14th International Symposium of Continuous Surface Mining

BOOK OF ABSTRACTS

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TECHNICAL UNIVERSITY OF CRETE
School of Mineral Resources Engineering

ISCSM 2018

International Symposium of Continuous Surface Mining

Public Power Corporation of Greece
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ABB in mining

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Epiroc Hellas provides service and sales for our surface and underground drilling and tunneling equipment including loading and haulage, hydraulic attachment tools, rock drilling tools and geotechnical equipment. Our sales and service team responsible for mining and demolition equipment have transferred from Atlas Copco to become part of the newly created company, Epiroc Hellas. Our products and factories are the same, staff is the same but we have a new dynamic name and image.

Epiroc is a leading productivity partner for the mining, civil engineering, infrastructure and natural resources industries. With cutting-edge technology, Epiroc develops and produces innovative drill rigs, tunneling equipment, rock excavation, hydraulic attachment tools, and provides world-class service and consumables. The company was founded in Stockholm, Sweden, and has passionate people supporting and collaborating with customers in more than 150 countries.

The decision to split from Atlas Copco was to create two world-leading companies that were fully focused on their different end markets and demands. Epiroc customers are from the mining, civil engineering, infrastructure and natural resources industries, whilst Atlas Copco is more focused on manufacturing and process industries.

HYETOS S.A. is a private Consulting Engineers Company which provides Engineering, Consulting, Research and Expertise Services of high quality on various scientific fields, such as Hydraulics, Environment, Geology - Geotechnics, Structural Engineering etc with a strong presence in Central and Western Macedonia.

Geosysta ltd provides engineering consultancy, scientific services and software systems directed towards the geotechnical and mining sector with great emphasis and experience in slope stability, landslides and geotechnical monitoring. Our core value is to sustain a strong connection with our clients while at the same time maintaining our technical and scientific independence.

Planetek Hellas is a Greek company, member of the Planetek Group that since 1994, operates in the field of Satellite Remote Sensing, Spatial Data Infrastructure and Software development for the "on board" and "ground" segment space applications. Founded in 2006, Planetek Hellas provides solution oriented services in the field of Geomatics, involving the use of EO data and systems for environmental & critical infrastructure monitoring, urban planning, civil protection and security.
Planetek has designed, built and commercializes Rheticus, the trademarked award winning Geospatial Analytics Platform, through which the company's solutions are offered in the market. Rheticus represents a disruptive approach of IaaS (Info as a Service) globally scalable, subscription based with low recurrent costs. Rheticus integrates and makes use of state of the art technologies of nowadays such as HPC, AI, Cloud and Internet. More info: www.rheticus.eu.
The company is also active in the field of promotion of Earth Observation and Cosmic Exploration data exploitation and pursues close relations with Education and Research Organizations inside and outside Greece.

HELMA S.A. and WIRTGEN GROUP cooperate for very long time in the field of road construction and mining technologies and machineries in Greek territory.
WIRTGEN GmbH has developed the methodology and technology of Selective Surface Mining, supplying Global Market with three different types of machines, 2200 SM, 2500 SM and 4200 SM and application in mines of iron, gypsum, bauxite, phosphate, limestone, granite, coal etc.
In Greece the Selective Surface Mining technology is applied in PPC mines in Ptolemaida.

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Session 1: Mine planning and design

Simulating the BWE-Conveyor-Stacker System in Python using Salabim

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The BWE-Conveyor-Stacker mining system has been simulated during the last 45 years using various IT tools including general purpose or simulation specific programming languages and commercial simulation software. The paper presents a simulator of the BWE-Conveyor-Stacker system developed using solely Open-Source Software tools that are freely available for downloading from the Internet. At present stage of development, the simulator can accommodate a mining system that consists of a BWE, any number of conveyor sections, and a Stacker or a Bunker Spreader. It runs on a single GUI window which is sectioned to include data input, simulation output and plots. A detailed output report for each project is generated, in pdf format, for printing and record keeping. The simulator has been developed in Python using Salabim, a discrete event simulation package recently available, and runs as Microsoft Windows application.

