Territorial Monitoring for Nuclear Power Plants Using Geoinformation

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Key words: geoinformation solutions, nuclear power plants (NPPs), evacuation plans, digital maps

SUMMARY

The article describes practical experience of providing the situational center with a set of geographic maps of the Russian NPP territories. There are examples of finished products and possible ways of its use when monitoring the territory, the organization of emergency response measures and elimination of the NPPs possible accidents consequences.

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The origin and extension of emergency situations depends on many factors. These factors, in turn, are caused by different objects, processes and phenomena, taking place on the Earth's surface, in geological and space environments [1]. Emergency of catastrophes on a global scale are usually multi-environmental. During a short period of time the emergency geospace (geoenvironment) can undergo significant changes, both qualitatively and quantitatively [2]. Technogenic natural-territorial complexes of NPPs appear to be the areas of possible radiation catastrophe and territories experiencing protracted influence of anthropogenic radiation contamination [3]. Such a dual territories condition requires a particular approach to their use and organization of a continuous monitoring system. One of the elements of the monitoring system is a monitoring subsystem for radiation polluted lands in the area of NPPs.

According to two largest nuclear disasters – on the Chernobyl NPP (USSR, 1986) and Fukushima NPP (Japan, 2011), the governments and emergency services of these countries weren't prepared for catastrophes of such a scale. On-line mapping of radiation situation remains one of the many technical issues while liquidating the accidents consequences at NPPs. Data received from the radioactive contamination monitoring were processed for a long time and their use was not possible because of the absence of geoinformation provision that could meet the requirements of urgency, accessibility and universality in the area of NPP.

The term "geoinformation solutions" denotes the new kind of activity, that is developing on the basis of computer technologies and that is developed to meet economic and social needs in geo-information for a particular territory by means of its collection, modeling of geoenvironment, spatial analysis, preparation of spatial solutions, integration and dissemination by means of GISs [4].

Up-to-date development of GIS technology allows carrying out various types of thematic digital mapping projects. The government policy is oriented to early warning of crisis management, that's why the development for modeling, analysis and prevention of emergency situations is very urgent.

Up-to-date means of spatial data acquisition contribute greatly to the development in this field. First of all, they space mapping systems and various sensors, including those integrated with the technologies of global navigation satellite systems (GNSS) that are used for monitoring the health of industrial facilities and the condition of natural objects.

Geoinformation solutions for crisis management can be divided into three main types [5]:

- timely and dynamically changing monitoring data of spatial objects condition;
- predictive spatial analytical models that describe various scenarios of crisis situations and elimination of their consequences;
- statistical spatial-situational models of crisis management.

While organizing crisis management of industrial objects of a high hazard level, such as NPP, these types of geoinformation solutions are used.

The continuous space monitoring of an object and the neighboring territory condition is provided in a dynamic mode. Sensor-based mapping systems, including GNSS, provide control of the object geometric characteristics. Up-to-date robotized electronic total stations with GLONASS/GPS enable to monitor the condition of objects and pick up the slightest changes of their spatial characteristics. The Automated System for Monitoring Radiation Situation (ASKRO) in constant stream mode provides the information about the radiation level.

Predictive spatial analytical models describe various scenarios of crisis situations. Thus, it is important to create the most complete list of situation development options and its possible consequences. Different mathematical models and analytical data on earlier crises are used to fulfill these tasks. As a rule, these models created are ranked in accordance with the possibility of their origin and the amount of damage, etc. [6, 7]. Received data from ASKRO enable to approximately assess the land condition pollution.

The third type of geoinformation solutions for crisis management (that is statistical spatial-situational models) is based on the created emergencies scenarios. These models of a generalized character serve for efficient crisis management when they emerge. As an example, the simplest situational models are the plans of people evacuation of from buildings, and the more complicated plans are those of population evacuation from the regions affected by radioactive contamination in case of accidents at NPPs), figure 1.

