Knowledge and Data Integration in the Tasks of Technogenic Noise Environmental Monitoring

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***Abstract*—The paper is devoted to the problem of integrating knowledge and data in the field of geo-ecology. The study of anthropogenic noise impact dependence on various objects on natural factors complex is an important component of forecasting geo-ecological risks. The geo-ecological risk assessment methodology has been developed at ICM&MG SB RAS, in which a low-frequency seismic vibrator is used as an instrument. Vibration sources provide stable emission of seismoacoustic signals with specified parameters, which allows them to be used as test signals. The paper considers the aspects of the development of the scientific information system "Active seismology", into which the experimental data of geo-ecological monitoring of technogenic noise were integrated, and the Knowledge Portal, which provides navigation and meaningful access to information resources of the subject area. The article also discusses an approach to building information systems on the Internet in which access to data and knowledge in a subject area is organized on the basis of ontologies.**

***Keywords*—environmental monitoring, ontology, scientific information system, knowledge**

I. INTRODUCTION

Residential areas, i.e. areas designated for human activity, located within cities and towns (land for construction of residential and public buildings, parks, streets, roads, squares) in recent decades have experienced a significant increase in the negative impact of various environmental factors, primarily technogenic ones. Increase in traffic flows, development of construction and industrial infrastructure is inevitably accompanied by growth of the negative anthropogenic impact on the environment, including growth of noise pollution. Experimental studies of recent decades reveal more than tenfold noise increase in large cities. [1,2]. It should be noted that both separate and combined impacts of acoustic pollution is a serious problem [3,4].

According to the State Report "On the State of Sanitary and Epidemiological Welfare of the Population in the Russian Federation in 2019" [5], among the complaints about unfavourable living conditions, the largest share of complaints about noise - 66.8%. And the share of residential buildings, where non-compliance with noise standards was identified, was 13.4%.

The leading source of noise in settlements is transport. Trucks and motorbikes are the noisiest among all types of vehicles. The next largest source of noise pollution is railroad transport. The Federal Service for Supervision of Consumer Rights Protection and Human Welfare has developed guidelines for assessing the health risk of the population from the effects of traffic noise [6]. These recommendations contain the definition of standardized noise parameters. The stages of noise risk identification include the identification, collection and analysis of all possible information about the sources of noise affecting the population in order to determine:

- noise level and frequency characteristics;
- noise distribution in the residential area;
- time of noise exposure: day, week, month, year, etc;
- population size exposed to acoustic effects;
- likely health problems associated with exposure to noise.

The main objectives of the hazard identification stage are to characterize the sources of man-made noise, to identify the features of its spatial and temporal distribution, to determine the size of the population exposed to harmful acoustic effects. Measurement of noise parameters is carried out in order to assess their compliance with hygienic standards.

Acoustic pollution associated with explosions at the test sites where obsolete munitions are disposed of and with industrial explosions in quarries are of great concern for the population. Noise pollution from blasts is associated with seismic vibrations and airborne waves [7,8]. When designing mass explosions in quarries much attention is paid to the acoustic effect of the explosion, in particular the radii of safe zones on the effect of air waves on people and on the glazing of buildings are determined. Acoustic waves are systematically monitored in quarries. However, the issues of assessing the meteorological dependence of seismoacoustic effects have not been fully studied.

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A comprehensive theoretical-experimental approach to solve the problem of reducing geo-ecological risks from anthropogenic noise has been proposed and analyzed at the ICM&MG SB RAS. The approach includes frequency analysis and the most harmful frequency noise components from explosions and various types of heavy transport assessment. Theoretical and experimental assessment of risk increase under the influence of weather factors on infrasound propagation in the atmosphere was also carried out. Risk compensation effect by means of afforestation depending on the infrasound-environment interaction parameters was numericaly assessed. [9]. As a result, a lot of field material has been accumulated that has remained unsystematic and accessible to a narrow range of researchers.

At the same time, current research related to environmental risks requires not only effective access to experimental data and analysis tools, but also access to various reference materials, including regulations that establish noise limits, train timetables, weather information, etc. Equally important for researchers is meaningful access to scientific articles on noise hazards, as well as information on organizations and individuals working in the subject area.