A Holistic Approach for Highly Selective Mechanical Process Chains

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The paper describes the holistic approach of the research project InnoCrush. The greater goal of the project is to prepare innovations in the field of mechanical driven and highly selective process chains in mineral extraction. The core features of such process chains lie in a) the use of mechanical excavation methods instead of drilling and blasting and b), the subsequent utilisation of a near-face mechanical, dry, selective comminution to create a pre-concentrate. With the synergetic use of both technologies, a major part of the waste material can be separated from the ore either during excavation as well as during subsequent comminution. Hence, the waste can directly be backfilled or dumped. The focus lies on vein like deposits that can profit most from such technological chains. The project itself focusses on Lead-Zinc and Fluorite-Barite Ores.

Such process chains can provide benefits in terms of great automation potential, minimization of emissions, increase of work and rock safety, as well as considerable financial savings during final comminution steps. The latter can be traced back to the fact that considerably less material must be milled during the final comminution steps. Limitations however, are present in the form of toughness and abrasivity of the rock as well as the potential of ore and waste for a selective comminution.

A summary of the present results within the project InnoCrush is given as well as discussing how a multilevel, holistic approach to synergy-dependent process chains is necessary in order to push the boundaries of mechanical excavation chains further.

Integrated Operation in Mining through Digitalization – from a Concept to a Solution

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The whole world is talking about Industry 4.0 or Digitalization. This trend also arrived in the Mining business a few years ago, but what does it mean for the Miner? This joint presentation with Elektroprivreda Srbije (EPS) is about a system approach by ABB to reach the convergence of Information Technology (IT) and Operational Technology (OT) to harvest the huge benefits of integrated operation. An actual project will be presented, where ABB is developing on behalf of EPS a system for pro-active planning and production control with the involvement of all required stake and shareholders.

The Production Planning, developed by DMD Consulting and integrated with ABB AbilityTM Stockyard Management System (SYMS), creates optimized plans for material homogenization on the belt conveyor systems from the source (mine excavators) to the destination (direct train loading or stockyard). To achieve a fully coordinated production all actions of the required machinery have to be performed in a strict sequence. Such a coordination requires a lot of well aligned activities. To support the operator all production management, control and planning functionalities need to be integrated in a single system.

For instance the mine excavators have to be positioned at the right spot and need to perform in a defined way. Further, in order to control such a complex system a dedicated way of delegation to Process Control, a good Material Tracking, Downtime Management and Production Control with forecast functionality is required. And ABB's Stockyard Management System covers all those roles.

In this common presentation EPS and ABB will explain the geological and technological reasons for the implementation of such a system, present the concept of a continuous mining methodology with online quality control to create the desired quality already on the belt conveyor system and state the challenges of implementation of such a digitalization project.

Current State and Development of Continuous Systems on EPS Opencast Coal Mines

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Currently, opencast coal mines of Electric Power of Serbia (EPS) produce about 40 million tons of coal per year within two basins and five opencast mines. On that basis, 70% of electric power is being produced in Serbia. Since some opencast mines are undertaking closure procedure, it is necessary to open replacement capacities in order to continue coal production. This paper shows the current state, development perspectives, opening plans for new opencast mines and planned continuous mining systems which are foreseen to operate in the future time period.

Session 2: Modeling and simulation

Ultimate Pit Limit Determination for Fully Mobile In-Pit Crushing and Conveying Systems: A Case Study

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Fully-mobile in-pit crushing and conveying systems have different pit shape requirements to traditional truck haulage systems due to linear bench and flat floor constraints imposed by conveyor systems. As the shape of a pit is largely based on the ultimate pit limit, it is desirable to have the additional shape requirements of fully mobile in-pit crushing and conveying systems included in the ultimate pit limit determination process. This paper discusses and highlights why there are different requirements for these systems, and what they are. A method of including these extra requirements during ultimate pit limit determination is presented. A case study has been included that shows the method working successfully, with scheduling of the pits to further highlight fully mobile in-pit crushing and conveying viability. This case study shows that through the reduced mining costs, a fully mobile in-pit crushing and conveying pit can return a higher Net Present Value, despite being smaller than the traditional truck and shovel pit for the same deposit. The development of this method provides the opportunity for the metalliferous industry to accurately determine ultimate pit limits for a mines considering the use of fully mobile in-pit crushing and conveying systems.

