State and problems of seismological monitoring in Latvia. Prospects and ways of solving problems.

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Despite the low level of seismic activity in Latvia, it is expedient to conduct seismological monitoring. This is due to the following factors: 1) the intensity of earthquakes (historic and modern) shaking reached 6 - 7 points, and the maximum magnitude - 5.2 (Kaliningrad, 2004); 2) unfavourable ground conditions (sedimentary cover with a thickness of about 1 km and its upper part - Quaternary deposits) can contribute to the intensification of fluctuations; 3) some infrastructure facilities (Incukalns underground gas sdtorage), agglomerations (Riga, Liepaja et al.), hydroelectric (Plavinu HPP) and nuclear power plants are located in areas with signs of geodynamic activity.

Seismic hazard assessments in 2007 showed that with a 10% probability within 50 years, shaking will exceed 10 - 13 cm/sec^2 in some regions of Latvia (Sigulda, Riga, Cesis, Aizkraukle, Olaine et al.). This level of shaking refers to the surface of bedrock, represented mainly by the Devonian. Taking into account the possibility of additional amplification of oscillations due to resonance phenomena, the level of oscillations on the surface can increase. This is probably why the intensity of some historical (1616, 1821, 1857) and modern (1976, 2004) earthquakes reaches 6 - 7 points. Local seismic-geological conditions play a significant role here. In particular, this was shown by the tremors from the 2004 Kaliningrad earthquakes.

Studies of regional seismicity began in 1994. However, full-fledged seismological studies have become possible since 2006, when the *Slitere* station was installed in Latvia, which was included in the international GEOFON network with its center in the GFZ Potsdam.

The station is equipped with typical seismological equipment used in the GEOFON network. Participation in the GEOFON network made it possible to receive data from other stations in the Baltic region and thereby create the Baltic Virtual Seismic Network. The area of responsibility of Latvian seismological monitoring covers the Eastern Baltic region (EBR) (φ = 53.9°N - 59.7°N; λ = 19.4°E - 29.6°E).

Most of the seismic events localized using the BAVSEN network are associated with artificial sources that are associated with industrial quarries and the Baltic Sea. These are industrial explosions for the extraction of oil shale, dolomite, gypsum and limestone. In the Baltic Sea, the explosions are associated with the destruction of sea mines left after the war. The BAVSEN network annually registers 300 - 400 regional seismic events. For example, in 2020, 310 regional seismic events were recorded within the FBG. Magnitude range changing from 1.2 to 2.8. Most of the seismic events take place during business hours (from 9 am to 5 pm local time).

After the Kaliningrad earthquakes in 2004, tectonic earthquakes in the EBR occurred mainly in Estonia (northern and western Estonia, Lake *Võrtsjärv* region). According to macroseismic data, one seismic event (November 22, 2010) was felt in some places of Riga and its environs. It was associated with a tectonic earthquake confined to the zone formed

by the subparallel tectonic faults *Olaine-Incukalns* and *Bergi*. The stations of the seismic network BAVSEN did not register it. Distances between stations reach 150 - 250 km.

One seismic event in Lithuania on June 12, 2015 occurred in the area of geothermal resources and oil wells development and was identified as an induced earthquake.

Signs of geodynamic activity have been found for the *Olaine-Incukalns* fault, the largest tectonic fault in Latvia. It crosses the territory of Latvia, including the territory of Riga, from southwest to northeast. In the southwest, anomalous velocities of movement of the opposite sides of the *Cirulisi* fault were found, which adjoins the *Olaine-Incukalns* fault. A radon anomaly was found on the northeastern edge of the *Olaine-Incukalns* fault. In the central part, as already mentioned, tremors were felt in 2010.

Hydroelectric power plants are other objects requiring increased attention, including seismic monitoring. The area of *Plavinas* reservoir and hydroelectric power station deserves special attention. In fact, the dam of the hydroelectric power station is located inside a graben-like structure formed by the *Piebalga* and *Aizkraukles* faults. In the area of the dam, unfavorable processes are noted associated with deformations and the removal of finely dispersed soil by water flows.

The main problems of seismological monitoring are associated with a rare seismic network in the East Baltic region (Estonia, Latvia, Lithuania, Kaliningrad region of Russia), poor seismic-geological conditions. The first factor limits the magnitude threshold of recorded seismic events. The second factor complicates the wavefield, especially the arrivals of the first P-waves. This is due to wave interference at the boundaries of the sedimentary cover.

It is proposed to expand the seismic network of Latvia with a uniform coverage of the territory. Taking into account its peculiar configuration, it is proposed to create 6 more stations. In areas of intense anthropogenic noise (Riga), it is proposed to organize borehole observations to reduce man-made noise.

Methods of recognition of tectonic earthquakes in conditions of a thick sedimentary cover overlapping the crystalline basement are of great importance. Unfortunately, so far none of the tested methods (spectral and amplitude ratios of P and S-waves, spectral-time analysis) has demonstrated efficiency. In this direction, the search for effective methods for recognizing the genesis of seismic events will continue. One of the options is the creation of a *National Data Center* (through the CTBTO) and access to the nearest infrasound stations (IS37, IS43, IS26). Infrasound stations can greatly facilitate the identification of explosions.

In the area of the *Plavinas* water reservoir and HPP, it was proposed to create a local system of seismological observations as an addition to the existing complex of hydrogeological, deformation, geodetic measurements.

The results of seismological observations are accumulated in the BAVSEN (SEISAN software) database. Seismological monitoring reports are published on the LEGMC website https://videscentrs.lvgmc.lv/lapas/seismologiskais-monitorings