Assessment of semistochastic radiation risks for the public and biota within the Semipalatinsk Test Site

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INTRODUCTION

Farming within the Semipalatinsk Test Site (STS) under radioactive contamination generates a need to analyze the radiation impacts for the STS population. Based on a system of models describing $^{137}$Cs and $^{90}$Sr behavior in the STS meadow systems, screening estimations were carried out of the accumulation of these radionuclides in farm products obtained within the STS. The results have demonstrated that when horses and sheep graze the most contaminated sites within testing areas “Balapan” and “Ground Zero”, the concentration of the long-lived radionuclides in the farm products may exceed the limits adopted in Kazakhstan (Spiridonov et al., 2005a). A logical extension of works on the assessment of the STS radioecological situation is dose estimation to the population and risk assessment. Components of pasture ecosystems are permanently exposed to ionizing radiation formed by long-lived radionuclides. Therefore, of great interest is the assessment of radiation risks not only for humans but also for the main component of these ecosystems – herbaceous vegetation.

MATERIALS AND METHODS

By ecological risk we mean a probability of unfavorable impacts of environmental systems contamination by radioactive and toxic chemical substances. The semistochastic method for ecological risk assessment employs probabilistic distribution of the acting factor characteristic. The radiation semistochastic risk is assessed on the basis of data on the distribution of dose burden (or dose rate in chronic exposure) and “point” value of the risk criterion. This method is less information consuming than the stochastic approach to risk assessment the implementation of which requires probabilistic distributions of risk criteria.

In the framework of risk assessment to the STS population consuming contaminated products the following studies were performed:

- identification of grazing areas for horses and sheep within testing areas “Balapan” and “Ground Zero”;
- analysis of spatial distribution of contamination densities by long-lived radionuclides ($^{137}$Cs and $^{90}$Sr) in the grazing areas;
- computation of dose burden distribution for different population cohorts;
- assessment of radiation risks, i.e. probabilities of dose limit exceeding.

As a dose criterion, a permissible level of extra irradiation of the public as a result of radioactive contamination of the STS territory after nuclear tests, 1 mSv/year, was considered.
The exposed population is divided into three groups:

- herdsmen pasturing farm animals;
- STS population;
- population living outside STS but consuming contaminated products.

It was assumed that the population of the third group was exposed to extra radiation only due to consumption of products that contained radionuclides. Farm animals graze the plots adjacent to industrial sites “Balapan” and “Ground Zero”. At these plots there are pastures of collective farms “Chaganskoe” (wintering ground “Atomic Lake”) and “Akzharskoe” (wintering ground “Taktaikol”). The areas of horse and sheep grazing are presented as circles centered at the above wintering grounds. Within the conservative estimation framework, the most contaminated sectors of the grazing areas are identified. In the computations of internal and external exposure of the population, results from prediction of $^{137}$Cs and $^{90}$Sr contents in STS meadow ecosystem components were used as the input data (Spiridonov et al., 2005a; Spiridonov et al., 2005b). Doses of external irradiation of herdsmen were calculated for two grazing variants – year-round grazing and that in the absence of snow cover. To calculate semistochastic risks – probabilities of dose limit exceeding, distributions of dose burdens were identified to various cohorts of the population living within STS and consuming contaminated products. Dose burden distributions were described using superposition of two cumulative functions of gamma-distribution.

For a comparative estimation of the radiation factor effects on humans and non-human biota for the pastures adjacent to the “Balapan” and “Ground Zero” sites, dose burdens to meadow vegetation were calculated. The mathematical description of dose distribution to plants also made use of gamma-distribution functions. As criteria in calculating semistochastic radiation risks for STS meadow vegetation, threshold values of dose burdens to terrestrial plants cited in the literature were used, 400 and 100 µGy/h (A graded Approach..., 2002; Bird et al., 2002). Besides, as a more stringent criterion, screening dose rate resulted in the ERICA Integrated Approach, 10 µGy/h, was considered (D-ERICA, 2007).

RESULTS AND CONCLUSIONS

At the first step, doses to the population were estimated based on the weighted averages of contamination densities by long-lived radionuclides in the grazing areas. Additional dose burdens to the population living outside STS vary between 0.036 and 0.37 mSv/year. It should be noted that even in the case of consumption of animal products derived from horses and sheep grazing the most affected sectors neat “Atomic Lake”, the additional dose burden is not above the adopted limit (1 mSv/year). A similar conclusion can be made for the STS population. For this cohort annual effective doses are 0.073-0.749 mSv. The maximum doses are received by herdsmen, who are a critical group of the STS population. Pasturing of farm animals in the vicinity of “Atomic Lake”, the most contaminated sector, results in the overall annual dose to herdsmen of 1.13–1.47 mSv. In this case the highest dose is received by “year-round” herdsmen. When analyzing sources of the overall effective dose to different cohorts of the public, worth noting that contribution of internal exposure to the total dose varies from 49.5% for the population not involved in animal pasturing to 25.3-32.9% for herdsmen. Table 1 summarizes values of the radiation risks describing probabilities of dose limit exceeding.
Table 1. Probabilities of dose limit (1 mSv/year) exceeding for different population cohorts living within STS and consuming contaminated products

<table>
<thead>
<tr>
<th>Area of farm animals grazing</th>
<th>Population living outside STS</th>
<th>STS population</th>
<th>Herdsmen (year-round grazing)</th>
<th>Herdsmen (excluding winter period)</th>
</tr>
</thead>
<tbody>
<tr>
<td>“Taktakoil”, grazing area</td>
<td>7 10^-4</td>
<td>6,7 10^-3</td>
<td>2,3 10^-2</td>
<td>1,5 10^-2</td>
</tr>
<tr>
<td>“Atomic Lake”, grazing area</td>
<td>9,3 10^-3</td>
<td>1,4 10^-2</td>
<td>3 10^-2</td>
<td>1,9 10^-2</td>
</tr>
<tr>
<td>“Taktakoil”, most</td>
<td>4,2 10^-2</td>
<td>4,7 10^-2</td>
<td>9,3 10^-2</td>
<td>6,6 10^-2</td>
</tr>
<tr>
<td>affected sector</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>“Atomic lake”, most</td>
<td>0,11</td>
<td>0,20</td>
<td>0,34</td>
<td>0,27</td>
</tr>
<tr>
<td>affected sector</td>
<td></td>
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</tr>
</tbody>
</table>

Hence, estimation of exposure levels of various cohorts of STS population consuming contaminated products has shown that dose burdens are in most cases within the adopted limit. It is because the grazing areas include not only sites with high levels of radionuclides in the soil but also large territories with the background levels of radioactive contamination. At the same time the results from the radiation risk analysis suggest that further radioecological studies within STS are necessary. These studies are to be aimed at specification of some parameters influencing dose formation, in particular space and time characteristics of animal grazing regimes.

The values of semistochastic radiation risks for meadow vegetation using 100 and 400 µGy/h as standards are negligible. With a more stringent criterion (10 µGy/h), the risk values range from 2.0 10^-6 to 8.2 10^-4. The highest risk value for meadow plants is reported for the wintering ground “Atomic Lake”. Based on the assessments of semistochastic radiation risks a conclusion is made that ionizing radiation does not influence the STS meadow vegetation. At the same time, at small plots of STS with high densities of radioactive contamination, effects are possible at the subcellular and cellular levels of biological organization. To study these effects, it is advantageous to make use of the method of stochastic radiation risks, considering not only dose burdens distribution but also plant radioresistance.

REFERENCES