Assessment of the Added-Value of Sentinel 1 & 2 for Mapping and Monitoring Surface Mining

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The Greek mining industry constitutes a major sector of the economic activity of the country and supplies essential raw materials for primary industries. Moreover, the industry provides a major source of employment in the country, and because, as a rule, the processing of these raw materials takes place in the region in which they are excavated, the industry also contributes considerably to coveted regional growth. Every mining activity impacts the nearby environment, causing the so-called mining hazards. Active mining operations are usually well monitored by the owners and by the mining authorities. In this framework, the issues of acceptance from local populations, corporate social responsibility, systems of quality control, and systems that allow collection and disclosure of full and accurate information (Databases, GIS, etc.) are all of particular importance. Within the EU Geocradle project a system is under development for monitoring legal / illegal quarries using satellite imagery in cooperation with the personnel of the Ministry of Environment / The Authority of the Ministry of Environment and Energy / Special Secretariat of Inspectors – Auditors / Body of Inspection for Southern Greece / Department of Mining Inspection. Surface mining also includes the activity of the coal mining. The methodology described in this work refers to the Monitoring of Lignite Mining Activities in Ptolemais basin in Greece.

Application of the Push-Relabel Algorithm to Lignite Surface Mine Optimisation

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Open pit optimisation is a process aiming at the determination of the extents of the optimum pit such that the profit made in mining the pit is maximised. The choice of blocks to mine for the optimum pit is an example of the selection problem. A selection problem is based on a set of tasks, where each task has a value or a cost. In most cases, there are certain relationships between tasks, such that in order to perform one task a number of prerequisite tasks must be performed. The solution of the selection problem is the subset of tasks that the sum of their value is the maximum possible within the set when performed. In terms of mining, each block (a task in the selection problem) in a 3D block model is assigned either a profit or a loss based on the revenues and costs associated with mining the block. Geologic constraints are used to establish slope requirements for each block which are used to determine the blocks which must be removed prior to the removal of any given block. Traditional methods of solving the selection problem in open pit optimisation included the floating cone algorithm and the Lerchs-Grossman algorithm based on graph theory. The latter dominated open pit optimisation software products and solutions in the 80s and 90s and offered mining engineers a solid solution to the pit optimisation problem. A decade later from the first implementation of the Lerchs-Grossman algorithm, Picard proved that the pit optimisation problem could be solved with more efficient maximum flow algorithms. In 1988 Goldberg and Tarjan published the first paper describing the Push-Relabel algorithm for solving the maximum flow problem. Later in 1997, Cherkassky and Goldberg published a paper describing a very efficient implementation of the more general Push-Relabel algorithm. This algorithm is used in our case study of surface lignite mine optimisation. A lignite deposit from the region of Kozani as well as all associated technical and financial parameters are used as input to the Push-Relabel implementation provided by a mine planning software package, and the optimisation output is analysed in order to assess the benefits of applying the Push-Relabel algorithm to lignite deposits.

Use of Mine Planning Software in Mineral Resources and Reserves Estimation of the Lava Lignite Deposit in Servia – Greece

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The use of mine planning software in the evaluation and estimation of mineral resources and reserves is well established nowadays in the mining industry for the design and scheduling of surface mines and it is a requirement for the reporting of mineral resources and reserves according to international reporting codes. The fundamental principles of these codes are the transparency of the reported material, the relevance of the information included in the report and the competency of the persons involved in the estimation and reporting process. This paper describes the application of mine planning software in the estimation and modelling procedures of the operational lignite mine of LARCO GMMSA at the Lava deposit in Servia, Kozani. All stages of exploration data analysis, geological modelling, grade estimation, resources reporting, mine design and optimisation, reserves calculation and scheduling of the mining operations are explained. Data integration, advanced 3D graphics and specialised modelling algorithms all within a user-friendly environment contribute to the successful implementation of mining industry accepted procedures to the effective planning and estimation of the surface lignite mine. The more than 10-year long user experience of LARCO GMMSA trained personnel (geologists and mining engineers) adds to the effectiveness of the mine planning software implementation.

