Environmental mapping of radiation-hazardous areas

M T Abisheva¹², V N Monayenko¹, E P Khlebnikova²

¹Branch “Institute of Radiation Safety and Ecology” RSE NNC RK, 2 Beibyt Atom Str., Kurchatov, 071100, Kazakhstan
²Siberian State University of Geosystems and Technologies, 10 Plakhotnogo Str., Novosibirsk, 630108, Russia

E-mail: Abisheva@nnc.kz

Abstract. The article presents algorithmization of notation design process using computer technologies for environmental maps design. Cartographic models displaying natural resources are considered as an example. The results of model color design based on developed coloristic principles for the adjacent territory in the area of the “Sary-Uzen” test site of the former Semipalatinsk Nuclear Test Site are presented. As a solution of environmental mapping tasks, the authors have shown the possibilities of territories assessment and using the results to create and update thematic layers in the GIS.

1. Introduction

The Semipalatinsk Nuclear Test Site (SNTS) where 456 nuclear tests were conducted using 616 nuclear devices [1], [2], [3], has a large territory (18 300 km²), characterized by relatively low population density and high radionuclide concentrations in selected sites.

Protection of the environment, especially humans, from the effects of residual and secondary radioactivity is the main point in solving the problems of the site. Additional work is required to assess the consequences of the SNTS contamination, followed by the development of recommendations on land use in terms of radiation safety. This needs scientific development and practical implementation of methods and ways to assess the impact of land cover contamination on the population living here.

Under these conditions, the role of radioecological mapping, which aims to develop environmental maps (radiation situation maps), in other words, cartographic works, designed to systematize the accumulated data on radiation situation of specific territories and to determine the most modified territories by people, areas of high risk to human life, etc., becomes relevant and obvious. Usually, these maps display the environmental situation in the studied area, areas of ecological disadvantage, areas of high risk to human life, etc.

The most common environmental maps are those that display:

- general radiation situation;
- soil contamination with both natural and technogenic radionuclides, and with other harmful substances;
- snow cover contamination;
- water quality assessment, etc.

Color scheme is applied to perceive effectively the radiation situation in the studied territory. The efficiency of applying color as the main graphic art is related to the visual perception of cartographic signs. Hence, color scheme for isolines of the isotopes areal distribution (cartographic method) has been developed, and the interval of specific activity of technogenic radionuclides corresponds to the established regulatory indicators in regulatory documents of the Republic of Kazakhstan.
2. Results and Discussion

According to the existing regulatory requirements, data about areas with the technogenic radionuclide activity of more than 300 Bq/kg are known as materials of restricted use (MRU), and the least significant specific activity (LSSA) is at: $^{241}$Am – 1000 Bq/kg, $^{137}$Cs – 1000 Bq/kg, $^{90}$Sr – 100000 Bq/kg, $^{239,240}$Pu – 1000 Bq/kg [4].

Design and creation of isolines color scheme (color scales) for environmental maps of technogenic radionuclides starts after the analysis and assessment of radiation parameters of “background” territory of the former SNTS. Based on radioactive isotopes content in soil, the following level of background global fallout has been recorded: $^{241}$Am – 1 Bq/kg, $^{137}$Cs from 16 to 20 Bq/kg, $^{239,240}$Pu – 5.2 Bq/kg, $^{90}$Sr from 0.9 to 16 Bq/kg [5].

The principle of color scheme is to choose a base color in such a way so that it will promote for a user a clear association of the given color with the essence of the phenomenon being mapped.

Color scheme from green to red (to dark red, in some cases) changing to the orange color, which is best distinguished by human eyes, is used for the best perception. This is especially important when creating environmental (radioecological) maps.

- green – the color of life, inspires calm;
- orange – the color of the warning;
- red – causes people to feel danger.

This color scheme is applied as follows: shades of green are used for up to fivefold of the global background value of the radioactive fallout, above fivefold of the global background value of the radioactive fallout to MRU begins to change from green to yellow-orange colors, values from MRU to LSSA and above changes from orange to red color (Table 1).

| Radionuclides specific activity in soils, Bq/kg | Base color and its name | Coordinates of a base color in the RGB system |
|-----------------------------------------------|-------------------------|-----------------------------------------------|
| $^{241}$Am                                      |                         |                                              |
| <1                                            |                         |                                              |
| 1-2                                           |                         |                                              |
| 2-5                                           |                         |                                              |
| 5-10                                          |                         |                                              |
| 10-30                                         |                         |                                              |
| 30-100                                        |                         |                                              |
| 100-300                                       |                         |                                              |
| 300-1000                                      |                         |                                              |
| >1000                                         |                         |                                              |
| $^{239,240}$Pu                                |                         |                                              |
| <5.2                                          |                         |                                              |
| 5.2-10                                        |                         |                                              |
| 10-25                                         |                         |                                              |
| 25-50                                         |                         |                                              |
| 50-100                                        |                         |                                              |
| 100-200                                       |                         |                                              |
| 200-250                                       |                         |                                              |
| 300-1000                                      |                         |                                              |
| >3000                                         |                         |                                              |
| $^{137}$Cs                                     |                         |                                              |
| <20                                           |                         |                                              |
| 20-40                                         |                         |                                              |
| 40-80                                         |                         |                                              |
| 80-120                                        |                         |                                              |
| 120-200                                       |                         |                                              |
| 200-250                                       |                         |                                              |
| 300-1000                                      |                         |                                              |
| >3000                                         |                         |                                              |
| $^{90}$Sr                                      |                         |                                              |
| <12                                           |                         |                                              |
| 12-25                                         |                         |                                              |
| 25-60                                         |                         |                                              |
| 60-90                                         |                         |                                              |
| 90-150                                        |                         |                                              |
| 150-200                                       |                         |                                              |
| 200-250                                       |                         |                                              |
| 300-1000                                      |                         |                                              |
| >3000                                         |                         |                                              |
| Pale green                                    |                         |                                              |
| Dark sea green 3                              |                         |                                              |
| Dark sea green 2                              |                         |                                              |
| Lemon chiffon                                 |                         |                                              |
| Yucca                                         |                         |                                              |
| Light goldenrod                               |                         |                                              |
| Light salmon                                  |                         |                                              |
| Ochre                                         |                         |                                              |
| Mars red                                      |                         |                                              |

