Land and Informational Approach to the Technological Security of Nuclear Testing Site Economic Use

B Z Akhmetov¹, G A Ustavich², A V Dubrovskiy³

¹Department of Cadastre and Assessment, Kazakh Agro Technical University S. Seyfulina, st. Zhenis 62, Nur-Sultan, Kazakhstan
²Department of Engineering Geodesy and Mine Surveying, Siberian State University of Geosystems and Technologies, ul. Plahotnogo 10, Novosibirsk, 630108, Russia
³Cadastre and Territorial Planning Department, Siberian State University of Geosystems and Technologies, ul. Plahotnogo 10, Novosibirsk, 630108, Russia

E-mail: Zunami89@mail.ru, ystavich@mail.ru, avd5@ssga.ru

Abstract. As of today, nuclear tests are prohibited by the Comprehensive Nuclear-Test-Ban Treaty (CTBT) that was adopted by the 50th session of the UN General Assembly in 1996. However, in the more than 50 years of nuclear testing, more than 2000 nuclear explosions have been carried out on nuclear test sites. Nuclear tests have caused irreversible damage to the local environment, in particular to the nuclear test sites themselves. Most of them have been shut down and have not been used for a long time. Today there have been attempts to use radiation polluted lands for economic purposes. The article explores the practice of topographic and cadastre surveys in the nuclear testing facility at Semipalatinsk. The goal of these measures is a land survey to measure the radioactive pollution and identify possible uses of the land with different degrees of pollution for economic purposes of the residents of the nuclear testing facility and its environs. The article introduces the term "forced land use", which results from the fact that people inhabit territories that have been previously polluted by radiation. The developed land and information approach proposes to divide the area into zones depending on the degree of radioactive contamination and possible types of economic activities. Land survey involves a land mapping that shows the registered amounts of radionuclide. Methods of geoinformation analysis and secondary radioactive contamination distribution simulation are employed to conduct the land survey and establish possible economic uses.

1. Introduction

Today on Earth there are 8 major nuclear testing sites (NTS) with the total area being more than 120 thousand km². Nuclear tests resulted in global radioactive contamination of the territories next the sites. For example, 304 000 km² of the Kazakhstan territory have been contaminated by tests conducted at Semipalatinsk NTS with an area of 18 500 km². In case of ground and surface nuclear tests, quite a large amount of soil and various objects get involved into the explosion and rise to the atmosphere together with radionuclides [1-3]. These radionuclides and contaminated soil particles are transported by air flows at different speed and in different directions. This transportation leaves the so-called "radioactive prints" by about 15 km to 100 km, and they also change their direction depending on air flows. At the same time the level of radioactive contamination of these prints is uneven with some areas being more polluted than others [3]. If there are even some small rivers or brooks in the
way of a radioactive cloud, radionuclides from these radioactive prints settle down on the water surface and then are transported with the flow over huge distances and accumulate in bed deposits. Nuclear tests have not been conducted for 20 years at the site, and the contaminated territories have been slowly drawn back into the land economic turnover. Residents of the Semipalatisnık NTS territory have not been relocated en masse from remote areas even when the site was used [4]. Today the site is used in agriculture, mostly for cattle grazing.

So, modern land survey systems must address the development of land and information approach to ensuring technological security of economic uses of nuclear testing sites.

2. Relevance and scientific importance of a question

Uncontrolled use of NTS lands for economic purposes can lead to a number of negative consequences for the environment and the health of the population. First, the use of lands polluted with radionuclides will inevitably increase the distribution of radioactive elements and result in secondary contamination of surrounding area. The use of such lands in agriculture can cause radionuclides getting into the human body. There is a need for the development of a land survey system to measure territories with radioactive contamination and identifying areas that can be used for certain types of economic activities. From the scientific point of view, a technology for radionuclide contaminated land survey and development of specialised environmental land survey maps that show plots and the relative degree of contamination is relevant.

3. Problem definition

Atmospheric, surface and underground nuclear explosions cause the so-called primary contamination of a territory [5] that happens over a short period of time after the test. Besides the primary contamination, there is also secondary pollution. There is a difference between these two types. Primary contamination affects a large area at a single occasion. The secondary contamination is, first, prolonged with radionuclides being distributed continuously to new non-polluted territories, and, secondly, it can happen many times due to the influence of various factors. To cite an example of such multiple contamination, in 1967 Karachai Lake was polluted as a result of wind-driven distribution. That year the ice surface on the lake reduced by at least two times due to lesser amounts of snow, and as a result the dry radioactive sludge deposits were blown away to the distance of about 50-75 km [5]. This leads to the creation of a man-made landscape [6]. This also allows us to consider the establishment of an emergency geographical space [7] with its borders changing with time. The land and information simulation approaches allow to forecast the migration of radioactive contamination. The main goal of the forecast is to divide the land into zones depending on their technological safety and development of recommendations to involve them into the economic turnover.