Carbon: A WebGIS Software to Evaluate and Model Open-Pit Lignite Mining Systems

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both at Evmolpos – Earth Science Consulting Company

Carbon is a web-based open pit lignite mining management system to assist mining scientists and land managers in achieving "best practice" mining outcomes. The Carbon-WebGIS application gives the ability to the user to: 1) evaluate mining borehole data, based on specific user criteria, and calculate the upper and the bottom lignite surface, 2) print the original and the evaluated borehole with depth, 3) produce spatial model of Tonnage distribution and Lignite/Overburden thickness, taking into account faults and borehole distribution, 4) calculate volumes of overburden and lignite deposits over an area, 5) design open pit and calculate overburden and lignite volume in it, 6) produce cross sections over model and/or boreholes, 7) design and edit spatial data of model areas, open pit areas and fault structures, 8) export model data in .grd, .img, .asc format, vector gis data in .shp, .dxf format and parametric data in .csv format, and 9) create 2D and 3D maps showing lignite with depth, the boreholes, the faults and the open pits. Carbon is created based on Open Source architecture, using PostgrSQL/PostGIS, UMN MapServer, GeoExt and OpenLayers for GIS data manipulation and 2D map creation, and Three.js for 3D map creation. The Carbon WebGIS system can be a powerful tool in Mining Management mechanism.

Model-based Investigations of Hybrid Mining Systems Using Cutting, Crushing and Conveying Technology in Medium Hard Rock

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One of the most important aspects in mine planning is the selection and dimensioning of equipment as it has a tremendous impact on the economics of the mining operation. At this stage, mine planners have to set up a philosophy how to mine, meaning either to use discontinuously or continuously operating equipment. In soft rock deposits the use of continuously operating equipment is already state-of-the-art, whereas it is not in medium hard rock. In the latter case truck and shovel operations are more common today, though the decision is not driven by economics but the degree of higher flexibility and lower initial investment. Another fact is the industry wide acceptance of this technology. But, there seems to be change in mindset as mining companies have to cope with stricter regulations concerning environmental factors. At this point, electrically driven and continuously operating equipment can make use of their inherent advantages.

This paper presents application potentials for continuous cutting, crushing and conveying systems. The evaluation methodology is a scenario-based comparison. Therefore, BARRACUDA®-type bucket wheel excavators, fully-mobile and semi-mobile In-Pit Crushing and Conveying systems, as well as discontinuous truck and shovel operations are compared against each other. A hypothetical mine cross-section is the basis of research and data is derived from literature, empirical values and project work. The results show application limits of abovementioned systems and outline potentials in cost effectiveness. In addition, it is the aim of the investigation to help mine planners in equipment selection and system process development.

Why One Dimension is Not Enough – A Comparative Study of Lignite Resources Estimation Using Drillhole Mineable Lignite Compositing of Uncorrelated Seams and Mineable Lignite Compositing of Correlated Lignite Seams

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Lignite deposits in Greece of the type consisting of multiple thin lignite layers are traditionally estimated using a one-dimensional compositing approach that suffers from large error margins particularly in the presence of medium to large tectonism and uneven vertical distribution of lignite seams. Each drillhole is evaluated using mining and processing criteria leading to a number of mineable lignite "packages", the sum of which is reported as the total mineable lignite at the drillhole horizontal location. The total minable lignite values from the various drillholes are interpolated horizontally leading to a two-dimensional model of the mineable lignite parameter. A more advanced version of this one-dimensional approach has been applied with improved results in the past. In this version, the one-dimensional approach was limited to a single mine bench and repeated separately for each bench, thus reducing the scale of potential errors and better approaching the vertical distribution of mineable lignite. In effect, each bench was approached as an isolated lignite "deposit", reducing the effects of applying a one-dimensional approach to a 3D modelling problem but not making them completely disappear. Lignite deposits, such as the one examined in this paper, require the development of a thorough stratigraphic model to allow the reporting of accurate lignite resources and form the basis for solid mine planning and lignite reserves calculation. The evaluation of mineable lignite using mining and processing criteria can then be applied to modelled raw lignite seams leading to an overall three-dimensional model of the deposit that allows accurate lignite resources calculation even in the presence of tectonism. This paper presents all three modelling approaches through an extensive case study based on part of a real lignite deposit. The effects of using each of the approaches are analysed and the benefits of the three-dimensional approach are clearly demonstrated.