Table 1. Base color choice for the areal contamination with technogenic radionuclides
Among all existing options for presenting data on a map showing the radiation situation in the studied area, isolines and signs are the two most popular mapping methods. The sign method is generally used to visualize single data (point data) and method of mapping with isolines is well suited to visualizing the areal distribution of any contaminants, e.g. radionuclides, both technogenic and natural.

In order to clarify and assess the overall radiation situation in the SNTS territory, a comprehensive survey is being carried out, including sampling of the surface soil layer using a regular net. In the course of laboratory testing of the selected samples, the content of contaminants such as $^{241}$Am, $^{137}$Cs, $^{239+240}$Pu, $^{90}$Sr is determined. These radionuclides are one of the long-lived isotopes that can lead to irreversible consequences if exposed to long-term effects on humans and animals living in the studied area.

Based on the results of laboratory testing of selected samples, maps presenting the radiation situation in the studied area are developed. For example, for visual perception of the areal distribution of technogenic radionuclides $^{241}$Am and $^{137}$Cs in the upper soil layer, maps are designed using the proposed color scheme (Figure 1).

The applied color gradation allows to characterize visually the actual concentrations of the main contaminants in the soil surface layer. According to the data obtained, it can be seen that the main part of the contaminated soil with technogenic radionuclides is concentrated in the south-eastern part of the
territory of the studied area, in the place where the radioactive fallout plume of September 24, 1951 nuclear test occurred.

In addition to the creation of maps of the areal distribution of contaminants using the isoline method, environmental maps displaying the ecological situation using the sign method were also created. For example, maps showing the content of radioactive substances in the surface soil layer, such as $^{239+240}$Pu and $^{90}$Sr were created. This method does not display the general ecological situation in the studied area, but shows an accurate localization of these substances concentration.

![Figure 2. Technogenic radionuclides distribution using sign method a) $^{239+240}$Pu, b) $^{90}$Sr.](image)

When creating these environmental maps, the method of color scheme presented was applied. On these maps, local areas with elevated values can be seen visually, which clearly indicates that the specific activity concentration of the studied radionuclides exceeds the background values. Accordingly, this provides ground for a more detailed survey of the areas with abnormally high values.

3. Conclusion

Accurate and logical design of environmental maps is one of the important stages of their creation. This allows to receive objective and reliable complex information on the general situation of environment of the studied area, and also on spatial differentiation of separate ecological problems in the studied territory and their combination.

The main advantages of forming environmental maps are:
- high information capacity;
- visibility and accessibility to perception;
- the possibility of spatial analysis;
- spatial assessment and prediction capability.

The high information capacity of environmental maps is achieved by improving the cartographic signage system. The application of GIS technologies in the design of cartographic products increases
the visibility, logic and accessibility of maps for direct perception and spatial analysis. For the best perception of the general environmental situation in the studied area, an important role is given to color scheme of this or that phenomenon display.

The development of color gradation was carried out in compliance with the existing regulatory requirements, which allows to characterize the overall radiation situation in the studied area more clearly.

References

[1] Nazarbayev N A, Shkolnik V S, Batyrbekov E G, Berezin S A, Lukashenko S N and Skakov M K 2016 Conducting a Set of Scientific, Technical and Engineering Works to Bring the Former Semipalatinsk Test Site to a Safe State vol 2 (Kurchatov: RSE NNC RK) p 448

[2] Logachev V A 1997 Nuclear Tests of the USSR. Semipalatinsk Training Ground (Moscow: RSE NNC RK) p 347

[3] Yakovenko Yu Yu, Monayenko V N and Abisheva M T 2017 Geoinformation of Identification of Sources of Radioactive Pollution on the Example of the Semipalatinsk Nuclear Test Site Interexpo Geo-Siberia-2017 8 pp 25-32

[4] Hygiene Standards n.d. Available at: https://online.zakon.kz/document/?doc_id=38534553 (Accessed 15 06 2020)

[5] Kashirsky V V, Lukashenko S N, Yakovenko Yu Yu and Romanenko E V 2013 Actual Issues of Radioecology of Kazakhstan vol 2 (Kurchatov: Institute of Radiation Safety and Ecology RSE NNC RK) pp 11–24