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APPLICATION OF GEOINFORMATION TECHNOLOGIES TO MODEL THE RADIATION SITUATION AND SUPPORT EMERGENCY RESCUE OPERATIONS DURING ACCIDENTS AT NUCLEAR POWER PLANTS

Abstract. This paper examines the use of geographic information systems in assessing the radiation situation, developing measures to protect the population, and organizing emergency rescue operations during accidents at nuclear power plants. It is demonstrated that the use of geographic information systems allows for a clear representation of accident consequences, predicting the spread of radioactive substances, and facilitating decision-making under time constraints. It is also noted that integrating various data (maps, contamination models, population information) facilitates a more rapid response to emergencies and reduces risks to people and rescue services.

Keywords: radiation situation, radioactive contamination, population protection, emergency rescue operations, emergencies, modeling, radiation safety, risk management.

Introduction. Modern energy is largely based on the use of organic and nuclear fuels. Despite the high efficiency of nuclear energy, accidents at nuclear power plants are accompanied by the release of radioactive substances, posing a serious threat to the population and the environment. The spread of the radioactive cloud depends on meteorological conditions and can lead to large-scale contamination of territories and radiation exposure. In emergency situations, prompt decision-making aimed at protecting the population and organizing emergency rescue operations is crucial. This requires processing significant volumes of information in a short time, which is impossible without the use of modern information technologies.

The primary energy source currently is organic fuels (coal, oil, natural gas), followed equally by hydropower and nuclear fuel. The generation of nuclear energy in nuclear power reactors at nuclear power plants is accompanied by the accumulation of radioactive substances, which pose a significant danger to the population and the environment. Radioactive substances emitted from the damaged reactor in the form of gases, vapors, and aerosols form a cloud that, spreading downwind, causes radioactive contamination of the environment and leads to radiation injuries to the population. This paper presents calculations to assess the radiation situation during the destruction of a nuclear power reactor and determines the feasibility of using new information technologies to prevent accidents at nuclear power plants [1].

Information support for emergency prevention and response measures involves processing large amounts of information, resulting in decision-making and the adoption of specific measures. Time is an important factor when assessing the situation and deciding on emergency rescue operations.

The use of modern information technologies can significantly reduce the time required to obtain and prepare data, greatly simplifying the decision-making process.

Modern information technologies offer extensive capabilities for presenting and processing data using electronic maps.

Electronic maps and plans can eliminate redundant information, which is often unnecessary, and allow for quick adjustments to the situation while simultaneously automating the emergency management process.

To determine the impact of radioactive contamination of the terrain and the ground layer of the atmosphere on the lives of the population and the conditions for rescue and other emergency operations in contaminated areas, the radiation situation is identified and assessed.

The use of geographic information systems (GIS) technologies for monitoring NPP safety will allow a visual representation of a potential emergency.

Visualization of monitoring results will provide:

- a clear representation of the facility's status and an assessment of the hazard of an NPP event by level (IAEA scale);
- a physical map of the area where the NPP is located and the formation of zones of potential radioactive contamination, taking into account the influence of local conditions (meteorological data, terrain, etc.);
- the ability to perform calculations (in text or graphic form) for any facility represented on the diagram over a wide range of scales and with any level of detail;
- determine the routes and methods for conducting emergency rescue and other urgent operations and their scope;
- calculate the deployment of RSChS forces and resources to eliminate the consequences of an emergency;
- calculate the permissible time for all types of work by civil defense units in the contaminated area, taking into account the radiation level;
- identify settlements and economic facilities that will be in the radioactive contamination zone and measures to prevent or reduce their exposure to radioactive radiation;
- define a set of measures to protect the population and territories from the harmful effects of radioactive exposure;
- identify categories of the population located in the radioactively contaminated zone that require shelter in protective structures, urgent evacuation, iodine prophylaxis for the thyroid gland, etc.;
- identify zones of radioactive contamination where radiation levels for a certain period after the accident exceed the maximum permissible level for habitation in the area;
- display and manage all of the above actions on an electronic map.

Having detailed information in the geographic information system at the initial stage of an emergency will enable emergency services and the manager to make informed decisions regarding rescue operations and mitigation. Displaying the progress of the entire ASDRMS system dynamically on the electronic map will make monitoring and adjusting decisions more realistic and timely.

The calculation of measures to protect the population as a result of an emergency at a nuclear power plant was carried out using the AGZ training manual "Methodology for Assessing the Radiation Situation During the Destruction of a Nuclear Power Reactor at a Nuclear Power Plant," Novogorsk, 1995 [2].

At 2:00 PM on April 1, as a result of an accident at the Udomlya Nuclear Power Plant in Tver Oblast, the VVER-1000 nuclear power reactor was destroyed, destroying the power unit, releasing radioactive substances into the atmosphere, and contaminating the area.