The peculiarities of this plan are the following:

- combined representation of thematic symbols and digital topographic map on the territory integrated territory plan ;
- the fragment of a digital map limited by 100 kilometers zone around NPP that is used as a topographic substrate. Territories of several regions of the Russian Federation may belong to this zone. Foreign territories can be shown on a map if necessary;
- all thematic information without any generalization is plotted on the evacuation plan;
- except the main evacuation plan of scale 1:100,000, the industrial zone of NPP and the residential area near the station are shown in the form of insert maps in a larger scale. To compile insert maps, satellite images or airphotoplans of high resolution can be used.

The following results have been achieved:

- digital maps (in vector form) of ten Russian NPPs locations of scale 1:200000 and 1:100000 (respectively 100 and 30 km area) can be published in GIS MapInfo format;
- separate thematic map layers of 10 Russian NPPs that are used for planning and carrying out measures to eliminate accidents consequences at nuclear power plants have been prepared;
- electronic layouts of 100 and 30 km area near Russian NPPs are prepared on the basis of digital maps and separate thematic layers;
- rigid map tablets in the amount of 40 pieces, representing NPPs locations of scale 1:200,000 and 1:100,000 (respectively 100 and 30 km area) have been made;

- four map-cases and six wall sets for hanging tablets have been made.

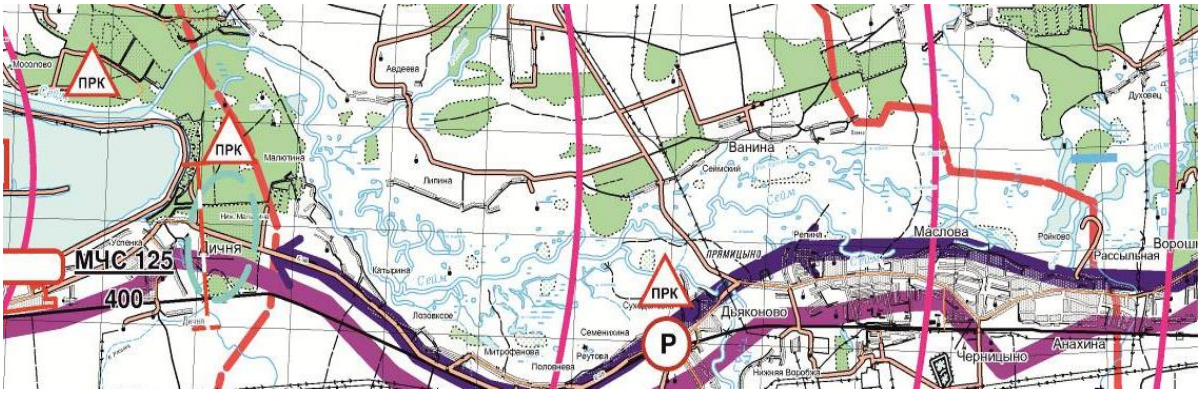

Figure 1 – Fragment of digital evacuation plan from NPP area

Evacuation plans were introduced at the situation center. Metal-base evacuation plans nowadays represent the key element of the emergency management center's technological infrastructure, Fig.2.

Figure 2 – Wall maps in the emergency operations center.

The digital plans of NPPs area can be used while conducting geoinformation analysis and modeling, for the following:

- to interpolate the contamination according to ASKRO sensors data (fig. 1,a);
- to detect automatically the number of polluted settlements and their citizens in the constructed buffer zone (fig. 3, b);
- to model radiation contamination depending on the wind speed and its direction (fig. 3, c);
- to generate reports for evacuation echelons routes (fig. 3, c) [6];
- on-line updating the evacuation plans.

