GIS Modelling of Radionuclide Transport from the Semipalatinsk Test Site

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Abstract

In this study, the software complex MigRad (Migration of Radionuclides) was developed, tested and applied for the territory of the Semipalatinsk test site (STS; Republic of Kazakhstan). It is oriented on integration of large volumes of different information (mapping, ground-based, satellite-based survey, and multi-environment and -scale modelling). The MigRad was designed as a tool for comprehensive analysis of complex territorial processes influenced by former nuclear explosions on the STS territory. It provides possibilities in detailed analyses for (i) extensive cartographic material, remote sensing, and field measurements data collected in different level databases; (ii) radionuclide migration with flows; (iii) thermal anomalies caused by explosions and observed on STS and adjacent territories, and (iv) long-range transport of radionuclides with analysis of dynamics.

Introduction

The STS, created in 1947, was used to carry out tests of nuclear weapons. The consequences of such impact turned out to be very serious and will probably reveal themselves over a long period of time. The last test was conducted in Oct 1989, but the level of radiation on STS is still much higher than background values. Due to precipitation, water and wind soil erosion radionuclides are transported and redistributed over the STS territory as well as beyond its boundaries. Therefore, people living in the nearby areas and rather far from it boundaries, consuming vegetable and animal products (which might be contaminated with radionuclides), can obtain an external irradiation and, thus, are always under continuous risk of radioactive pollution.

Semipalatinsk Test Site

TST is situated at the intersection of three administrative regions: Pavlodar, Karaganda, and North-Kazakhstan oblasts, and it is extended from 49°N, 77°E to 51°N, 79.5°E (total area of 18,000 km²). The climate is sharply continental with high daily and annual variations of temperature. Due to existing natural characteristics the main climate is sharply continental with high daily and annual variations of temperature. Overhead and戈 wind the soil erosion radionuclides are transported and redistributed over the STS territory as well as beyond its boundaries. Conversely, the surface temperature before and after explosions. Further studies of such impacts turned out to be very serious and will probably reveal themselves over a long period of time. The last test was conducted in Oct 1989, but the level of radiation on STS is still much higher than background values. Due to precipitation, water and wind soil erosion radionuclides are transported and redistributed over the STS territory as well as beyond its boundaries. Therefore, people living in the nearby areas and rather far from it boundaries, consuming vegetable and animal products (which might be contaminated with radionuclides), can obtain an external irradiation and, thus, are always under continuous risk of radioactive pollution.

Thermal Anomaly

The anomaly high temperature of the underlying surface is one of the factors imposing strong influence on wind erosion formation. It was discovered using remote sensing data (Sultanov et al., 1998; Zakarin et al., 1998). Satellite-based images of the STS territory obtained since 1997 showed clearly outlined hot epizones where temperature by 7–10°C exceeds the average background temperature of the surrounding area. This effect is especially clearly identified at the end of summer – beginning of spring (when snow on STS is melting and soil is frozen). Hence, people living in the nearby areas and rather far from it boundaries, consuming vegetable and animal products (which might be contaminated with radionuclides), can obtain an external irradiation and, thus, are always under continuous risk of radioactive pollution.

GIS Project MigRad

From our point of view the most important processes in terms of their impact on population include transfer of radionuclides by surface waters to the closely-located areas and long-range atmospheric transport of radioactive species from the STS territory to other regions of the Republic of Kazakhstan as well as neighboring countries. The modern way to evaluate abovementioned processes is based on application of the geo-information system (GIS). In our study (Balakay, 2008), development of the GIS oriented project called MigRad (with integration of territorially distributed data from different databases and results of multi-environment and multi-scale modelling and remote sensing methods) was performed including:

- informational modelling for STS area using GIS technologies and remote sensing data;
- modelling of radionuclide migration with surface waters and precipitation/ rain flows causing local redistribution of radioactivity in underlying surface (using RUNOFF; Halih et al., 1984);
- cartographic modelling of wind epicentres carrying radioactive aerosols and considering localization of nuclear test areas, distribution of surface activity of radioactive substances, and repeatability of high temperature areas;
- modelling and analysis of long-range atmospheric transport, dispersion, and deposition of 137Cs from 3 selected locations — Balapan, Delegen, and Experimental Field — within the STS area (using DERMA, Bakanov et al., 2006; Mahura et al., 2005).

Schematics for detection places of maximal probable localization of sources for wind carrying out of aerosols is shown in Fig. 1a. The method is based on assumption that under other equal conditions (vegetation cover, types of soil cover, etc.) the main defining factors are: a) places where testing/ explosions of nuclear devices were conducted; b) distribution of surface activity of radionuclides is calculated for the moment of modelling; and c) repeatability of high temperature zones increasing erosion ability of underlying surface.

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For simplicity, in long-term simulations of radionuclide atmospheric transport, dispersion and deposition patterns we assumed: 1) a point continuous hypothetical release of radioactivity with discrete emitting of puffs; 2) only 1 radionuclide of key importance, 137Cs; 3) simulations on a daily basis considering 10 days of atmospheric transport; 4) simulations covered period from 1 Jan to 31 Dec (years of 1983, 1985, 2000); and 5) calculated parameters included air and time integrated concentration, dry, wet, and total depositions. At post-processing the simulated values were re-scaled depending on erosion ability of soil cover and surface activity of 137Cs in the epicentres of carrying-out of radioactive aerosols (assumption fraction of 137Cs mobile form was equal to 90% in spring-summer; and in autumn-winter – 0, since sources of wind transport are either covered with snow or their soil is frozen).