRODUCTION

After closure of Semipalatinsk Test Site (STS) neighboring farm units have provided a free access to grazing areas of Semipalatinsk Test Site. There were places of constant residing of the people who are engaged of live-stock gazing.

14 wintering grounds located in radius of 35 km from ground zero were detected at the inspection of “Experimental Field” test site territory. These wintering grounds belong to “Akzharski” collective farm enterprise of Maiski region, Pavlodar Oblast, which is located to the north part of STS. “Taktaikol” wintering ground is one of the resident place of people at STS. This wintering ground is located to the northwest from “Experimental Field” site and is closer to the ground zero of the first nuclear explosion. Beef and dairy products are used for private consumption and for sale. Excess is sold in the neighboring settlements and on the markets of the Semipalatinsk and Kurchatov cities.

Grazing areas of some wintering grounds are located close to the nuclear tests areas (Figure 1) [1]–[3]. People living at the wintering ground and summer pastures, are occupied with grazing of cattle, sheep stock and drove of horses. Farm animals wildly move at the STS area and even enter the Experimental Field site. Radioactive contamination of the site is caused by ground and above-ground nuclear explosions [4]. We should note a number of features of cattle handling in the studied region. All cattle except for dairy cows are outside at the pastures the year round, if weather is favorable in winter.

On the basis of analysis for references, field and laboratory experiments, main ways of pasture ecosystems contamination at STS are revealed and radionuclide are determined which make the most contribution to the additional radiation exposure to population carrying on economic activity in the region. The radiation hazardous territories are determined and the cartographical base territory is prepared to carry out the researches on the basis of topographical map. On the basis of references and monitoring data of the STS territory the character of agricultural production was revised. Schematic maps are constructed for distribution of economic agents, the necessary initial material on characteristics of ecosystems was selected: soil and agrochemical maps, the information about kinds and production techniques, the data about a forage reserve and to diets of feeding of animals, flock structure. Using all available information, evaluation is carried out for actual condition and a prediction is made for possible negative consequences of radioactive contamination to the population of the former STS.

II. INSTRUMENTS AND METHODS

To analyze the specific character of the radionuclide contamination of the former STS makes impossible to determine the degree of hazard for human-being. On the one hand we have a formed pattern of radioactive contamination, and currently, there are no any technogenic sources of additional exposure to the environment. On the other hand, natural factors (dust storms, ground and surface water, other processes and events) may cause redistribution of the contamination and create an emergency situation for separate
regions of the former test site, which recently were considered as almost “clean” and caused no hazard for population. There is one more important point that should be noted – spot nature of STS contamination. With radioecological studies at the test site, local areas are detected with high level of technogenic radionuclide contamination. This is the result of different experiments for nuclear weapon. Non-uniqueness of natural and technogenic factors affecting the life in the region cause a necessity to apply probabilistic evaluation method for the impact to human-being, which the risk calculation method being actively developed is referred to.

Therefore, for accurate evaluation of radioactive contamination impact to the population, it is reasonable to apply radiation risks calculated for population of the Semipalatinsk test site as indexes, which reflect probabilistic nature of negative ionizing radiation consequences. This type of risks can be classified as radioecological as they are caused by radioactive contamination of STS ecosystems.

To evaluate radiation risks for different population categories domiciling the STS and consuming contaminated products, the following steps are completed:

- Identification and analysis of spatial distribution of long-live radionuclide \( ^{137} \text{Cs} \) and \( ^{90} \text{Sr} \) contamination density at horse and sheep grazing area adjacent to Experimental Field site;
- Calculation of internal and external dose for population consuming contaminated agricultural products;
- Evaluation of deterministic and semi-probabilistic risks for different population categories.

Permissible level of additional population exposure at the local STS contamination areas resulted from radioactive fallouts after nuclear tests is considered as the dose criteria. According to the intervention criteria, when local radioactive contamination is detected, protective measures are required to limit population exposure with additional effective dose of over 0.3 mSv/year [5].

Population exposed to radiation is divided into 2 groups:

- Shepherds grazing the live-stock;
- Population living outside the test site area, but consuming the contaminated products.

