TRANSFORMING THE RAW MATERIAL INDUSTRY WITH RESPECT TO THE ENVIRONMENT

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Abstract

Moving from the traditional industrial model, in which waste is considered the norm, EU needs to develop an integrated industrial integrated systems in which everything has a next use. By exchanging industrial energy, water, by-products and materials between sectors, waste from one industry becomes raw material for another. Industry is encouraged to emulate the sustainable cycles of nature, minimizing the burden imposed on the earth and using its resources more efficiently. The raw materials industry transformation with respect to the environment is an integral part of these initiatives and efforts. The paper aims to consider what would be required for mining companies to operate as a modern advanced technology-driven business. It reviews how waste management is a business strategy and examines issues of cost reduction with respect to the environment.

Keywords: Ecosystem services, waste management, industrial integrated systems, resource efficiency, advanced technology

Introduction

The European Commission was putting forward seven flagship initiatives within the Europe 2020 strategy to catalyze progress for smart, sustainable and inclusive growth. One of the supported priorities is the "Resource efficient Europe" to help decouple economic growth from the use of resources, support the shift towards a low carbon economy, increase the use of renewable energy sources, modernize logistics sector and promote energy efficiency. The main goal is to enhance a framework of ecosystem services for the use of market-based instruments (e.g. emissions trading, revision of energy taxation, state-aid framework, encouraging wider use of green public procurement); promoting renewable sources of energy,

supporting zero waste entrepreneurship and industrial networks and development of new eco-efficient technologies.

This core European strategic material has also impact to raw material industry development taking into account the environment issues. Before the raw material community stood aim to adapt these new challenges to traditional principles of mining industry. It was clear already ahead that the transformation of this type of industry will have inexhaustible consequences of the use of new approaches and technologies for innovations to be applied to outdated approaches of this sector management and development. Especially environmental approach did not have any support in mining operations so far. An objective is a concept proposal to achieve some of the challenges to transforming the raw materials industry with respect to the environment for the new European concepts in the field of so-called green technologies for processing near-to-zero waste production. Such a concepts aim to help EU industry and manufacturing companies in adapting to global competitive pressures by improving the technological base of manufacturing across a range of sectors. The consistently putting these concepts into practice in a global - distributed operations, manufacturers and producers strongly pushing information also in non-traditional areas - thus adding intelligence into every area of their operation, as well as the products themselves. Distribution of sensors, processors and communication tools within the enterprise and linking them into an integrated infrastructure creates a comprehensive process visibility across previously discrete processes. The result is an advanced technology, the technology that is not a goal but a means to achieve efficiency.

1. The industry environmental transformation:

The Europe successful economic development over the past century is based on the ever increasing use of natural resources. If we continue with our current consumption, it would be inevitable to avoid irreversible damage to the Earth's natural environment and threaten its ability to provide these resources and the ecosystem services that we are so dependent upon. Resource efficiency is seen as the path where economic development and human well-being can progress with lower resource use and environmental impacts. Waste prevention has been assigned the highest priority under European attitude. The initiatives which have been taken so far have not reduced the regular annual increase in total waste arising across Europe; we are still some way from achieving sustainable use of resources. An increasing number of products and services are being produced and consumed in industrialized countries. This development is reflected in the amount of waste generated. According to Eurostat, Europe is annually

generating about 4 billion tons of agricultural, domestic and industrial wastes.

The problem is not only the quantity of waste but also the quality, i.e., the hazardous nature of some types of waste, especially industrial waste. Industry today in general uses a wider range of materials and produces more complex products than in past decades. There has also been an overall increase in the quantity and variety of products and services and a continuous creation of new products (Commission of the European Community, 2003). The waste management and the waste prevention have to be perceived through a holistic perspective to make it work efficiently and effectively. The society moving in the direction of sustainability must be based on an understanding of the system functioning principles usually referred to as the eco-sphere (e.g. thermodynamics; the biogeochemical cycles; the ecological interdependencies of species; the societal exchange with, and dependency on, the ecosphere). Operational approaches need to comply with the complementary, non-overlapping, conditions for social and ecological sustainability. This systematic approach involves close cooperation with other strategic approaches towards sustainability, the utilization of tools such as Life Cycle Assessment in order to evaluate the present situation of material flows, and the implications of various technologies, industrial designs and policy options at a micro and macro-level.