Unsupervised Machine Learning Applications on Greek Lignite Mining Industry

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In the new competitive environment, the surface lignite mining operations face many challenges which require the application of appropriate data mining techniques and analysis of all available data considering the whole mine life cycles. In this framework, statistical or machine learning algorithms can contribute to improve mining operations and increase efficiency and competitiveness.
In this paper, a proposal to implement two significant unsupervised machine learning methods and algorithms, the Principal Component Analysis (PCA) and Clustering, in all phases of surface lignite mining operations is presented.
In the first stage, it is suggested to apply PCA and Clustering in the phase of primary mineral deposit investigation, using the data acquisitions of borehole logs, geophysical exploration, satellite images, geological maps, etc. in order to determine the kind, magnitude and location of the future mineral exploration, considering extensions to regions with geological lack of data or origin.
Furthermore, applications of PCA and Clustering to mine planning phase can contribute to the improvement of mine planning efficiency. The segmentation of the whole mining area into characteristic operational sectors can be achieved based on PCA and Clustering results. Case studies in two surface lignite mines are included. The main task here is to use the method of clustering to geographically separate the mining regions according to their properties. An advantage of the method is fast, accurate and friendly to user implementation in R code.
Another application of PCA and clustering refers to the operational mine phase comprehension and improvement. An example is provided concerning the actual monthly operational data of a continuous surface mining project as explanatories variables. The divergences between scheduled and real production indices and characteristics are revealed related to factors through PCA.
Finally the application of unsupervised learning techniques to the evaluation of environmental impacts of mining activities is also discussed. As case study regarding the lignite bearing fields mine water and regional waters relations is additionally presented.

An Evolutionary Solution for Coal Reserves Modelling and Production Scheduling

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Coal and other stratigraphic deposits consisting of multiple layers commonly require a lot of time and effort to produce a representative geological model that will allow accurate estimation of reserves and provide a solid basis for effective mine planning. The transition from such a 3D geological model of stratigraphy to an effective Run-Of-Mine model that can be used to calculate reserves is a critical part of this process. Approaches to achieve this transition range from one-dimensional mineable coal compositing of drillhole data to more effective three-dimensional aggregation of mineable coal seams based on an appropriate stratigraphic geological model. There are very few commercial software packages that integrate a complete stratigraphic modelling module, and even fewer that have the capability to take the process further into production scheduling. The solution presented in this paper is based on two commercial software packages part of the same family of products – Maptek Vulcan, a general mine planning package with advanced stratigraphic modelling capabilities, and Maptek Evolution, a mine scheduling package based on evolutionary algorithms. The examples presented in this paper show how the two packages together provide a complete solution for coal reserves modelling and production scheduling.

Geostatistical Estimation of Coal Reserves in Kardia Mine using Kriging and Conditional Simulation Methods

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Representative estimates of the total tonnage of coal deposit and its spatial distribution are key factors for mine planning and the design of the affiliated power plant. Accurate knowledge of such estimates is crucial for long-term mine planning as well as to determine economically feasible energy production needed to meet demands. Geostatistical methods have been extensively used in reserves estimation and mine planning in order to address such problems. The family of kriging methods provides tonnage accurate estimates as well as confidence levels that give an approximate estimate of uncertainty. Furthermore, conditional simulation methods can represent in more detail the uncertainty and spatial variability of the reserves.
In this study, both kriging interpolation and conditional simulation are applied to drill-hole data from the Kardia lignite mine, which is located in Northern Greece. After investigating the statistics of 608 drill-hole data from the area, multilinear regression was used to estimate a deterministic trend function. Different variogram models were fitted to the residuals that represent the spatial fluctuations. Based on the weighted square error, the best variogram model was selected. The optimal variogram model was then used for the application of Ordinary Kriging to the residuals, and the kriging predictions were combined with the deterministic trend to estimate the spatial distribution of coal. The resulting kriging maps were utilized to evaluate the reserves over the area of interest. Finally, to more accurately estimate the confidence levels of the reserves, 1000 conditional simulations were generated using the method of kriging-based polarization of unconditional realizations. The latter were generated by means of (i) the covariance matrix decomposition and (ii) the turning bands method.