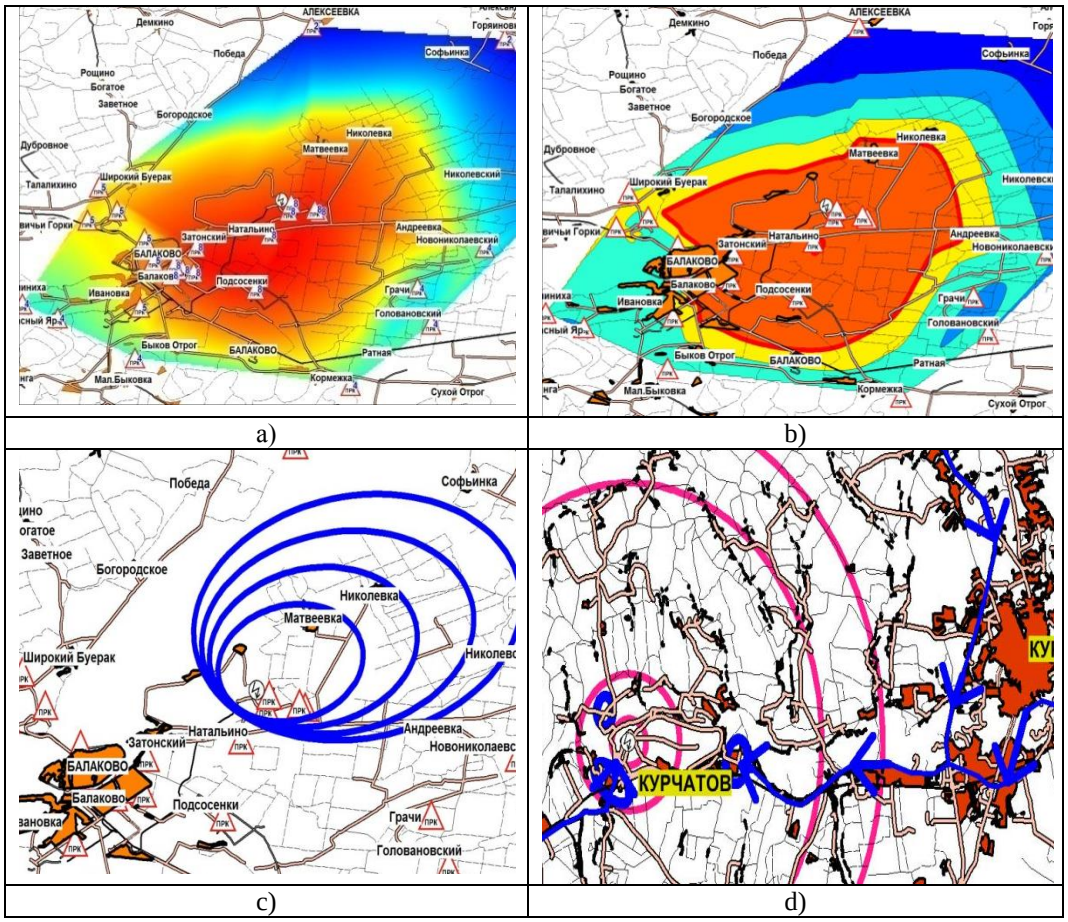

Figure 3 – Examples of GIS analysis and modeling with digital evacuation plans of NPP area: a - interpolation of contamination according to ASKRO sensors data ; b - construction of polluted buffer zone; c - modeling of radiation contamination depending on the wind speed and its direction; d – reports generation of evacuation echelons routes.

GIS technology for territory monitoring near NPPs represents a complex system of interacting elements. The geoinformation land monitoring in the area of NPP except for its main functions: "monitoring, analysis, forecast and management" [8], has some peculiarities:

- it controls the radiation situation in the area of NPP, which is part of a unified state environmental monitoring system (USEMS) ;
- monitoring faces some problems connected with negative factors of radiation contamination;
- borders of the monitoring zone coincide with those of emergency situation geoenvironment and they change dynamically due to the degree of radiation influence of various factors;
- the life and health of people who don't only live in the region monitored , but also use food produced in this region depends on the efficiency and reliability of land monitoring data;
- geoinformation basis of land monitoring must contain the systematized complex of the region (territory) data about various groups of spatial objects, processes and phenomena;
- the effectiveness of the monitoring depends on the information exchange

comprehensiveness between the land monitoring system and the monitoring systems controlling the condition of such environments as water, air, geological.