4. Theoretical part

The majority of the contamination of territories after a nuclear explosion is caused by the following factors [3]:
- horizontal migration of radionuclides with the wind over long distances;
- horizontal migration of radionuclides from higher grounds to lower grounds with precipitations;
- vertical migration of radionuclides deeper into the soil.

Land and information simulation of land plots uses 3D images. For example, if only daylight surface has been contaminated, then the survey should just register its borders by mapping the characteristic points of this daylight surface. If underground waters have also been polluted, then the borders must be mapped with the characteristic points of this daylight surface and the limits of contaminated border distribution.

Semipalatinsk NTS is specific due to the fact that these areas are used for various economic activities, including agriculture. What is more, the relocation of the residents to others less polluted regions of Kazakhstan was not conducted during the active testing period (unlike in Chernobyl) and has not been done yet. This is why today we propose to apply the term of forced land use to former
NTS and surrounding grounds [8]. The main specific features of the process of forced land use are shown in Figure 1.

**Figure 1. Specific features of forced land use.**

Forced land use is a feature that must be considered during land surveys and land-use planning at NTS and adjacent territories. Forced land use is a type of land use by the population that inhabits a territory with considerable environmental quality disadvantages as a result of man-made or natural impact, including radioactive or chemical contamination. Humans are exposed to radioactivity due to the following reasons [9, 10]:

- external exposure to radionuclides radiating from the soil surface, plants and bushes;
- internal exposure due to inhaling dust-contaminated air as a result of various agricultural, mining and construction activities;
- internal exposure due to inhaling contaminated air during steppe wildfires, dust and snow storms;
- internal exposure caused by the consumption of contaminated vegetable and animal-based food produced in the contaminated territory;
- external exposure due to contaminated soil and water from water bodies and wells coming in contact with the skin.

Under Nuclear Safety Standards 99, the annual effective dosage of man-made radionuclide exposure for the population must not exceed 1 mSv per year [11]. We must say that Semipalatinsk NTS is the only such site in the world with the local population. What is more, the residents use the land for economic purposes. When approaches to land surveys and cadastral value of radionuclide contaminated lands are developed, it is essential to consider the type of forced habitation and stay of humans, including economic uses of the given territory and time limits for human residence, for example [8, 12–15]:

- residency and agricultural activities without residence time limits;
- residency and agricultural activities during limited periods of time;
- residency only without agricultural activities;
- agricultural activities without residency;
- only regular visits to the territory for a bus or truck driver.

5. Practical importance, offers and results of introductions
We have developed a set of topographic, geodesic and land survey measures to conduct a land survey under the Semipalatinsk regulations. The following efforts have been made [14]:

- topographic characteristics have been established (including the lay of the land) for a land plot with a view to further use it;
- a comprehensive radiological research of the environment has been conducted (degree of land surface and underground water contamination of an areas and adjacent territories) [16];
- measures to survey a land plot (including the reconstruction of the borderline, setting border in the field);
- a land survey map showing the regime for every land plot.

The land survey plan should contain the following thematic sections that together help to see the whole picture of possible regimes for using the land plots.

1. Borders of an NTS and adjacent territories and territories of neighbouring countries (if necessary). This section must include the information on the location of a territory or a land plot as regards to the NTS: site borders, administrative districts and rural communities (including adjacent territories). This information is used for forecasting possible secondary contamination, and resulting decrease in the cadastral value of such land plots. At the same time land surveys are conducted using a set of surveying methods and radioactivity control-and-measuring equipment. When there is no borderline, it is essential to reconstruct the surveying and survey control network at NTS [17].

2. Radioactive situation in agricultural and industrial areas. The information is used for the calculation of the cadastral value of an individual land plot.

3. Topographic foundation. It must include relevant space photographs, orthophotomaps of NTS adjacent administrative districts and digital maps and plans with various scales depending on the type of an economic purpose of the plot. The lay of the land is used for forecasting the distribution of radionuclides by surface waters from contaminated to less contaminated areas.

4. Agricultural and industrial activities in adjacent territories. This section contains information on the areas of permanent and temporary economic activities. Communities, wintering and grazing grounds, planned and developed deposits, construction sites of factories and roads must also be marked. Such comprehensive information will allow to establish the cadastral value of land plots depending on the contamination level and economic activities.

5. Water bodies (rivers, brooks, wells and bores) and agricultural lands. As for steppes, information on non-contaminated water bodies will significantly increase the value of land plots and, information on even insignificantly contaminated water bodies will decrease it.

6. Vegetation, including agricultural crops. In case of contamination, this information influences the type of economic activities and the cadastral value of a land plot.

7. Geological characteristics and soil map. This section presents information on the geological structure of a territory, as it impacts the nature and direction of the distribution of contaminated underground waters.

8. Territory Use Regime (permanent and temporal residency).

9. Future development of agricultural and industrial activities in the given territory taking into account the contamination and further contamination migration.