This paper proposes an approach to solve the problem of accumulating, storing, and providing effective access to information on geo-environmental monitoring of anthropogenic noise.

II. Materials and Methods

Theoretical and experimental studies of the anthropogenic noise impact dependence on various objects on the natural factors complex have been carrying out for the last decade at the ICM&MG SB RAS. A methodology for evaluating geoecological risks has been developed, in which a stationary low-frequency seismic vibrator is used as an instrument [10,11]. Vibration sources provide stable emission of seismoacoustic signals with specified parameters, which allows them to be used as test ones.

Experiments were carried out to register the signal from a vibroseismic source under various meteorological conditions, explosions in the Kuzbass quarries, Shilovo test site in Novosibirsk region, registration of noises from ground vehicles. Numerical modeling of weather-dependent spatial redistribution of infrasound intensity, numerical calculations to assess the directional effects of the infrasound sources acoustic wave field arising against the wind, characterized by azimuthal direction and speed, numerical assessment of risk compensation effects by means of afforestation depending on the interaction parameters of infrasound with the environment have been conducted.

During the experimental and theoretical work, a large amount of information was accumulated: field material, results of computational experiments, research results presented in scientific articles and reports, various reference material containing normative documentation, information about weather conditions, etc. This information requires systematization for efficient use.

One way to integrate data, applications providing their computational analysis, and domain knowledge (software) is to build integrated systems that combine the functionality and technical properties of knowledge-based expert systems with databases or information-computing systems [12]. This combined approach makes it possible to organize effective access and analysis of data, as well as meaningful search of the necessary information.

The Laboratory of Geophysical Informatics of ICM&MG SB RAS developed an intellectual scientific web resource consisting of two subsystems: SIS "Active Seismology" and the knowledge portal "Active Seismology" [13]. The SIS under consideration consists of:

- a digital library (DL) for storing text documents;
- cataloged experimental data;
- metadata database (DB), containing indexes and description of the experiment, coordinates of signal sources and recorders, signal parameters, etc;
- application for the construction of experiment maps;
- computational module.

The computational module is an application that runs directly in the operating system environment of the server. To provide enough performance for online mode, the application is written in C++ and uses software libraries with low-level optimization Intel Performance Libraries.

The information core of the Knowledge Portal (KP) on active seismology is an ontology [14]. When organizing the ontology and knowledge portal, the methodology and technology for developing knowledge portals of the Artificial Intelligence Laboratory Ershov Institute of Informatics Systems (IIS) SB RAS was used. [15]. This technology supports the development of knowledge portals without the participation of developers in the field of artificial intelligence. According to this methodology, the subject area is described in the form of two basic ontologies: Ontology of scientific knowledge and Ontology of scientific activities. The ontology of scientific activity contains such notions as Object of research, Method of research, Subject of research, Problem, Result, Publication. Scientific activity ontology contains the following concepts: Organization, Person, Event, Activity. The use of ontologies allows to make the process of developing an KP more technological, in particular, to use the previously obtained and formalized knowledge.

This resource was reorganized to integrate data and knowledge on geo-environmental risk assessment methods using vibroseismic technologies. The reorganization included the following stages:

1. The digital library was supplemented with reference material (tolerance tables, information on meteorological conditions, etc.)

2. The directory tree of experimental data was added to the folders containing files of records of signals from geo-environmental monitoring experiments (records of signals from explosions, ground transport, vibration sources).

3. Database (DB) tables were expanded with metadata describing geo-environmental monitoring experiments.

4. The ontology of the problem domain is developed on the basis of the “Active Seismology” ontology developed earlier by the authors of the article. Subclasses and objects

related to the problem domain were included in the classes uniting such basic concepts as Activity, Subject of research, Research method, Object of research. Ontology links classes and objects of different classes by semantic relations. Subclasses and objects within a class are linked by relations of inheritance from "parents".

5. The functionality of the knowledge base has been expanded on the basis of the developed ontology, new information objects related to the problem area have been included.

