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Gamma-background radiation control systems as a factor of Bulgaria's national security

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***Abstract*. The sources of ionizing radiation and nuclear facilities on the territory of Bulgaria may cause a change in the radiation gamma background in the event of an accident or accident. With the conduct of military operations on the territory of Ukraine and in the Middle East, this danger should not be underestimated.**

Already in the 90s of the last centuries, systems for monitoring the radiation background were being built in Bulgaria for various ministries and departments. The report reviews some of these systems, analyzes their positive and negative sides, and makes recommendations for improving their functioning and optimizing the submitted data.

Keywords: automated system, gamma radiation background, monitoring station, radiation, national security, probe characteristics, values.

I. INTRODUCTION

After the major accident at the Chernobyl nuclear power plant, located on the territory of the current Ukraine, and then in the USSR, in April 1986, in Bulgaria, as well as in most European countries, the lack of systems for continuous measurement of the radiation gamma background was reported, to provide reliable information in real time about the radiation status [1], [2], [3], [4]. In the second half of the twentieth century, the use of sources of ionizing radiation expanded significantly - nuclear power plants were built, medical diagnostics expanded, and radiation using these rays also entered industry. But the Chernobyl accident became a prerequisite for monitoring the use of ionizing radiation and controlling environmental pollution with such radiation. As a result, in the countries of Europe and around the world, the construction of automated systems for continuous monitoring of the gamma-background radiation and their integration into national security and their connection in various international networks have begun [5], [6].

In Bulgaria, the construction of the National Automated System for Continuous Control of the Radiation Range - background in the Republic of Bulgaria (BULRaMo) also began in 1992 by the German company "Hormann" - GmbH. In 1997, it was put into operation in accordance with the Ordinance on the Construction, Operation and Development of the National Automated System for Continuous Control of the Radiation Gamma Background in the Republic of Bulgaria - PMS No. 434/19.11.1997. The department responsible for building and maintaining the system is the Ministry of Environment and Water (MOEW) through the Environmental Executive Agency (EAOS), with financial resources under the PHARE program [7], [8]. The built control system covers the territory of Bulgaria and is the only national network. There are such systems built for other ministries and departments, but they are not intended for use by the entire population and have to solve specific tasks - there are such systems built for the Ministry of Défense, the Ministry of Internal Affairs, the former already Civil Defense and others.

II. MATERIALS AND METHODS

The main purpose of this national real-time radiation control system is:

- Continuous monitoring and monitoring of the gamma-background radiation level on the territory of the entire country and the storage of the obtained information in a national database, with the monitoring points selected based on the availability of such objects, the availability of resources, population density and others.
- Early disclosure in the event of an increase in the level of gamma-background radiation as a result of an accident of a different category with radiation pollution of the environment or a conflict with the use of nuclear weapons on the territory of Bulgaria or in its vicinity.
- Submission of operational information to the relevant state bodies responsible for the radiation situation in Bulgaria and making the relevant decisions.
- Submission of operational information to the European Radiological Data Exchange System

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(EURDEP), the Agency for the Use of Nuclear Energy for Peaceful Purposes (IAEA) and other organizations with which Bulgaria has data exchange [9].

In 1997, the work of the National Automated System for Continuous Gamma-Background Radiation Monitoring (BULRAMO) under the Ministry of Environment and Water began.

In 1999, all Local Monitoring Stations (LMS) on the territory of Bulgaria were finally launched and included in the system for autonomous operation in online mode.

In 1999, the Automated Information System for External Radiation Control of the Kozloduy NPP was integrated into BULRAMO, which expanded the range of radiation gamma-background monitoring with another 8 LMS in the area of the Kozloduy NPP, where two power units operate of the water-water energy reactor type VVER-1000 [10].

In the same year, the Central Station (CS) software was successfully upgraded to run under Microsoft Windows 2000 Server and Microsoft SQL 2000 Server, due to their better qualities than the previous operating system [1], [10].

After the expiration of the warranty service in 2001, the post-warranty service of BULRAMO started, as the company "PROSERVIS NT" Ltd. has built a service base for the repair of practically all components of BULRAMO.

The BULRAMO system was integrated into the European platform for the exchange of radiological data - EURDEP in 2003. As a member country of EURDEP, Bulgaria is obliged to send a continuous flow of data on the state of the radiation background, as well as has the right to real-time access to information from similar systems of the EU member states. Bulgaria's access to EURDEP is extremely important in the event of a nuclear accident or nuclear conflict and is carried out online [11].