A key activity of the objectives set in the environmental field is the Zero Emissions/Zero Waste concept. This concept represents a shift from the traditional industrial model to integrated systems in which everything has its use. It promotes an industrial transformation whereby companies emulate the sustainable cycles found in nature and where society minimizes the load it imposes on the natural resource base and learns to be more efficient with Earth's resources. The concept of "zero waste" requires a targeting of the various environmental aspects:

- zero waste of resources - energy, materials and human,
- zero emissions - air, soil, water, solid waste, hazardous waste,
- zero waste in activities - administration, production,
- zero waste in product life - logistics, use, end-of-life,
- zero use of toxics - processes and products.

The key guiding principles for zero waste industrial networks have to commit to the social, environmental and economic standards, use the prevention principle, minimize waste to landfill or combustion, use producer responsibility feature: taking back products & packaging, re-use, recycle & compost materials as resources, prevent pollution and reducing waste - and thereby maximizing resource efficiency, use of economic motivations for customers, workers and suppliers, sell products or services

that is not wasteful or harmful to the environment and finally use of non-toxic production, re-use and recycling processes.

How to achieve this innovative approach? Firstly, there is a need to define a common vision on “zero waste entrepreneurship”. Then the focus should be taken on new technological developments, waste prevention methodologies and strategies and should adapt existing software tools supporting waste prevention. All this knowledge should be formalized into an innovative production model for resource-use optimization and waste prevention. The goal should be at least 70% of overall re-use and recycling of waste.

2. The raw materials industry transformation:

The European Commission launched the EU Raw Materials Initiative in 2008 with the aim of establishing the necessary framework to foster the sustainable supply of raw materials from European sources, boost overall resource efficiency and promote recycling. The mining industry faces a number of challenges which require technical solutions that encompass the entire network and include the economic, social and environmental issues. The industry needs a new image based on pioneering solutions and a modern structure that can exploit minerals at greater depths and promote both high productivity and safe working conditions.

Many initiatives mark the start of a series of development activities aimed at realizing the concept of an invisible, zero impact, deep mine. The extractive sector, still seen as being old fashioned and environmentally unfriendly, will join forces to revise this image by showing that mineral extraction and processing can be done in a highly innovative and sustainable manner with low impact underground and zero impact above ground.

One of the biggest R & D programs of the European Commission under the 7^{th} Framework Program is the I^2Mine project titled "Innovative technologies and concepts for intelligent mining mine of the future" (Fig. 1), which involves the VRP workplace of Technical University in Kosice, where we also used some of the results and outcomes Biomass project for the solution. This initiative is designed to focus of the technological challenges the mining industry is currently facing including the exploitation of ever deeper deposits and the aspiration for an invisible, safe, zero impact mine. The project will be carried out by a consortium of 27 organizations from 10 European countries. The concept of the I^2Mine is to develop the innovative methods, technologies, machines and equipment necessary for the efficient exploitation of minerals and disposal of waste, all of which will be carried out underground. This will dramatically reduce the volume of surface transportation of both, minerals and waste, minimizing the above ground installations and reducing the environmental impact.

New eco-efficient technologies should be applied in order to make the entire mining process more efficient and environmentally sound.

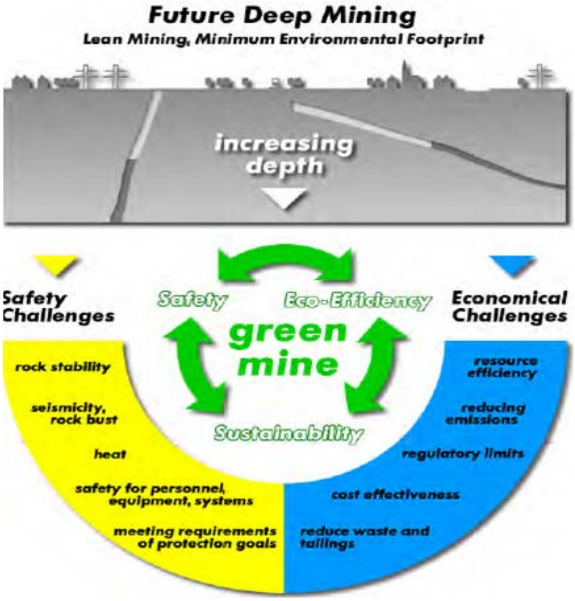

Fig. 1 Innovative technologies and concepts for intelligent mining mine of the future

The concept is for an integrated mine, with the majority of the installations underground, and only the final product will be transported above ground to be shipped to the customer. Production waste will be treated and stored underground and gaseous emissions will be managed underground as far as practical. I^2Mine will also focus on ideas and concepts that increase energy efficiency and decrease waste. In deep mining health and safety aspects are also critical. The ultimate safety in deep mining can only be achieved with no humans, or zero entry, in the operational area. Although not immediately achievable, the zero entry mine will be based on full automation, semi-automation and remote control for all machinery. The first step will be carried out within the framework of I^2Mine. The project will develop innovative solutions in terms of methods, technologies, machines and equipment.