III. Results

Storage, administration, and computational analysis of data from experiments to assess geo-ecological risks from explosions and traffic noise have been organized. The data and metadata are included in the SIS "Active Seismology". An ontology describing the concepts of the problem domain has been developed.

Fig.1 shows a fragment of the ontology, which describes all relations of the object "Assessment Impact of Explosions", belonging to the subclass "Monitoring acoustic Noise" of the class "Problem" with the objects and classes of the ontology. Thus, this object is linked to the object "Acoustic signal" of the "Object of research" class by the relationship "explorers". The object "Assessment Impact of Explosions" is linked to the class "Methods and means" and to the object of this class "Vibrational sounding", because all objects belonging to the same class have the properties of inheritance from their "parents".

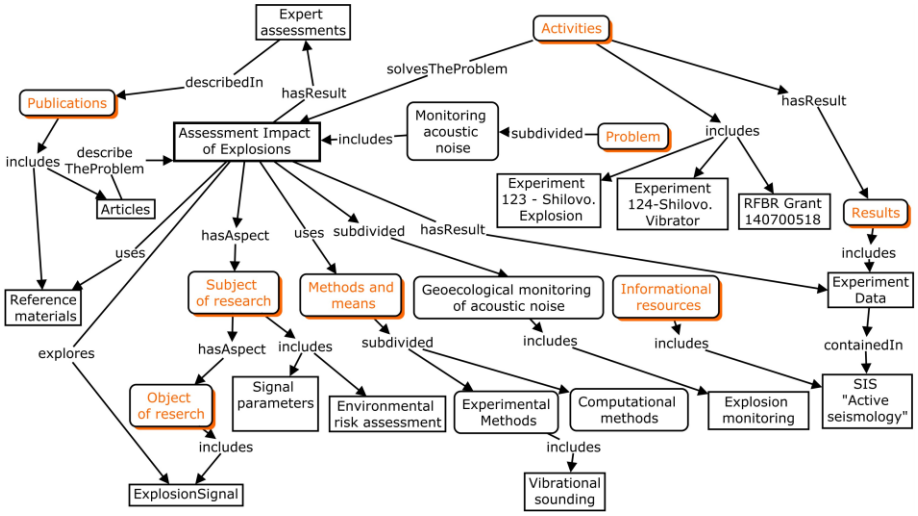

Fig. 1. Fragment of the ontology.

In accordance with the ontology, the functionality of the Knowledge Portal has been expanded, new information objects have been included. Fig. 2 shows the Portal page containing the description of the "Assessment Impact of Explosions" object.

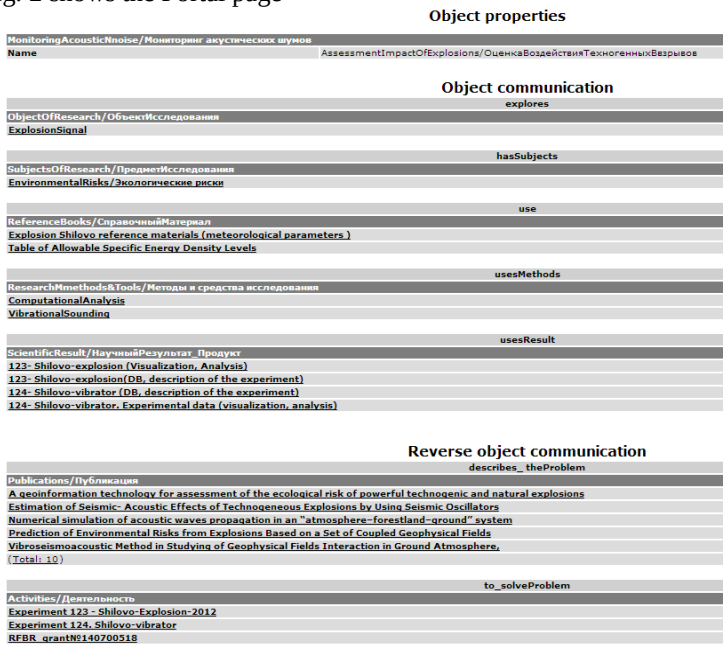

Fig. 2. Portal page

Hyperlinks provided on the Portal page can be used to navigate directly to the information objects. Fig. 3 and Fig. 4 shows the transition via the hyperlink "Experimental data - Shilovo-2012" to the SIS "Active seismology" and the result of performing a computational analysis at the user's request.

