

Integrated approach to geophysical hazards induced by exploration and exploitation of georesources - to facilitate the way of attaining excellence.

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Background The increased need for energy and minerals requires a variety of complex industrial processes to be performed under more and more difficult environmental conditions.

The problem of hazards induced by exploration and exploitation of georesources focuses growing interest of science, industry, public administration, NGO-s and general public. This is especially true in the densely populated Europe, where such technological activities take place close to inhabited and other protected areas. Anthropogenic seismicity, i.e. the undesired dynamic rockmass response to georesources exploitation, is one of the examples of unwanted by-products of technological occupation of humans. It becomes a real problem in areas previously known as aseismic and in association with quite diverse technological processes. The induced earthquakes accompany underground and open-pit mining, both conventional as well as unconventional hydrocarbon exploitation, impoundment of surface reservoirs of liquids, geothermal energy production, underground fluid and gas storage and many other technological processes that perturb the boundary conditions in the affected rockmass. The socio-economic impact of the induced seismicity is very significant. Induced earthquakes can cause material loss, injuries and even fatalities.

Hazards resulted from exploitation of georesources are undoubtedly linked to particular inducing technologies. It is obvious that a successful investigation of the Earth's response, that is the result, cannot be done without a simultaneous analysis of conditions of the technological activity, that is the cause. To make research of the cause-effect relations feasible, the collaboration between science and industry must be enhanced to reach a trustful level of synergy. On the other hand, whereas the inducing technologies are different, the rockmass reactions of the same physical kind have much in common. The research focused on common features of these reactions and transverse to inducing technologies seems to be the way to accelerate recognition of the problem.

The present level of IT development provides new opportunities to accomplish the above mentioned goals. High quality virtual access not only makes it possible to share infrastructural resources but enables also an unconstrained face-to-face collaboration and an immediate exchange of information between geographically dispersed research groups.



Long-term plan The above assertions were the basis for actions undertaken to integrate research in the field of anthropogenic seismicity and, more wide, of anthropogenic hazards. Only in 2010 Stanislaw Lasocki and Beata Orlecka-Sikora from Institute of Geophysics

Polish Academy of Sciences formulated and presented publicly the world initiative THAIS - Teamwork For Hazard Assessment For Induced Seismicity (<http://thais.igf.edu.pl/>). THAIS is an integration program for modern science based on integrated thematic research infrastructure and the most advanced ICT solutions. It proposes international research groups and representatives of industry to cluster in virtual research centers in order to study commonly specified problems in the field. The virtual research center, a virtual access activity is backed by an IT environment, which enables the scientists to work together in the same way as they were in one physical laboratory. The data to be analyzed and other needed infrastructural components are integrated in this IT environment and become accessible through virtual access points. Innovative and tested solutions are transferred to industrial partners. THAIS initiative has been welcomed by individuals and institutions from Europe and beyond and also appreciated with a letter by International Association of Seismology and Physics of the Earth Interior.

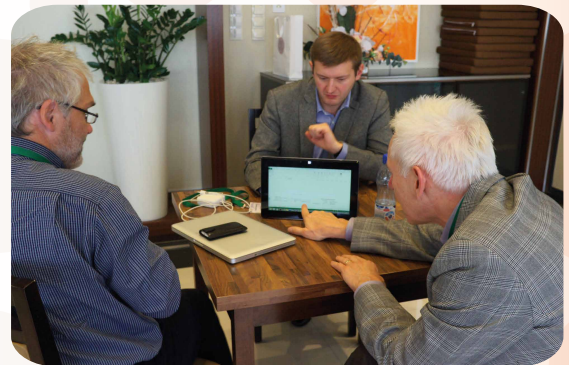


Infrastructures for Georesources working group of EPOS *EPOS: European Plate Observing System is a long-term plan for the integration of national and transnational research infrastructures for solid Earth science in Europe to provide seamless access to data, services*

and facilities (www.epos-eu.org). It was approved by the European Strategy Forum on Research Infrastructures (ESFRI), included in the ESFRI Roadmap in December 2008 and began a preparatory phase in 2010. It became clear for THAIS initiators that the thematic component of infrastructure of the planned undertaking in the field of anthropogenic seismicity and other geophysical hazards implied by technological activity of humans could and should be built within EPOS. The positive response of EPOS Project Development Board effected the creation of working group *Infrastructure for Georesources*. The working group of representatives from science and industry of 15 European countries, led by Beata Orlecka-Sikora from Institute of Geophysics PAS, has been working out strategies of integration of research infrastructure of the field, common science plans uniting research groups dealing with the effects of different technologies and new approaches to science – industry partnering cooperation. Three classes of research infrastructure have been distinguished. The data class is a collection of anthropogenic hazard episodes. The episode is a comprehensive data description of a geophysical process, induced or triggered by human technological activity, which under certain circumstances can become hazardous for people, infrastructure and the environment. The software class is a collection of problem-oriented, specific services (software) with the particular attention given to services facilitating analysis of connections between technology and geophysical response. The document class is a collection of relevant publications and other written materials.

EPOS programme foresees integrating national thematic research infrastructures in the so called Thematic Core Services (TCS), technically supported by the most up-to-date ICT solutions. Following its ambitious plans, the *Infrastructure for Georesources* working group has decided to gather its infrastructures in one TCS - TCS Anthropogenic Hazards (TCS AH).