Besides topographical measures, a comprehensive radiological research of the environment has been conducted, including:
- establishment of the general level of radionuclide contamination of a given land plot and, if possible, adjacent areas (to identify the possibility of secondary contamination of the land plot);
- identification of areas with increased contamination level in a territory;
- research of the radionuclide contamination of underground waters;
- selection of the method for reducing the impact of radionuclide exposure.

6. Conclusions
The tested land and information approach to the man-made environment safety of economic uses of NTS using the case of Semipalatinsk NTS allows to carry out controlled, consistent return of the lands into the economic turnover. The main goal is also achieved, as the conditions are created for minimizing the radioactive exposure of the NTS residents. As the degree of contamination caused by man-made and natural factors (for example, wind or agricultural cultivation of lands) changes, the frequency of land surveys and assessments must be adjusted accordingly. The asynchronical results of
the observations form the foundation of the forecast model of contamination migration employing the geographic information and space analysis [18, 19].

References

[1] Morokhov I D 1970 Atomic explosions for peaceful purposes (Moscow: Atomizdat) p 124
[2] Lukashenko S N Strilchuk Yu G and Subbotin S B 2011 Semipalatinsk test site (Kurchatov: Press House) p 47
[3] Mikhailov V N 1997 Nuclear tests of the USSR: goals, general characteristics of the organization of nuclear tests of the USSR (Sarov: SARNII) p 286
[4] Logachev V A 1997 Nuclear tests of the USSR Semipalatinsk test site (Moscow: Publishing House) with 125.
[5] Fokin A D, Lurie A A and Torshin S P 2011 Agricultural Radiology (Moscow: Bustard) p 415
[6] Pytalev I A, Domozhirov D V, Gaponova I V 2019 The Formation of Man-Made Landscape With the Use of Wastes of Mining and Metallurgical Production on the Example of the “Vostochny” (Quarry International science and technology conference "Earth science" IOP Conf. Series: Earth and Environmental Science 272 022179 doi: 10.1088 / 1755-1315 / 272/2/022179)
[7] Karpik A P, Dubrovsyky A V In 2012 Analysis of natural and technogenic features of the emergency geospace (Iterexpo GEO-Siberia-2012 VIII International Scientific Congress, April 10-20 (Novosibirsk: International Scientific Conf. “Geodesy, geoinformatics, cartography, mine surveying”: collection of materials) vol 3 (Novosibirsk: SSGA) pp 171-177
[8] Statutory G A, Dubrovsky A V, Akhmetov B F 2016 Zoning and land surveying of lands adjacent to nuclear testing sites for economic use (on the example of the Semipalatinsk nuclear test site) Bulletin of SSUGiT 4 (Novosibirsk: SSUGiT) pp145-157
[9] Pavlotskaya F I 1974 Migration of radioactive products of global fallout in soils (Moscow: Atomizdat) p 215
[10] Rikhvanov L P 2009 Radioactive elements in the environment (Tomsk: STT) p 430
[11] SanPiN 2.6.1.2523-09 "Radiation Safety Standards NRB-99/2009" (registered with the Ministry of Justice of the Russian Federation on August 14, 2009, registration No 14534) p 120
[12] Lukashenko S N 2010 Radioecological state of the “northern” part of the territory of the Semipalatinsk test site Actual issues of radioecology of Kazakhstan 1 (Kurchatov: Press House) p 234
[13] Aleksakhin R M, Vasiliev A V and Dikarev V G 1991 Agricultural Radioecology (Moscow: Science) p 253
[14] Akhmetov B J 2017 Preparation of a boundary plan in the conditions of soil contamination with radionuclides and mapping of the borders of pollution at a given time (Interexpo GEO-Siberia-2017: Sat materials X International Scientific Congress. Interexpo GEO-Siberia) vol 2 (Novosibirsk: SSUGiT) pp 190-192
[15] Dubrovsky A V 2012 Management of technogenic natural-territorial complexes using spatial data (for example, the Novosibirsk reservoir) Materials of the International Conference, September 18–09, 2012 Innovative technologies for collecting and processing geospatial data for managing natural resources (Almaty: KazNTU named after K.I.Satpayev) pp 263-269
[16] Lurie A A 2007 Agricultural Radiology and Radioecology (Moscow: Moscow Agricultural Academy named after K.A. Timiryazev) p 227
[17] Sholomitskii A, Lagutina E 2019 Design and Preliminary Calculation of the Accuracy of Special Geodetic and Mine Surveying Networks (International science and technology conference "Earth science") IOP Conf. Series: Earth and Environmental Science 272 022010 doi: 10.1088 / 1755-1315 / 272/2/022010
[18] Dubrovsky A V, Antipov I T, Kalenitsky A I 2018 Elements of Geoinformation Support of Natural Resource Management System International Journal of Advanced Biotechnology and Research vol 9 Issue 1 pp 1185-1202
[19] Dubrovsky A 2015 Possibilities of applying geoinformation analysis in solving problems of monitoring and modeling spatial structures *University proceedings. Geodesy and aerial photography* 5 pp 220–224