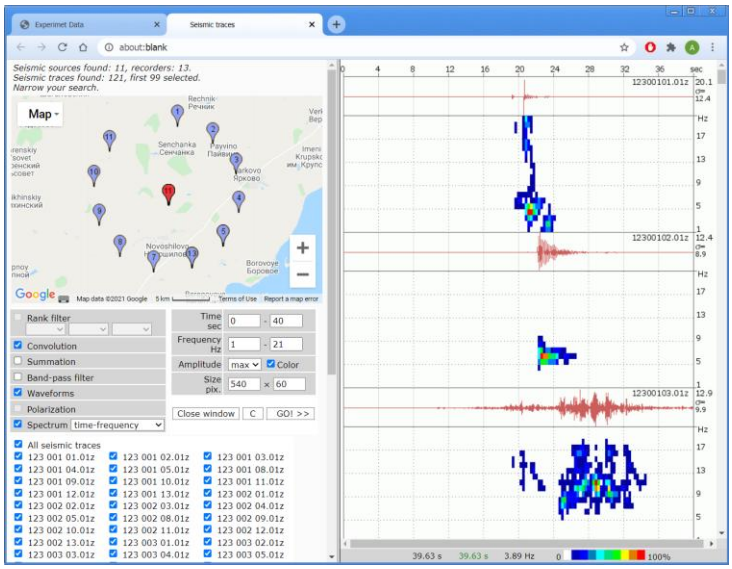

Fig. 3. SIS "Active Seismology" page. Result from the portal page link "123 – Shilovo blast". Visualisation. Analysis.

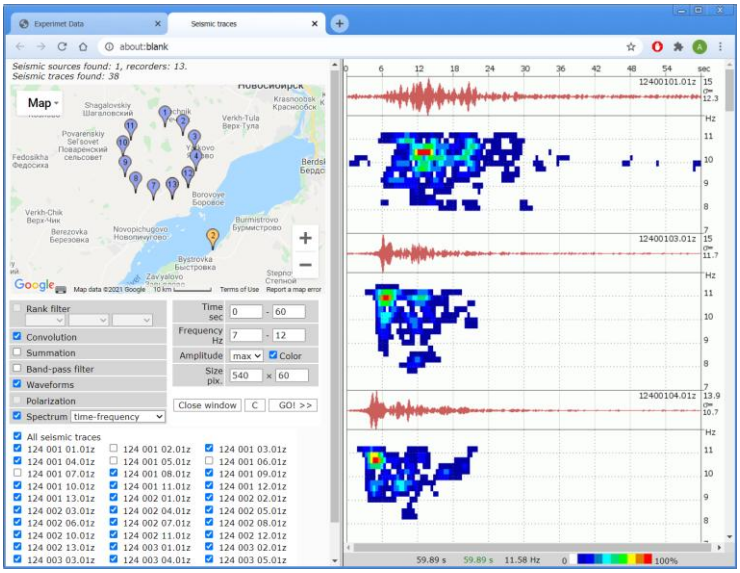

Fig. 4. SIS "Active Seismology" page. Result from the portal page link "124 – Shilovo vibrator". Visualisation. Analysis.

IV. Conclusions

The relevance of the tasks related to the monitoring of anthropogenic noise is primarily due to the fact that noise pollution is one of the key risk factors for the population. The presented work is aimed at informational support of research related to the assessment of impact from anthropogenic noise. The aim of the work is to provide a wide range of researchers with the results of field and computational experiments on the problematic topic. These results are obtained on the basis of the methodology developed at ICM&MG SB RAS, in which a stationary low-frequency seismic vibrator is used as an instrument.

The scientific information environment developed by the authors integrates knowledge and data related to the field of acoustic noise research. Researchers are provided with the possibility of meaningful access to data and their analysis, as well as systematic information related to this issue.

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