RECONSTRUCTION OF THE NORTH-WEST RADIOACTIVE TRACK DURING THE ACCIDENT AT THE FUKUSHIMA-1 NPP (JAPAN) USING SOKRAT/V3 AND PROLOG SOFTWARE


The radioactive track formed on March 15, 2011 during the accident at the Fukushima-1 nuclear power plant (Japan) is reconstructed using the PROLOG–SOKRAT/V3 software system. The emission of radionuclides into the atmosphere and the radiation conditions are estimated taking account of the complex relief of the location. Comparing the computed activity, radionuclide composition and fallout density showed satisfactory agreement with actual measurements.

In compliance with regulations, the consequences of design-basis and beyond-design accidents at NPP are calculated when validating the safety of an object, specifically, in the probabilistic analysis of level-III safety. Similar calculations are performed in emergency response training and in the case of real accidents to determine protection measures. In all cases, the physical processes in the damaged nuclear facility and the propagation and fallout of radioactive substances are actually modeled. At the Institute of Problems in the Safe Development of Nuclear Energy (IBRAE), these problems are solved using the PROLOG–SOKRAT/V3 system, whose function is multivariate analysis of the radiation conditions and the dose of ionizing radiation to the public taking account of and neglecting countermeasures [1, 2].

In the present article, the PROLOG–SOKRAT/V3 system is used to reconstruct the north-west radioactive track formed during the accident at the Fukushima-1 NPP (Japan), mainly on March 15, 2011, which demonstrates that this system can be used to calculate the consequences of serious accidents with melting of fuel in NPP with VVER [3]. The SOKRAT/V3 code was used to analyze the development of the accident in the No. 2 unit of the Fukushima-1 NPP and estimate the radionuclide emission into the atmosphere taking account of filtration during bubbling in a water tank of the containment shell (torus). The results of the calculation performed with the SOKRAT/V3 code (time dependences of the activity of radionuclides emitted into the environment) were used as the initial data for the PROLOG software system, which was used to calculate the transport of radionuclides in the atmosphere in the presence of a complicated underlying relief.

The calculations were based on the initial data accessible in 2011–2012. For this reason, the results presented will probably be corrected at a later date as more accurate data become available.

Formation of the North-West Track. The emissions on March 15, 2011 made a significant contribution to the formation of the radiation conditions during the accident at the Fukushima-1 NPP [4, 5]. The emissions during the first half of the day on March 15, which occurred during ventilation of the containment shell in the No. 2 unit, for the most part formed the southern track, which initially was recorded by sensors on the industrial site of the Fukushima-2 NPP and in Ibaraki prefecture [5, 6]. The chronology of the events in the NPP makes it possible to associate the north-west radioactive track with emissions from the No. 2 unit assuming depressurization of the containment shell in the period from 12 to 15 h Japanese time.
The radioactive emissions propagated in the north-west direction above a strongly nonuniform relief, whose height exceeds that of the cloud level (Fig. 1). The spotty pattern of the contamination is largely due to fallout washed out by precipitation, which was nonuniform in the direction of emission [5].

**Evaluation of Radionuclide Emission into the Atmosphere.** According to the actual data on the events in the No. 2 unit of the Fukushima-1 NPP, after the failure of the main system providing high-head makeup to the core at 69 h of the accident the pressure in the reactor remained at the level 7 MPa for a long period of time as a result of periodic actuations of the control safety valves. The steam shedding through the valves gradually lowered the water mass in the reactor. SOKRAT/V3 modeling of the physical processes at the main stages of the accident in the No. 2 unit of the Fukushima-1 NPP, starting with the loss of heat removal from the core to the emission of radionuclides into the rooms of the reactor building, showed that the core started to dry and heat up at about 73 h (Fig. 2) [8]. Fission products flowed together with steam and hydrogen into the water tank of the containment shell. By the time that the operators opened the safety valves and the pressure in the first loop decreased (76.5 h), the core was almost completely dry and partially melted.

Calculations showed that the intense steam production at the time the overheated core was flooded with water (86 h after the accident started) caused a pressure peak in the reactor–containment shell system, which could have led to partial...