In 2004, the IAEA started issuing a daily bulletin about the radiation situation in the country on its website every day without Saturdays, Sundays and holidays, which is visible to all users.

In 2005, the Ministry of Defense, through the Centre for Collection, Processing and Analysis of Information on Nuclear, Chemical and Biological Situations, became a user of BULRAMO's operational information, and an Additional Monitoring Centre was built on its territory.

The same year, the Ministry of Health, through the National Medical Coordination Centre, became a user of BULRAMO's operational information, but did not build an Additional Monitoring Centre, unlike the Ministry of Défense.

In 2008, the State Enterprise "Radioactive Waste" (DP "RAO") built a Local Monitoring Station for continuous control of the radiation gamma-background in the municipality of the village of Novi Khan, due to the increased public interest in the level of radioactivity, around the existing repository for radioactive waste - Novi Inn. This is currently the only repository for radioactive waste on the territory of the Republic of Bulgaria. The newly built station is technically fully compatible with the Central Station of BULRAMO and through its integration, the system has been expanded with a new station owned by DP "RAO". The new repository for radioactive waste, which will be located adjacent to the Kozloduy NPP, falls within the range of the plant's local monitoring stations.

After the Fukushima accident in 2011, the BULRAMO system switched from daily to hourly reporting to the European Radiological Data Exchange Platform - EURDEP. This was dictated by the need to monitor the radioactive background and increase the security of the population and the state.

Later in 2013, the IAEA started issuing the daily bulletin on the radiation situation in the country and on weekends, all done automatically.

In 2013-2014, the BULRAMO system was updated according to the project of the operational program "Environment 2007-2013". All measurement sensors, communication channels, computer equipment and the specialized software serving BULRAMO have been updated. An additional 16 spectrometric gamma probes have been installed [12], [13].

In addition to the daily bulletin, the EAOS page now provides information on the last 24 hours in real time through the EURDEP widget from BULRAMO and the systems of other European countries. At the same time, the information is updated every 10 minutes on working days and every 30 minutes on weekends and holidays. If necessary, these renewal intervals can be made smaller if the security of the population requires it [4].

III. Results and discussion

Structure and equipment of BULRAMO at launch and operation in 1997.

1. BULRAMO consists of:

- 26 Local Monitoring Stations (LMS) equipped with:
  - o Gamma probe: IGS421B.
  - o Rain detector: RD200
  - o Computer data logger (Data logger) – DLM1440
  - o Communication equipment – mast with antenna
  - o Meteorological stations in 8 of the LMS: AMC100.
- Radio channels for transmitting the measured values.
  - o Repeater stations.
  - o Radio communication centers (RCCs).
  - o Central station (CS) located in the building of the Environmental Executive Agency (EAOS) carrying out:
  - o Communication and transfer of LMS data.
  - o Storage of the received information in a database.
  - o Visualization of the radiation and technical status of the LMS.
  - o Generate newsletters from the database.
  - o Data replication to the Additional Monitoring Centres.
  - o Alarm notification in case of increased values of radiation gamma-background.
- Additional monitoring centres (DMCs), performing monitoring and analysis of the data replicated by the CS.
- Mobile monitoring station – A vehicle equipped with the equipment of an LMS.
- In addition to BULRAMO are joined:

o 8 LMS from the Kozloduy NPP external radiation control system. These stations are under the administrative and technical management of Kozloduy NPP. Data from these stations is received via radio channel and stored in the BULRAMO database.

o 1 LMS of DP "RAO" - town of Novi Khan. This station is under the administrative and technical management of DP "RAO". Data from this station is received via radio channel and stored in the BULRAMO database.

The location of the local monitoring stations on the territory of Bulgaria is shown in figure 1.