The core of the project will be to develop breakthrough technologies for autonomous, highly selective, continuous mineral extraction processes and machinery based on new sensor technologies, face front separation as well as innovative concepts for mass flow management and transportation integrating state of the art technologies. The concept of an invisible, zero impact mine requires a refined process underground that selectively extracts the mineral thereby reducing waste. For this reason, improved extraction machines and near to face processing methods, including backfill procedures, need to be developed. These developments include rock

mechanics and ground control solutions, incorporating health, safety and environmental issues. New innovative solutions with respect to the environment should focus on the entire cycle of mining with the following objectives:

- Concepts for innovative mining methods for deep deposits, leading to improved resource efficiency through higher extraction rates, a higher selectivity of extraction together with a higher deposit utilization as well as increasing productivity and decreasing production costs.
- Tailor-made concepts for underground near to face beneficiation to reduce the mass flow to surface.
- High resolution 3D exploration methods for deep deposits.
- New concepts for mine management to reduce operational expenditure and new methods for predicting, monitoring and controlling subsidence.
- New methods to handle waste rock underground and backfill products with similar characteristics to the original rock.
- Health and safety design criteria and guidelines for the new concepts and technologies developed.
- Concepts for clean, safe and comfortable climate conditions in the underground workings.
- New concepts and technologies for deep mine rescue.
- On-line best practice database for all environmental aspects associated with mining projects (water management, waste management, emissions, subsidence, etc.).

In today's industrial sector in EU, mineral resources industry not excluding, an innovation trends are changing the way companies produce, distribute and support their products. Economic constraints has opened up markets and sourcing opportunities for producers everywhere. It has brought new customers and increased sales, along with new competitors, unfamiliar customer expectations, relentless margin pressure, and the complexities of global supply and distribution. To adapt within this borderless market environment, society have adopted new innovation ideas: lean principles, continuous improvement and other process disciplines aimed at increasing efficiency, improving quality, reducing waste, lowering costs and abbreviating development cycles (Horizon 2020, 2011).

For a reason of new challenges a new strategic research agenda is preparing by a consortium of relevant stakeholders from mining or raw materials area, creating a network on industrial handling of raw materials for European industries. Such a vision or strategy stated that new challenges required advanced research and innovation to improve the capacity

of existing technologies to discover new deposits, new manner of raw materials processing and to improve the efficiency of the entire life cycle from mineral extraction and processing to product design, use re-use and the exploitation as secondary resource of product at the end of their industrial life. The development of a circular economy incorporating a maximum level of recycling, substitution and optimized use of resources must become a top priority in the coming decades. The concept also accepted a growing interest to describe the whole process chain to improve the efficiency of minerals and metals extraction (geo-metallurgy). There is a need to extend the studies to include all the relevant minor elements in increasingly complex raw materials. A mine-to-metal concept would be the most appropriate approach at this respect.

To summarize all the initiatives, visions, trends, direction and strategy in the area of the raw materials industry transformation with respect to the ecology and environmental issues we can state, that dealing with the research and development of technologies used for the raw material extraction and treatment is the imperative of the content of many European project ideas using innovative technologies to reach the objective, listed following:

- environmental footprint reductions by developing new technologies and applications: water treatment, gas streams handling, etc.,
- radical changes and innovations in mineral and metallurgical processes to improve efficiency and decrease environmental negative impacts,
- clean processes (hydro, bio, pyro) for treatment of complex ores and wastes aiming to reduce environmental impact,
- materials and chemicals to reduce environmental footprint,
- monitoring tools and sustainability environmental management standards, indicators,
- technological and administrative tools for reduction of mining waste,
- management and disposal of wastes in mining operations,
- assessment of the environmental impact of mining activities on groundwater and soils - evaluation of the current knowledge base, mitigation or remediation technologies,
- rehabilitation and chemical and biochemical processes for extraction, sequestering or stabilization of pollutants from contaminated land,

3. Ecosystem services:

It's a new kind of services based on innovative methods, technologies, applications and approaches related to environmental footprint reductions like intelligent monitoring tools and sustainability environmental management standards, indicators, technological and administrative tools for reduction of waste and resource efficiency supporting tools. Resource efficiency is seen as the path where economic development and human well-being can progress with lower resource use and environmental impacts.