At carrying out of calculations it was necessary that the population concerning to the 2nd group, are treated to action of an additional radiation only at the expense of the use of production containing the radionuclide.

Farm animal (horses and sheep) are gazed on the sites, adjoin to the “Experimental field” site. The grass areas of “Akzharsky” collective agricultural enterprise (“Taktaikol” wintering ground) are located at the sites.

To the basic characteristics of the radiating factor, making negative impact to the population at contamination of grazing ecosystems by radionuclide, concern:

- The content of radionuclide in animal products
- Accumulated radiation dose at various categories of the population, formed as a result of an internal and external irradiation.

In calculations of external and internal doses the information describing distribution of radioactive substances in soils and calculation data of radionuclide content in livestock production are used.

As risk assessment criterion for population the specifications legislatively confirmed and reflected in corresponding standard documents, accepted in the Republic of Kazakhstan (Radiation Safety Standards and Sanitary-epidemiologic rules and standards) were used [6].

To evaluate radiation factor impact, a dose criterion is used, which represent radiation dose limit values, formed by population additional exposure. Use of dose standard is possible at adequate radiation dose estimations of various categories of population that demands to carry out of calculations on the basis of corresponding dosimeter models.

Based on available information it is effective to examine deterministic and less probability (standard) risks (where only uncertainty technogenic factors is considered) as assessment criterion for population.

Risks of radiation factor effect to population and pasture herbage are evaluated for grazing areas of farm animals (horse and sheep) within the Experimental Field site. As part of the conservatist estimate the most contaminated section is distinguished within grazing area.

It must be emphasized that risks values are calculated in the assumption that all considered categories of the population use farm products (meat and milk), that were took at a grazing of horses and sheep at contaminated territories of STS.

It is supposed that radiation exposure to population living outside of STS is resulted from the consuming of radionuclide contaminated products, without additional external exposure. Food ration which includes milk and meat of horse and sheep is taken the same for different population categories. Values of daily consumption of livestock products were estimated on the basis of the literary data [7].

III. RESULTS

As a result of processing of the raster information characterized by radionuclide contamination of grazing areas of horses and sheep, shares of the areas (from total areas of the specified areas), with various contamination density \( ^{137} \text{Cs} \) and \( ^{90} \text{Sr} \) are received. The average contamination density is \( ^{137} \text{Cs} \) of grazing territories with the centers in “Taktaikol” wintering ground for both modes of grazing are from 12.9 to 29.5 kBq/m\(^2\). Values of similar indicators for \( ^{90} \text{Sr} \) – from 7.6 to 11.9 kBq/m\(^2\).

It is necessary to notice that farm animals can graze at sites with various density of radioactive contamination within grazing areas. The content of long-living radionuclide in soil of these sites can essentially exceed the average content of radioactive substances at the considered area territory. Take into account circumstances the conservative estimate of buildup of radionuclide in farm products and radiation dose on the population is carried out. At realization of such approach it was supposed that sheep and horses are grazed in the most
contaminated sector which territory represents the fourth part of the circle covering an area of grazing.

Dose of internal and external radiation exposure of population living at the STS territory and consuming radionuclide contaminated products is calculated using approaches developed during analysis of consequences of Chernobyl NPP accident [8]. Prediction results for $^{137}$Cs and $^{90}$Sr content in STS grassland ecosystem components, obtained using migration models, are used as input information [9], [10].

Average additional radiation exposure to population, living outside the Semipalatinsk Test Site, is currently within 0.06 - 0.14 mSv/year. With consumption of livestock products having horses and sheep grazed within the most contaminated area, additional radiation exposure is below the intervention level (0.3 mSv/year). Analyzing sources of formation of a total effective dose of an irradiation of various categories of the population, it is necessary to notice that for the population which are not living at STS territory, the additional dose is defined only by an internal irradiation, and for the shepherds living at test site and grazing of livestock at contaminated sites, the contribution of an internal irradiation to a total dose is about 50%.