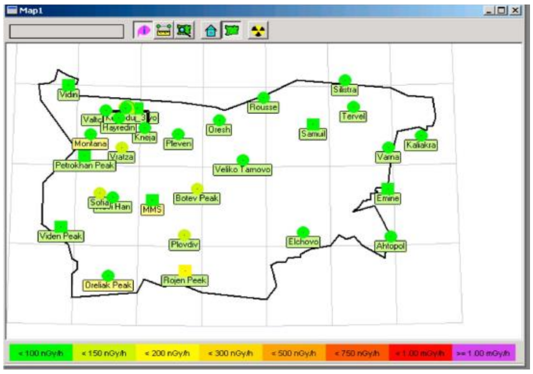

Figure 1: LMS location on the map of Bulgaria - view from the old visualization program (label color - technical status, station color - radiation status)

2. Data stored by BULRAMO:

- 10 minute average value of absorbed dose rate (air kerma) in units of nGy/h generated by IGS421B.
- Presence or absence of rain.
- Technical status for IGS421B.
- Technical status for DLM1440.
- CS calculates hourly and daily averaged values for absorbed dose power based on 10-minute averaged values.

3. Structure and equipment of BULRAMO after the renewal of the automated system.

The BULRAMO system was updated according to the project of the operational program "Environment 2007-2013" in 2013-2014 [14].

The reason for the update is that at the time the update started, a number of components were out of date. Additionally, from the start of the system's operation in 1997 to 2013, there have been significant developments in computer and communication technology, making old equipment technically incompatible with new computer and communication components. It is necessary to replace many of the gamma probes because they are morally obsolete and their defects are becoming more frequent [3], [15]. The overall architecture of BULRAMO has been assessed as successful and has been preserved. The renewal of the National Automated System for Continuous Control of the Radiation Gamma Background – BULRAMO covers:

- LMS
- Communication channels
- The central station
- The mobile monitoring station
- The additional monitoring centres

4. Local monitoring stations.

All measuring sensors have been renewed, additionally installed in 16 of 26 LMS spectrometric gamma probes. The manufacturer of the gamma probes and rain detectors is ENVINET GmbH. The new installed components are:

- Gamma probe: IGS421B -H measuring power of the ambient equivalent dose in |iSv/ri.
- Rain detector: RD203.
- Computer data logger (Data logger) – DLM1440 has an improved ARM based processor module with embedded Linux and Lan interface.
- Spectrometric gamma probe – SARA IGS 710/910 (NaI/LaBr$_3$).
- Communication equipment – GPRS/3G and the communication equipment of the radio channels is preserved.
- Meteorological stations – IAES has no obligation to measure meteorological parameters, and due to the fact that the main manufacturers of equipment for radiological monitoring systems in the environment do not offer such equipment, the available weather stations are preserved but their renewal is not foreseen.

5. Communication channels.

An IP/VPN network of GPRS/3G modems in LMS and DSL modems in CS and some DMCs was built, which became the main communication environment. Radio channels are preserved as backup communication channels, but due to their low transfer rate they cannot transfer the data to the gamma spectrometer probes. The new communication environment (GPRS/3G) allows the communication sessions from an interval of 30 minutes for the radio channels to go to an interval of 10 minutes, using optical wires for this purpose [5], [16].

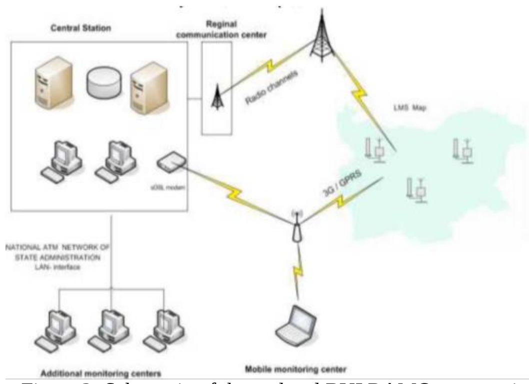

Figure 2: Schematic of the updated BULRAMO communication environment

6. The central station.

- The CS software equipment was based on Microsoft Windows Server 2012, Microsoft SQL Server 2012 and a specialized software package ountries ts.Net developed specifically for the renewal of BULRAMO. The ountries ts.Net package includes modules for:

- Communication and data transfer from LMS.
- Storage of the received information in a database.
- Visualization of the radiation and technical status of the LMS.
- Generate newsletters from the database.

- Data replication to the Additional Monitoring Centers.
- Alarm notification in case of increased values of radiation gamma-background.
- The servers and workstations serving BULRAMO's CS have been replaced.