Session 3: Equipment and mining systems

Experimental Investigation of the Activated Rock Cutting Process

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The development of hard rock cutting technologies represents a great interest in a number of mining and construction applications. Results of multiple researches demonstrate the potential of the activated rock cutting to significantly expand the application limits of the excavation equipment to harder rocks.
Basing on laboratory test results, the current study is focused on the investigation of the process of cutting granodiorite and dolomite samples with an activated cutting tool utilizing the impact rock fragmentation principle. The tests were carried out with the use of the Design of Experiments method. The obtained data enable characterisation of the influence of cutting parameters on the specific energy consumption and the advancing of the cutting tool into rock. Considerations on the applicability of the activated cutting technology to the continuous excavation of hard rocks are given in the paper.

Determination of Optimal Life Cycle of Bulldozer in Open Pits with Continual Systems in PE EPS

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Satisfactory time and capacity utilization of continual systems on open pits is possible just under the assumption of providing optimal conditions for their operation. One of the most significant preconditions is in-time and quality execution of all auxiliary works, which brings us to the fact that open pit has certain auxiliary mechanization (type, number, capacity, power, etc.). Currently, more than 330 heavy machines are hired in PE EPS`s open pits. One third of that number are bulldozers. Cost for procurement and operation of auxiliary machines are relatively high. In total cost it varies from 13% to 18%. Particular problem which distinguishes from others is that low availability of dozers and high costs of exploitation is present in the last years in PE EPS`s open pits. One of the reasons is untimely replacement of dozers which leads to additional costs for maintenance, higher fuel and grease consumption and low availability. This paper shows an overview on optimal dozer time period for replacement.

The Role of the Independent Expert in Material Handling and Mining Equipment Design and Approval

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Design and delivery of material handling and mining equipment such as bucket wheel excavators, spreaders, reclaimers etc. is a complex process, which is prone to many faults made by designers and manufacturers.
Independent Expert institution is the recently common procedure of calling the external institution for the design crosscheck. Only recommended by standards, however very common, almost mandatory in all new industrial projects.
Described procedure is introduced in purpose to improve the quality of the entire deliverable of the project. Independent Expert responsibilities are design assessment, manufacturing control, erection control as well as performance tests supervision on the delivered structure. Described procedure increase the initial costs of the project, however limits the future investments and downtime of the machine. In case of the objects, which desirable durability time is of about 30 years, this brings savings difficult to estimate. In the paper, authors present their experiences gained as the Independent Expert during many projects completed in the field of material handling and mining equipment.

Development of a Real-Time Mine-Face Inspection System for the Early Detection of Hard Rock Formations during Mining by Bucket-Wheel Excavators

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The existence of hard rock formation with high cutting resistance, during mining with bucket wheel excavator (BWE), causes frequent stoppages, increased equipment wear, or even severe damage of the BWE. These result to increased idle and break-down time, to high energy consumption, to low production rate and finally to increased mining cost. A proactive solution that was examined during the research project BEWEXMIN included the development of a real-time mine face inspection system. The system uses geophysical sensors for the early detection of hard rock formations during the excavation by BWE. More specifically an Electromagnetic (EM) sensor was employed for continuously measuring the electrical resistivity of the material in the mine face. The resistivity data were processed and evaluated in real time by specially developed software to estimate the diggability of the excavated material ahead of the excavation face. At the same time the risk of collision, between excavating buckets and hard rock formation, was also estimated. When the BWE approaches hard inclusions, visual and audio alarms were generated by the system. The above system was tested and evaluated in South Field Mine. Results indicated that the developed system can succeed high percentage of true alarms keeping at the same time the percentage of false alarms low.

Simulating the Performance of Bucket Wheel Excavators by Means of Soft Computing Techniques

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Fuzzy Cognitive Maps (FCMs) are signed digraphs, which consist of nodes representing the factors that describe the behavior of a system, and edges, which are weighted arcs connecting the concepts and representing the causal relationships among them. FCMs offer certain advantages (e.g. they can incorporate uncertainty, show high ability to demonstrate complexity, are not demanding in terms of funds and time). Thus, as a soft computing technique, they have been used in various and completely different applications from different areas. In this paper, FCM approach is used as a means for qualitatively modeling and analyzing the performance of bucket wheel excavators, a crucial component of continuous surface mining systems. Using both an extensive review of scientific literature and expert judgment as the basis of the analysis, a qualitative simulation framework is developed to perform qualitative simulations with respect to the performance factors of the bucket wheel excavator. To this end, several parameters, e.g. characteristics of the excavated material, number and thickness of lignite layers, bucket wheel capacity and fill rate, maintenance of the system, experience of the operator, etc., are employed to reveal cause/effect relationships, explore the dynamics of the system and carry out what-if and sensitivity analyses. The model is a first step towards simulations intended to help mining practitioners. The main goal is to propose a different simulation approach for mining complex systems that can interconnect the factors affecting system's behavior by providing a transparent and flexible model. In future research, the model can be combined with or tested against Learning Algorithms, which are used for automatic construction of FCMs from historical data, so as to developed a more advanced and accurate representation of the system under investigation.