The main goal for the future intelligent ecosystem services structure is to develop a decision support system for real time production control and optimization. Such a system will be beneficial for producers and miners to analyze real time data and take prompt necessary actions and utilize the front-edge techniques to increase productivity and decrease energy consumption for processing plants. The raw material and mining industry is highly dependent upon the acquisition and interpretation of data. Until the mineral resource is extracted from the host rock, every ton of ore is virtual, that is entirely based on data. Physical asset valuation is based on information, therefore it is critical that we manage the knowledge that is acquired within our organizations.

As a result, the output of such an ecosystem services should assist to supervise and control the production, back to predefined short-term production targets with most likelihood and optimal approaches. The implementation of such a service mainly consists of multi-criteria analysis, algorithms design, programming, simulation and/or commissioning. For raw materials industry, the multi-criteria are normally comprised of production rates, ore grades, time, environmental quality, and consumption of water, electricity and fuel. Effective ecosystem services for the raw materials extraction and treatment area should be based on three pillars:

1. Mine-wide digitalization and informatization model – an intelligent decision making platform which will use the information from simulation models, historical data and current signals to propose new or altered production strategies, performance, risk and cost analysis in long-term mining planning and safety strategies. The platform form will achieve real-time data from several mining sub systems. There are three main steps to be taken: analysis, evaluation and determination of the requirements, development of the models as well as modelling of the scenarios and connection to the intelligent platform for the support of the decision makers as above.

2. An advanced mine-wide decision support system - an intelligent decision making platform that aids the decision makers in making the right decision in a timely manner. The integral part should be also

an intelligent predictive monitoring system, system for monitoring key components of the production activities in real-time mode and safety policy related to intelligent mining processes. An advanced mine-wide decision support system should be based on control algorithms characterized by the following features:

- new or alternative production plans,
- performance-risk-cost analysis in long-term mine planning,
- reference models and digital engineering tool; modelling of scenarios,
- the computation of the sequence of control actions that minimize the management criterion and to take into account a relatively complex dynamic processes,
- formulate an optimization problem and explicitly predict the behavior of the process in the future,

3. Costs-to-benefit monitoring - offers the cost-to-benefit evaluation and monitoring of cost aspects accomplished by organizational, logistics and technology changes. Such a system of services should provide dynamic economic comparison of real data of the present state compared to data after technologic and logistics optimization. Companies would benefit from such a cost monitoring system taking into account their specific production, financial and environmental goals. Overall costs will be reduced to enable extending life of plant and overall profitability. The results are monetary statements to plant life cycle costs, mining costs, mining risks and performance of performance units. The benefits from cost monitoring are the following:

- the holistic and synchronous consideration of costs, risks and performance already during the strategic planning,
- the analysis and evaluation of technique and economic planning alternatives as well as the utilization analysis of multiple planning scenarios.

4. Costs-to-benefit monitoring:

As mentioned in the heading of chapter 4, resource efficiency is seen as the path where economic development and economical optimization can progress and vice versa. This solution will need an advanced approach to monitoring and managing the production economic parameters through the whole production process. The basis of the advanced approach to monitoring and managing the production economic parameters lies on the continual costs monitoring and the added value growth within the frame of entire production process in segmentation into elementary job operations, its aggregation into technological operation and consequently

into technological processes, that are characteristic for the production node. Costs monitoring in terms of species should be only a secondary criterion. The decisive factor is to identify the reasons and causes of the product or process costs and their relation with the value added growth as well as the ability to regulate their height! The suitable tool for process control of costs creation and value added is the value analysis.

a) The benefits of value analysis

Value analysis is a methodical approach to sharpening the efficiency and effectiveness of any process. Often, businesses apply it to the processes used in product creation or service delivery. In this way also resource efficiency within ecosystem services is seen as the solution where economic development and human well-being can progress with lower resource use and environmental impacts. Paramount to the value analysis is the practice of breaking down a process into each individual component and considering ways to improve that component's value as measured by cost and importance to the process. The benefits for ecosystem services could consist of the following items:

- Eliminating resource costs - a critical advantage to using value analysis is its potential for reducing costs, which is a benefit that permeates all advantages of the system. Because value analysis breaks down a product or service into components, it enables you to analyze each component on its own, evaluating its importance and efficiency. A value analysis correctly implemented and applied allows you to identify components that are not worth the cost they require and that can be eliminated or replaced with alternative. In this manner, the process for the product or service being analyzed is refined to be done at less expense.
- Modernizing resource approaches - the value analysis process often allows users to root out practices that have grown out of date and can be replaced with more modern approaches. This is particularly beneficial when something has been done the same way for an extended period of time. Because the old way works and was new when it was instituted, you have had little impetus to make changes. However, a value analysis, which calls for questioning every step of a process, can reveal new methods that are cheaper, more efficient and sometimes more effective.
- Eco-flaws designing - value analysis can uncover design flaws that not only operate inefficiently but also create problems. In the case of a product, this could mean a high rate of malfunctioning items, creating customer complaints and warranty claims that put a strain on personnel and inventory. It also can lead to bad publicity and

damage to the product brand and the company producing it. Similarly, in the case of a service, value analysis can help pinpoint design flaws in the customer support system that causes service to fall short of customer expectations.

- Customer ecosystem service - value analysis is oriented to weigh costs and the benefit to customers of a product or service. It forces you to consider every aspect of a process in the context of how it serves the customer, which could be a consumer or another business. This means that each step in the process is scrutinized and questioned from the perspective of the benefit that it provides the customer. If the benefit to the customer is small and the step is not necessary for the product or service as a whole, it can be eliminated, allowing you to streamline your operation and to reduce the use of resources.

The authors are members of the team of solvers for advanced approaches and technologies in raw materials extraction and treatment area, where intelligent costs monitoring is an integral part of innovative approaches taking into account also the environmental aspects. Our approach is cost-to-benefit-monitoring compliant and consists of objectification (determination of value added) parameters of aggregates in the sequence of the production cycle. It's a combination of quantitative and qualitative parameters. A quantitative represents chemistry (determination of the percentage of various elements and compounds). These cost parameters are added by the parameters of so-called Address extraction based on customer orders. Based on the economic benefits (in terms of target company) we will be able to determine what disposition of input materials and their fractions we can dynamically prepare and mixed the desired output material according to customer needs and with respect to the environment.

b) Economic impacts in European projects

The European industry faces a number of challenges which require technical solutions that encompass the entire network and include the economic, social and environmental issues. The industry needs a new image based on pioneering solutions and a modern structure that can exploit minerals at greater depths and promote both high productivity and safe working conditions. The concept of an underground mine of tomorrow will need to move from a static control model to a dynamic control system that is capable of processing large quantities of a wide range of data. This mass flow and logistics model will be based on plant design, economic parameters and an intelligent technological logistics system which maximize performance. The concept of future mine will need a comprehensive mine wide network dealing with integrated information management and control

systems. Due to the large amount of varying kind of data, for on-line monitoring, short and long term planning, safe and economic production a new decision support instruments is needed. During the strategic innovation projects planning, the economic framework for the raw materials capacities and investments needs to be defined. To get significant decisions during the strategic planning process there has to be designed a technique concept, including the expected technologies. Therefore a reference model and engineering tool for performance, environmental issues, risks and cost analysis in long-term raw materials planning should be developed.

c) Additional economic impacts

The I^2Mine project is developing new autonomous machinery and equipment enabling for automated extraction and road heading. Due to boundary layer detection, the amount of waste rock cut during mining operations will be reduced. Automated operation will in the longer run reduce costs. The integrated near-to-face processing approach provides significantly higher concentrations of valuable mineral, thus reducing transportation costs. Integrated monitoring and on-line maintenance activities as well as advanced decision making support based on reliable information of the entire mine will also increase productivity through reduction of downtime and could be seen as a new ecosystem services. Altogether, an increase of productivity of eco-friendly activities of at least 20% will be the aim and in some operations towards 30% is envisaged. The work of I^2Mine is dedicated to developing highly innovative tools, methods and machinery for underground mining operations. The work will create significant advances in the knowledge base of the sector, which contributes to reaching or sometimes maintaining world-wide technology leadership in the field. The results of project will, for the mining companies, provide for the ability for selling mineral products at lower prices and increase the available mineable reserves. The equipment manufacturers will maintain and most likely improve their global leadership in providing mining technology. Universities and research facilities shall build upon their knowhow, experience, research and development as well as attract world class researches and students to the industry, as well as build a health respect of what industry require. Considering all of the above facts, I^2Mine will definitely transform the global competitiveness of the European raw materials and equipment producing industries with respect to the environment.