Fig. 4 shows the enlarged scheme of geoinformtion monitoring in the area of NPPs.

The fully-functional system of GIS collection, representation, analysis and predictive modeling with the ability of transferring the received data to the competent services and agencies to control the situation must be a basic component of the monitoring system in the area of NPPs.

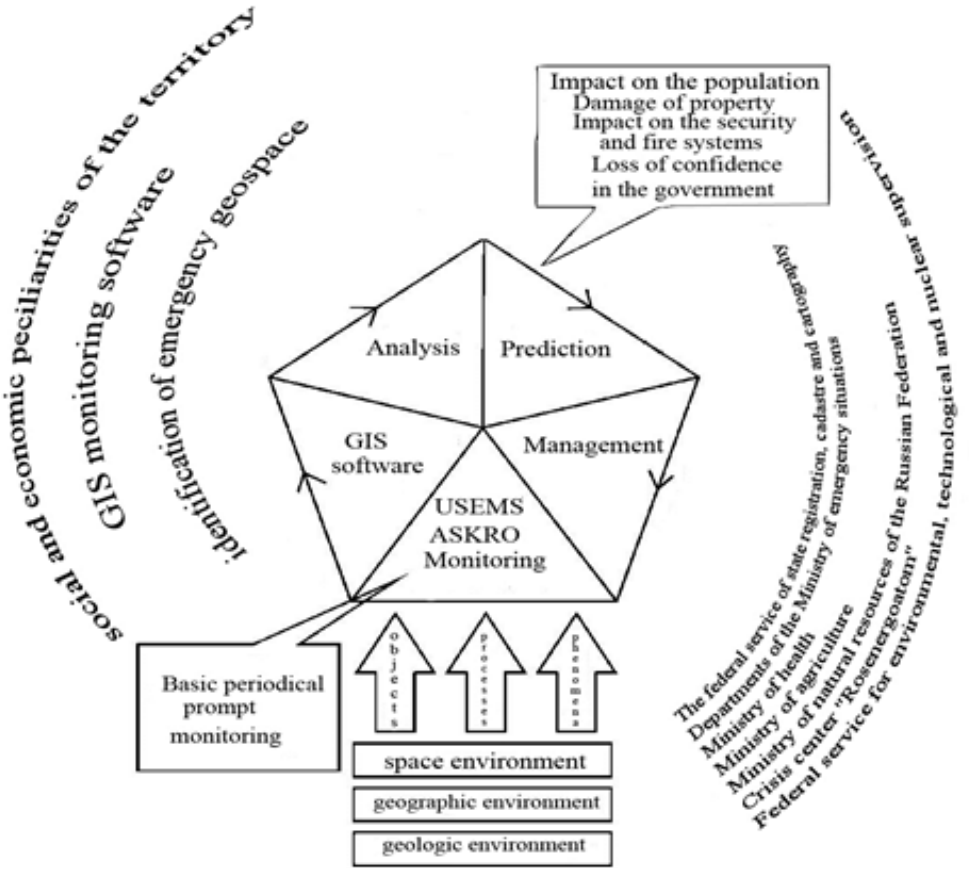

Figure 4 – Generalized scheme of GIS monitoring in the area of NPPs

Thus, the basic principles of geoinformation solutions for the NPPs safe maintenance are the following:

- to create the network of active base stations to organize high-precision satellite positioning system, to increase the accuracy of geodetic measurements and to control the NPP technological fcilities;
- to develop and introduce the high-precision coordinate system of NPP;
- to create the unified GIS basis in the area of NPP, including large-scale digital plans of NPP industrial site and the residential area near the station (the scale is 1:100 - 1:1 000);

digital maps of a sanitary protection zone (at scale 1:10,000); digital maps of 30 km monitoring zone (at scale 1:100, 000); digital maps of 100 km evacuation zone (at scale 1:200,000) [9];

- to create spatial 3D models of technological objects and the machinery at NPPs that are digitally integrated into unified GIS basis (environment) of a given territory;
- to create the complex monitoring system of the area near NPP, including geodetic monitoring system, hydrometeorological observations, automated system of radiation control, the environmental control system. Information received from various sensors must have a coordinate referencing and is to be integrated into the unified GIS basis of a given territory;
- to develop the mobile navigation software to solve the problems of emergency response, navigation, mapping the NPP territory, the increase of geodetic measurements accuracy;
- to introduce the GIS and create the automated workstations (AW) in the departments of NPP office, situation center, Municipal Bodies administration of NPP area, Civil Defense and Emergencies divisions;
- computer simulation modeling of probable emergencies scenarios of natural and technogenic character;
- to develop catastrophe (accident) – prevention plans and evacuation measures with a GIS application.

Fig. 5 shows the interaction scheme of basic principles of geoinformation solutions for the NPPs safe maintenance.

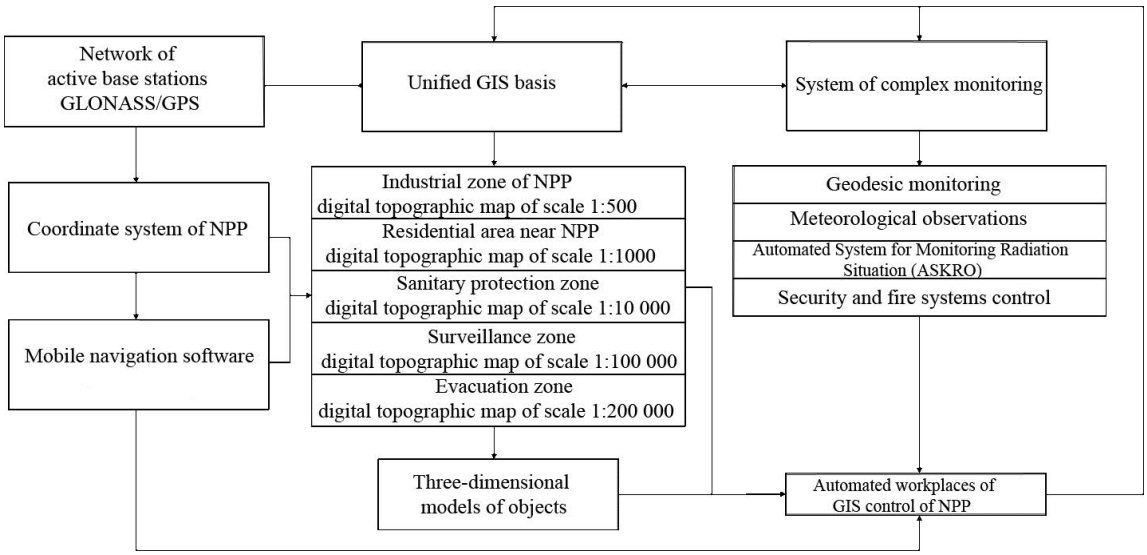

Figure 5 – Interaction scheme of basic principles of geoinformation solutions for the NPPs safe maintenance.

Specialists from the Siberian State Academy of Geodesy (SSGA) have developed methodological and technological approaches to realize basic principles of geoinformation solutions for the NPPs mentioned above. Our developments in the field of geoinformation

solutions have been tested and successfully implemented in a complex of works carried out at the Leningrad, Kursk, Beloyarsk NPPs. Geoinformation solutions for catastrophe (accident) – prevention plans and evacuation measures developed by our specialists is nowadays widely used at all Russian NPPs.

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