7. The additional monitoring centers.

The software equipment of DMC is based on Microsoft Windows 7, Microsoft SQL Server 2012 express and specialized software package ountries ts.Net. At a later stage at the beginning of the third decade of this century, a higher level of operating system was already used. Table captions and titles should always be right aligned and placed above the tables. Tables are numbered consecutively with Roman numerals and have reference in the main text [6], [17], [18].

Figure 3: Mast of LMS Rozhen - Gamma probe and Meteo station

Figures 3 and 4 show pictures from the LMS operating in the NASNKRGF and a comparison between the old and new probes.

Figure 4: Photo of the upgraded sensors on an LMS. On the left is the spectrometry probe, in the middle is the start and on the right is the new dosimetry probe

Also of interest are the radioactive contamination control systems at the NIMH, where a radioactive contamination prediction system operates in the event of an accident in some of the nuclear power plants located on the European continent [1], [2], [3], [19]. A disadvantage of this system is that too few people know about it and it is more unrecognizable to the population.

The BERS (Bulgarian Emergency Response System) system works operationally every day at NIMH, calculating trajectories, concentrations and depositions (deposits on the earth's surface). The WRF meso-meteorological model is used, which is fed with prognostic information from the American GFS (Global Forecast System) with a resolution of 0.25 deg and makes a forecast three days ahead for the area of Europe. Wind information in space and time is used in the calculation of forecast trajectories. Concentrations and depositions are calculated from the three-dimensional model EMAP (Eulerian Model for Air Pollution) created at NIMH for describing the distribution of atmospheric pollutants. The meteorological input of the model is the WRF-calculated prognostic fields of a number of meteorological parameters that determine the intensity not only of transport, but also of a number of other dispersion processes such as diffusion, dry and wet deposition, chemical and radioactive transformations, etc. As a source of pollution, a simulation of a powerful nuclear accident was used, the parameters of which are described on the right of the animated picture [6], [20].

Visualized maps are a forecast, not a real situation. In them, the eventual spread of radioactive contamination within 72 hours after the occurrence of the accident is done on an hourly basis and the development of the process over time is visualized. The results are achieved on the basis of the forecast of the speed and direction of the winds in the area of the accident at different altitudes. The selected elevations are 100, 300 and 1000 meters above the surface of the Earth's crust in the area.

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Two types of information are presented on a BERS system page:

Predictive trajectories of particles released at different altitudes over selected 36 European nuclear power plants. In their calculation, only the three-dimensional wind field was taken into account. In other words, only one of the many dispersion processes - transport - is modeled.

The animated prognostic fields of concentrations and depositions of radioactive material discharged from each of the above plants, taking into account not only transport, but also other dispersion processes: diffusion, dry and wet deposition on the earth's surface, transformation of pollutants, etc.

Initially 49 NPPs were selected in the system, but at a later stage they were reduced to 36.

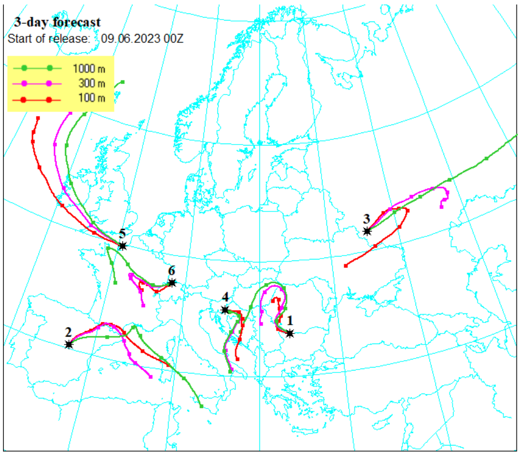

Figure 5- Forecast of radioactive contamination

In fig. 5 shows the results for the possible spread of radioactive contamination at a height of 100, 300 and 1000 meters above the ground level after 12, 24, 36, 48, 60 and 72 hours after an accident at 6 NPP - 1 - Kozloduy, Bulgaria, 2 - Jose Cabrera, Spain, 3 – Kursk, Russia, 4 – Krisno, Slovenia, 5 – Papuel, France and 6 – Leibstadt, Switzerland. Analogous maps can be seen for the other NPPs that the system monitors and forecasts.

In fig. 6 shows a similar map of pollution as a result of a possible accident, and here under No. 20 is the Zaporizhzhia NPP, which is on the territory of Ukraine and is under the control of Russian forces and the monitoring of the IAEA. It is of interest to us because it is located close to us, the predominant part of the winds would bring radioactive pollution to Bulgaria, and military operations are taking place near it.