DIGITAL
RESEARCH
SPACE
OF
INDUCED
SEISMICITY
FOR
EPOS
PURPOSES



THEMATIC CORE SERVICE
FOR ANTHROPOGENIC SEISMICITY

INTER-SECTORAL
KNOW-HOW
TRANSFER

CONSOLIDATION
OF
SCIENTIFIC
COMMUNITY



SYNERGY OF SCIENCE
AND INDUSTRY



INTEGRATION
OF
DISPERSED
RESEARCH INFRASTRUCTURE

CLOUD COMPUTING



IS-EPOS: Digital Research Space for EPOS Purposes Polish national project Consequently, Institute of Geophysics, Polish Academy of Sciences with three other Polish partners in the EPOS WG Infrastructure for Georesources, namely with Academic Computer Center CYFRONET AGH, Kraków, Central Mining Institute, Katowice, and the industrial partner: Coal Company, formed a consortium, which applied in 2013 for funding *IS-EPOS: Digital Research Space for EPOS Purposes* project. The project was accepted for co-financing by the European Regional Development Fund (ERDF) as part of the Operational Programme Innovative Economy (OP-IE), Intermediate Body – The National Centre for Research and Development, Operational Programme Innovative Economy 2007-2013, Priority Axis 2 – Infrastructure of R+D Sphere, Measure 2.3 – Investments connected with development of IT infrastructure of science. The project has been led by Stanislaw Lasocki from Institute of Geophysics, Polish Academy of Sciences. Its total budget is more than 16M PLN (about 4M€) in 2013-2015.

The IS-EPOS project aims to build a prototype of TCS Anthropogenic Hazards belonging to pan-European multidisciplinary research platform created within EPOS. The prototype deals with anthropogenic seismicity. The IS-EPOS IT platform provides a virtual access to six episodes of anthropogenic seismicity respectively linked to underground hard rock and coal mining in Poland, hydro energy production in Poland and Vietnam and geothermal energy production experiment in Germany. The researcher accessing the platform can make use of low level software services for data browsing, selecting and visualizing and a number of high level services for advanced data processing. It has been assumed that the prototype will have all the basic functionalities of the target TCS Anthropogenic Hazards and that it will be developed to this target form during the construction phase of EPOS.



IS-EPOS follow-ups within EPOS IP project of H2020 In 2014 EPOS ended its preparatory phase and began preparing the application for funding the implementation phase. EPOS WG Infrastructure for Georesources presented a comprehensive plan of implementing TCS Anthropogenic Hazards, whose starting point was IS-EPOS platform. This plan was well recognized by EPOS Project Development Board and resulted in strong position of the plan in EPOS successful application for financing the EPOS Implementation Phase (EPOS IP) project (call: H2020-INFRADEV-1-2015-1; topic: INFRADEV-3-2015; type of action: RIA). In the framework of EPOS IP project Institute of Geophysics PAS, and personally Beata Orlecka-Sikora, lead a separate Work Package 14 *TCS Anthropogenic Hazards*, with participation of 14 European research institutions and one associated partner from Vietnam. The budget of WP14 is some 1.8M EURO from EC and 1.7M EURO of own partners' contribution for 2015-2019.

The works in WP14 will result in converting the IS-EPOS prototype into a fully operational e-research platform - TCS AH and in integration in TCS AH research infrastructures of WP14 participants. The virtual access to e-research platform will enable unconstrained in-silico experimentation on the integrated infrastructures. TCS AH will be mutually integrated with other communities' TCS-s and EPOS Integrated Core Services (EPOS ICS) through the EPOS compatibility layer.



Connections of IS-EPOS IT platform with research projects Starting from the beginning of 2016 the IS-EPOS prototype and its TCS AH developments will serve the SHEER: *Shale gas exploration and exploitation induced risks* H2020 research project:

(call H2020-LCE-2014-2015; topic: Understanding, preventing and mitigating the potential environmental impacts and risks of shale gas exploration and exploitation; type of action: RIA; coordinator AMRA Italy). SHEER is monitoring on-site the seismicity, state of underground water and state of air during and after shale gas exploratory hydrofracturing in Pomerania in Poland. According to recommendation of Stanislaw Lasocki, a leader of Institute of Geophysics PAS membership in SHEER and a member of SHEER Project Management Team, the collected data as well as the data gathered from relevant past case studies will be integrated, and partially processed in IS-EPOS/TCS AH IT platform.

The IS-EPOS/TCS AH platform will support German project *MINing Environments: continuous monitoring and simultaneous inversion*, led by GFZ, funded by the BMBF/DFG Programme Geotechnologien, Tomographie des nutzbaren Untergrundes. The platform has been indicated as a foreseen IT medium in an application of the National Institute for Earth Physics, Romania for the national structural funds project *Advanced Research on Characterization of Multiscale Seismic Energy Radiation and Associated Seismic Hazard using Dense Seismic Networks and Arrays*. The IS-EPOS/TCS AH platform will be also an IT environment for data storage and in-silico experimentation for investigations of reservoir triggered seismicity carried on in the framework of the agreement on research cooperation between Institute of Geophysics, Vietnam Academy of Science and Technology and Institute of Geophysics, Polish Academy of Sciences.

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