Shepherds took the maximum doses of radiation (from 0.18 to 0.51 mSv/year) that representing critical group of STS population. Thus, it is possible to conclude that most radiological hazardous situation arises in case of coincidence of three conditions:
- Critical group of the population – shepherds;
- Maximum contaminated site by long-living radionuclide (critical);
- Heavy (all-the-year-round) duty of grazing farm animals.

Dynamic of total radiation exposure to shepherds, grazing horses and sheep at different territories of STS and population living outside the STS and consuming contaminated food is shown in Figure 2. One can see, that shepherds, grazing farm animals at contaminated territories, will receive additional exposure dose which exceeds the standards for about 10 years more.

To assess radiation factor effect to a human-being, Radiation Impact Factors (RIF) are estimated [11] which represent the ratio of radiation exposure, calculated on the basis of weighted average of density for contamination at the territories studied, to critical exposure dose 0.3 mSv/year (Table 1). Upon farm animals grazing conditions within the most contaminated sites RIF values vary within the range of 0.5 (for population, consuming contaminated products), to 1.7 (for shepherds, grazing farm animals).

Values of RIF are actually the values of deterministic risks as risk criterion is the value of additional annual radiation exposure (0.3 mSv/year). Analysis of risk assessment results, performed on the basis of deterministic method enables to conclude, that risk is significant (radiation impact factor is over 1) for critical population category (shepherds), living at the STS in the most radiation hazardous conditions.

Under the evaluation of semi-probability risks – possibility of dose standard excess, distributions of radiation dose for various categories of the population living at territory of test site and consuming contaminated products have been identified. Distributions of radiation doses were described with use of histograms of accumulation, constructed for various sites of grazing territories on the basis of software tools and the databases integrated into geoinformation system (GIS) [12]-[13].

Density of probability of radiation dose distributions on various categories of the population living at STS territory and consuming contaminated products are shown in Figure 4, and values of semi-probability risks are shown in Table 2. It must be emphasized that density of probabilities are identified concerning to grazing areas, with the center corresponding to “Taktakoil” wintering ground or to the most contaminated areas within these areas.

Comparison of deterministic (Table 1) and semi-probabilistic risks (Table 2) shows that these indicators are connected among themselves nonlinearly. As noted above, deterministic risks described by corresponding indexes, calculated without radiation exposure distributions which essentially change depending on radio ecological characteristics of concrete territories. The semi-probabilistic risks representing probabilities of dose criterion excess are more adequate indicators from the point of view of the account of uncertainty of the operating (radiating) factor.

The tables and diagrams are as follows:

**Table 1: Values of Radiation Impact Factors for Various Categories of Population**

<table>
<thead>
<tr>
<th>Grazing territory of farm animals</th>
<th>Population, living outside of STS</th>
<th>Shepherds (all-the-year-round grazing)</th>
</tr>
</thead>
<tbody>
<tr>
<td>&quot;Taktakoil&quot; grazing area</td>
<td>0.2</td>
<td>0.6</td>
</tr>
<tr>
<td>&quot;Taktakoil&quot; contaminated area</td>
<td>0.5</td>
<td>1.7</td>
</tr>
</tbody>
</table>

**Figure 2: Dependence of Additional Effective Dose from Grazing Mode**

[Graph showing dependencies and RIF values as described in the text]
The preferable method of probabilistic index for radioecological assessment is calculation we consider the radiation exposure distribution, characteristics are nonlinearly connected. Since in risk factors for the same population groups shows that these values for different population categories with radiation impact are different comparative assessment. Comparison of standard risk radioecological, represent unified factors applicable for effect.

I is reasonable to apply radiation risks as factors for adequate assessment of STS radioactive contamination effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect. Their application enables to consider spatial uncertainty of radiation exposure and determine probability of a negative effect.

**IV. DISCUSSION AND CONCLUSION**

TABLE 2

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<tr>
<td>“Taktakoil” grazing area</td>
<td>0.05</td>
<td>0.13</td>
</tr>
<tr>
<td>“Taktakoil” contaminated area</td>
<td>0.14</td>
<td>0.46</td>
</tr>
</tbody>
</table>

REFERENCES