Analysis of Dislocation of Continual System at "Field D" in Function of Overburden and Coal Production at Eastern Part of Kolubara Coal Basin

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Large reserves of lignite and suitable locations of basin, mountain-geological and climate conditions, geometry of deposit and physic-mechanical characteristics of working area enables use of high productive continual mechanization for excavation of overburden and coal throughout open cast mines within Kolubara coal basin.
For excavation, transport and disposal of overburden in use are co called ECS systems (excavator-bucket wheel or chain, conveyer belts with rubber, spreaders), and for coal exploitation ECC or ECL (excavators, conveyer belts, crushing plant or loading place) systems.
Use of this kind of systems has a lot of advantages comparing to discontinuous systems, but far more less flexibilities during occurrences of incidental cases, such as big land sliding or changes of technology and dislocation to new site caused by different circumstances. At Field D, which work continually for 58 years and with total production, for that time, of more than 500 mill.tons of coal, complex configuration of coal seams demanded special technology for work with often reconstructions and movement of systems. During 2007.almost all of production was stopped due to unsolved legal ownership, particularly problems about local cemetery. To ensure continuity in production it was necessary to relocate several systems to new location (former outside dump yard) and in a very short period, and for that strict demanding and complex organization of works was conducted. This kind of work, at open cast mines, is always difficult and multiplex and with long time preparation period with no production which, in this particular case, had to be established in short time period.
This paper work shows activities taken during dislocation of system, starting from planning, engagement of all other mechanization until re-establishment of production at this mine.

A Real-Time Event-Driven Database System for Maintenance Planning and Productivity Analysis in Continuous Surface Mining Operations

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This paper presents a real-time event driven data management tool, which was developed as a Productivity and Maintenance Planning Tool for the surface lignite mines in northern Greece. The mines operate using a continuous mining system, utilizing bucket wheel excavators, conveyor belts, spreaders and stackers. Each mine features its own control center installation comprising of PLCs, Aspect Servers, OPC servers and a SCADA system. The data management system is installed on the network backbone and draws data from the OPC servers. Data are automatically populated by events and data polls and can be subsequently modified by control tower personnel. Reports are typically generated on a daily basis for production monitoring, productivity, equipment performance and utilization as well as maintenance tasks. The system has been operational since 2011.

Methods of Decreasing of Bucket Wheel Excavators Failures Working In Soils Including Unmineable Intrusions

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The article presents the work carried out in the Poltegor Institute, which aims to reduce the number of failures of bucket wheel excavators operating in soils including unmineable intrusions. This will be achieved by adaptation of bucket wheel excavators already in service and newly built to for exploitation in such conditions, monitoring of the load bearing capacity of a bucket wheel excavator, developing a diagnostic signal analysis method for current superstructure damage hazard assessment and continuous endurance monitoring.

Open Pit Mine Conveyor Belt shifting using modern surveying equipment – An overview

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One of the basic but most important procedures of an open pit mine is shifting of the conveyor belt and its relevant drive station and tail station. The cm high accurate shifting of the conveyor belt and respective positioning of the drive stations and tail stations pontoons is of crucial importance as it secures –surveying wise- that the belt will better operate. This paper presents a detailed analysis of the surveying method, equipment and computations needed -regarding both fieldwork and office work- for conveyor belts' and drive station / tail station on pontoons' shifting.