According to meteorological data, the wind speed at the vane height (10 m) is $U_0 = 5$ m/s, wind direction is $\varphi = 90^\circ$ (southeast), the weather is clear, the air temperature is $t_v = 10^\circ \text{C}$, and the degree of vertical stability of the atmosphere is isothermal.

1. Length of the radioactive contamination zone is L_x
2. The width of the zone is calculated using the formula:

$$L_y = a \times L_x \quad (1)$$

where a is a coefficient depending on the degree of vertical stability $a = 0.6$.

3. The area of radioactive contamination zones is calculated using the formula:

$$S = 0,8 \times L_x \times L_y, \text{km}^2 \quad (2)$$

The radiation level in the area after the passage of the radioactive cloud, moving in a northwesterly direction, is 500 mSv/h (50 rad/h) - zone A (Fig. 1). The dimensions of this zone are: length - 44 km from the nuclear power reactor, width - 2.6 km, and a total area of 93.2 km².

According to the basic provisions of radiation safety standards (NRB-99), the entire population is urgently evacuated from this zone, with mandatory iodine prophylaxis for the thyroid gland [2].

The dimensions of zone B (Figure 1), where the radiation level is 100 mSv/h (10 rad/h), are: length - 180 km, width - 10.8 km, area - 1555.2 km². The town of Rameshki falls within this zone.

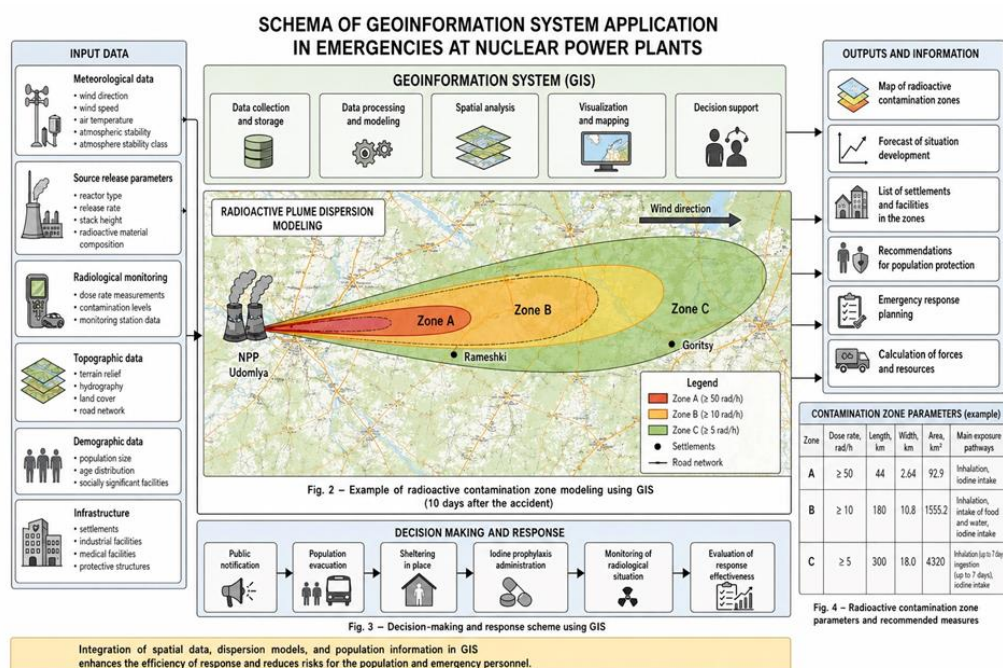


Figure 1 – Calculation of activities

An analysis of the calculations revealed that the following measures must be taken in the town of Rameshki:

1. Evacuate the population outside shelters (in open areas), pregnant women, and children, with mandatory iodine prophylaxis.
2. Evacuate pregnant women and children sheltering in the basements of single-story wooden houses.

Zone B (Figure 1), where the radiation level is 50 mSv/h, covers an area 300 km long, 18 km wide, and has a total area of 4,320 km². The town of Goritsy is located within this zone.

An analysis of the calculations revealed that the following measures must be taken in the town of Goritsy:

1. All rescue and other emergency operations in the town of Goritsy are carried out only with the use of respiratory and skin protection.
2. Populations outside shelters for more than 7 days must be placed in shelters and given iodine prophylaxis for their thyroid gland.
3. Pregnant women and children are temporarily relocated outside Zone B and receive iodine prophylaxis for their thyroid gland.

Assessing the radiation situation is an important step in planning public protection measures and organizing emergency rescue operations. It includes determining the size of radioactively contaminated zones, radiation levels, and possible consequences for the population and economic facilities [3].

The use of geographic information systems can significantly improve the effectiveness of analysis and management in emergency situations [4]. Electronic maps make it possible to display the spatial distribution of radiation contamination, taking into account terrain, meteorological conditions, and population density.

GIS technologies provide:

1. Visualization of radioactively contaminated zones;
2. Modeling the spread of the radioactive cloud;
3. Identification of populated areas within the impact zone;
4. Planning evacuation routes;
5. Calculation of the forces and resources required for emergency rescue operations;
6. Determination of the permissible time of personnel stay in the contaminated zone.