A visualization of 3-day forecast trajectories of particles released from selected nuclear power plants in Europe can be called up by clicking on the tabs above the image. The 36 NPPs are presented in groups of 6 for better visibility. The names of each NPP can be found by number from the list on the right.

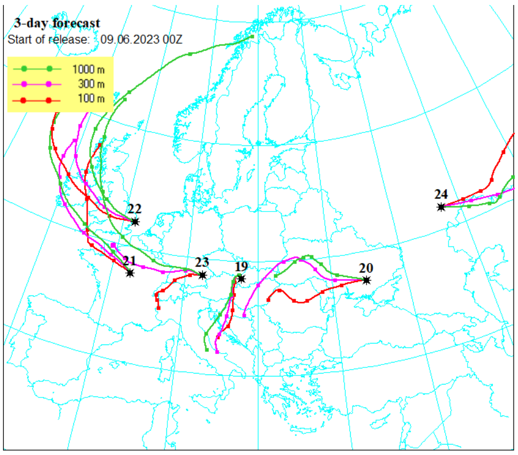

Fig. 6. Forecast of radioactive contamination

The depicted trajectories from each point correspond to 3 release heights: 100 m, 300 m and 1000 m

The start time of each trajectory is 00:00 of the current day. The points on each trajectory determine the position of the particle after 12, 24, 36…, 72 hours. The positions of the NPPs themselves are shown with asterisks.

Concentration and deposits (menu on the right)

Hovering over a NPP name in the list on the right brings up a drop-down menu with 2 options: Concentration and Deposition, which are links to animations of a simulated nuclear accident. The parameters of the accident are fixed (shown in the animation) and simulate a powerful release of radioactive material.

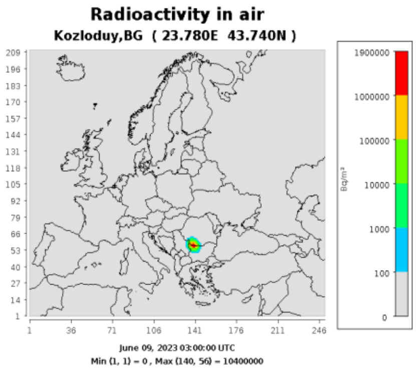

Fig. 7. Concentration of pollution during an accident at the Kozloduy NPP

In fig. 7 shows the concentration of pollution in the event of an accident at the Kozloduy NPP, and in fig. 8 shows the concentration of deposits on the soil during an accident at the Zaporozhye NPP. A snapshot of the two animations was taken, but the site itself tracks the dynamics of changes in the concentration of radioactive air pollution and radioactive deposits on the soil. Forecasts are made on the basis of the current movement of air masses and the forecast for its change within up to 72 hours after the accident.

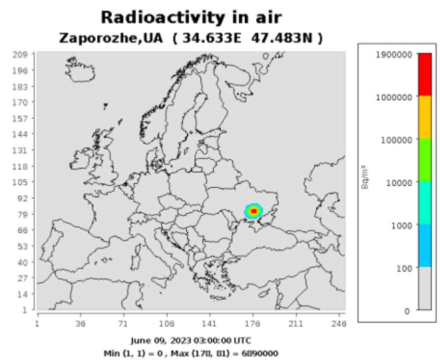

Fig. 8. Concentration of deposits during an accident at the Zaporizhia NPP, Ukraine

Due to the nature of the other radioactive control systems, their operation is not analyzed in this article. They have specific purposes and serve a specific category of users and are mainly used for business purposes.

IV. Conclusions

1. The National automated system for continuous control of the radiation range is well developed and organized - background in the Republic of Bulgaria for informing the population in case of radiation incidents;

2. The radiation gamma background is within the limits of background values typical for the country and in recent decades there have been no deviations from the normal values for the specific regions. The values of each station are different because the natural radioactive background is not the same;

3. A program for ensuring nuclear safety has been developed and is being implemented, but a consistent and predictable policy of the authorities in the field of the use of sources of ionizing radiation, including power units, is needed. Bulgaria lacks consistency and transition between governments regarding the development of nuclear energy and its safety. There is decision making with political advantage but without broad professional expertise.

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