Conclusion

Transforming any other kind of industries, the raw materials not excluding, should examine and develop new innovative approaches and

effective strategies for the prevention of environmental impacts in industries. Industrial cooperation should concerned in regional collaboration of companies from traditionally separated sectors which exchange by-products, energy, water and materials in such way, that the waste from one industry becomes raw material for another. The development of innovative technologies, waste-prevention methodologies, strategies and system tools or services (e.g. eco-design, local industrial clusters, and resource exchange) should be exportable into other European and worldwide contexts. The final goal is to develop a structured and innovative production model for resource-use optimization and waste prevention, also taking residues as secondary raw materials, and test it in real cases of sustainable industrial networks. Results from practice will translate the vision of sustainable development into elements of a sustainable entrepreneurship, focusing at enhancing business opportunities according to a "towards zero waste" approach. A presented facts are supported by own original research (which also includes both authors) used in some structural projects and international projects which promote the above general presented facts. Our workplace is established in the European structures farthest from the Slovak R & D organizations. We are a member of European Technology Platform for Sustainable Mineral Resources (ETP SMR), where we are a member of High-Level Group and one of the founders of new platform. We are the member of the largest European research project - FP7 Program/Project I²Mine: Innovative technologies and concepts for intelligent deep mine of the future. We are the member of another FP7 project: ERA-MIN dealing with building a European research network in industrial raw materials and the cross-border co-operation program HUSK: Virtual reality laboratory for factory of the future. Our workplace is a proactive member of the consortia for the new European Innovation Partnerships: European Innovation Partnership (EIP) on Raw Materials and KIC (Knowledge Innovation Community).

Acknowledgement

„This contribution / publication is the result of the project implementation New technologies for the effective energetic environmental and economic biomass assessing supported by the Research & Development Operational Programme funded by the ERDF“ (ITMS: 26220220063).

References:

Horizon 2020 (2011). The Framework Program for Research and Innovation, Communication from The Commission to The European Parlament, The European Economic and Social Committee and The Committee of The Regions, Brussels, COM (2011) 808.

EUROPE 2020 - A strategy for smart, sustainable and inclusive growth , Brussels, COM(2010).

The Green Paper (2000). “Towards a European strategy for the security of energy supply”, COM 769.
Lavrin, A., Zelko, M. (2011). New trends improving the management and technological base of production on Earth resources. In: Transactions of the Universities of Košice. č. 1, s. 18-22., ISSN 1335-2334.
Koštial, I., Rybár, P., Podlubný, I. (2002). Informatization of raw materials extraction and processing – looking forward to the XXI century, Acta Montanistica Slovaca, Košice, 4 (1), 231-234.
Lavrin, A., Zelko, M. (2006). Knowledge sharing in regional digital ecosystems, Organizacija, Slovenia, 2006, 39 (3), 191-199.
Lipsett, M. G., Ballantyne, W. J., Greenspan, M. (1998). Virtual Environments for Surface Mining Operations, CIM0 Bulletin, 1 (1).
Prawel, D. (2007). The Advent of Visual Manufacturing, White Paper, President & Principal Consultant, Longview Advisors Inc, London.
Spišák, J., Zelko, M. (2010). The Advanced Technologies Development Trends for the Raw Material Extraction and Treatment Area, Products and Services, from R&D to Final Solutions, SCIYO, Croatia, ISBN , 257-278.
Zelko, M., Dorčák, D., Husárová, M., Olijár, A. (2010). The proposal of new technology within the concept of "invisible mine", Proceedings from conference, Czech Republic, Ostrava VŠB-TU, 1(1), 197-203.
Zelko, M., Petruf, M., Spišák, J. (2010). Environment and risk factors as the part of the European technology platform for sustainable mineral resources, Proceedings from conference, Slovakia, p. 131-136.
Koštial, I., Mikula, J., Naščák, D., Gloček, J. (2012). New technologies for granular materials thermal treatment. In: SGEM 2012: 12th International Multidisciplinary Scientific GeoConference: conference proceedings: Volume 2: 17-23 June, 2012, Albena, Bulgaria. - Sofia: STEF92 Technology Ltd., 2012 P. 415-423. - ISSN 1314-2704.