Of particular importance is the ability to quickly update data and display emergency situation dynamics in near real time. This allows for timely adjustments to decisions and improves the efficiency of resource management.

The use of GIS also facilitates the integration of various information sources, including radiation monitoring data, demographic characteristics, and the area's infrastructure. This ensures a comprehensive approach to situational assessment and decision-making.

Table 1 – Activities carried out in predicted radioactive contamination zones

Name of zone	Events held	Predicted radiation dose, rad/h	Size of zone		
			L _x , km	L _y , km	S, km ²
A	- evacuation of the population; - iodine prophylaxis of the thyroid gland.	50	44	2,64	92,9
Б	- evacuation of children and pregnant women; - evacuation of adults outside shelters; - iodine prophylaxis for thyroid gland	10	180	10,8	1555,2
В	- use of respiratory and skin protection during emergency response and other work; - shelter for people in open areas for more than 7 days; - resettlement of children and pregnant women outside the zone; - providing iodine therapy for the thyroid gland.	5	300	18	4320

Conclusion

The calculations conducted have shown that a nuclear power plant accident raises numerous challenges related to rescue, emergency recovery, and protective operations in high-radiation zones, posing risks to life and health. Moreover, measures to protect the population are of paramount importance and require prompt action.

In my opinion, the use of GIS technologies will enable management bodies and the management of potentially hazardous economic facilities to implement measures to promptly prevent and avert emergency situations, and, if they do occur, organize emergency rescue and recovery operations in the emergency zone.

The rationale for using information technology to ensure the safety of economic facilities is that new technologies provide the most universal approach to integrating the most diverse information and provide the most direct and intuitive way to search for diverse information in databases, significantly reducing the time it takes to make management decisions and increasing the likelihood of saving lives and reducing material losses.

When planning and implementing a set of protective measures, starting from the time an emergency situation is declared at the station, it is necessary to take into account local conditions and the capabilities of emergency response forces and means in each specific case.

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АЭС АПАТТАРЫ КЕЗІНДЕ РАДИАЦИЯЛЫҚ ЖАҒДАЙДЫ МОДЕЛЬДЕУ ЖӘНЕ АВАРИЯЛЫҚ-ҚҰТҚАРУ ОПЕРАЦИЯЛАРЫН ҚОЛДАУ ҮШІН ГЕОАҚПАРАТТЫҚ ТЕХНОЛОГИЯЛАРДЫ ҚОЛДАНУ

Аңдатпа. Бұл жұмыста радиациялық жағдайды бағалау, халықты қорғау шараларын әзірлеу және атом электр станцияларындағы авариялар кезінде авариялық-құтқару жұмыстарын ұйымдастыру кезінде геоақпараттық жүйелерді қолдану қарастырылады. Геоақпараттық жүйелерді қолдану апаттың салдарын көрнекі түрде көрсетуге, радиоактивті заттардың таралуын болжауға және шектеулі уақыт жағдайында шешім қабылдауға көмектесуге мүмкіндік беретіні көрсетілген. Сондай-ақ, әртүрлі деректерді (карталар, ластану үлгілері, халық туралы ақпарат) біріктіру төтенше жағдайға тезірек жауап беруге және адамдар мен құтқару қызметтері үшін тәуекелдерді азайтуға көмектесетіні атап өтілді.

Түйінді сөздер: радиациялық жағдай, радиоактивті ластану, халықты қорғау, авариялық-құтқару операциялары, төтенше жағдайлар, модельдеу, радиациялық қауіпсіздік, тәуекелдерді басқару.

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ПРИМЕНЕНИЕ ГЕОИНФОРМАЦИОННЫХ ТЕХНОЛОГИЙ ДЛЯ МОДЕЛИРОВАНИЯ РАДИАЦИОННОЙ ОБСТАНОВКИ И ПОДДЕРЖКИ АВАРИЙНО-СПАСАТЕЛЬНЫХ ОПЕРАЦИЙ ПРИ АВАРИЯХ НА АЭС

Аннотация. В данной работе рассматривается применение геоинформационных систем при оценке радиационной обстановки, разработке мер по защите населения и организации аварийно-спасательных работ при авариях на атомных электростанциях. Показано, что использование геоинформационных систем позволяет наглядно отобразить последствия аварии, спрогнозировать распространение радиоактивных веществ и помочь в принятии решений в условиях ограниченного времени. Также отмечается, что объединение различных данных (карты, модели загрязнения, информация о населении) помогает быстрее реагировать на чрезвычайную ситуацию и снижать риски для людей и спасательных служб.

Ключевые слова: радиационная обстановка, радиоактивное загрязнение, защита населения, аварийно-спасательные операции, чрезвычайные ситуации, моделирование, радиационная безопасность, управление рисками.

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