Overview of the Results of Researches Related to Adaptation of Bucket Wheel Excavators Operating in Romanian Lignite Open Pits for Excavation in Rocks with Increased Cutting Resistance

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The paper deals with the results obtained in the field of lignite and overburden rock cutting process using BWE-s in the conditions of Romanian lignite open pits, focused mainly on the newly arisen problem of occurrence in the working faces of structures with increased resistance. Due to changing geological environment, in Romanian lignite open pits endowed with BWE-s, the occurrence of structures with increased resistance – continuous layers, boulders - and a general decreasing trend of cuttability parameters of all overburden rocks is more and more present. Based on results of previously performed researches, and the new ones facilitated by the activity in the frame of BEWEXMIN project, the team of professionals from the University of Petrosani, CEO and University of Alba Iulia has extended the researches from cuttability assessment and teeth – bucket improvement towards the analysis of the operation in these conditions and its impact on the mining system of BWE. The main results of the performed theoretical, laboratory and field research is presented in the paper.

New Method of Residual Lifetime Assessment of Bucket Wheel Excavators Operating in Romanian Lignite Open Pits

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The paper deals with a method of residual lifetime assessment of the BWE-s operating in Romanian lignite open pits which is based on the correlation between the failure history of a fleet of BWE-s with different age and different working hours in working environment with different degree of difficulty with a laboratory- field fatigue assessment method based on hardness increase with the number of loading cycles of the elements of the boom structure. The results allow estimating the residual lifetime of the existing excavators and also to the forecast of overall system reliability of new or refurbished excavators to be implemented.

Session 4: Geotechnical engineering

The Role of Geological Faults in Mine Stability: Amynteon mine, Western Macedonia (Greece) as a Case Study

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Landslides are destructive phenomena, related to negative environmental and economic effects. In many cases, geological faults hold a key-role, as they are responsible for the triggering of landslides. In the present paper, we examine the geological setting of the wider Amynteon lignite mine region (Western Macedonia, Greece), where a complicated landslide phenomenon occurred on June 10th 2017, leading to the cancellation of mining activities and the partial evacuation of the adjacent Anargyri village. The mine is located in a lignite-bearing Neogene lacustrine sequence, while six major fault zones are documented in the broader area, two of them affecting the mine itself. They are the NE-SW trending normal fault zones (Anargyri and Vegora faults) and the mine is located at the transfer zone between the overlapping tips of these two zones. Anargyri and Vegora faults are dipping to the NW and SE, respectively, forming a graben, as well a multitude of internal secondary faults. The presence of the geological faults is decisive for the mine stability, as they cause fragmentation of the lithological formation and cohesion degradation, while the hydrological conditions and mining activity further affect the mine stability. The combination of those factors led to the Amynteon lignite mine landslide phenomenon, proving the great importance of geological faults study during excavation activities.

A Cloud-Based Real-Time Slope Movement Monitoring System

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Excavations and slopes in mines all over the world get deeper and steeper. This has been possible because of the significant technological achievements in mining technology and the increased efficiency of the excavating and hauling equipment. As mines become deeper, stability problems become more important and need to be evaluated and assessed even on a daily or hourly basis. Mining personnel must have access to accurate information on excessive slope movements and/or imminent failures. To assess slope conditions requires installing and maintaining a substantial monitoring system. Most such systems can generate significant data per hour or per day depending on the specific monitoring application. This vast amount of data needs to be efficiently processed and transformed to information that can be stored and evaluated quickly and efficiently in order to make operational decisions.

This paper presents a cloud based database software monitoring system that can efficiently record, transfer, store, analyze and evaluate monitoring data and generate easy to view and easy to use information. Data can be manually uploaded by mine personnel or automatically retrieved from monitoring devices. The data are stored in a firebird cloud database where they are automatically analyzed to generate appropriate displacement, velocity and other time series data. The results can be easily compared with other data, such as precipitation values, deep inclinometer readings, etc. The system can reliably and quickly generate information about excessive movements, alarm levels etc. and alert authorized personnel. Utilizing this system in every day mine operations in high and difficult slopes enhances safety and increases productivity.

The Impact of the Coal Clay in the Slope Geometry of the OCM Radljevo North Opening Cut

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Opening a new surface coal mine is a very complex process depending on a large number of factors that directly or indirectly define the conditions and dynamics of mining operations. The investigation of the future excavation area should be at such a level that available data should show the state of the terrain as realistic as possible on that occasion. It happens often that the influence of certain parameters is ignored or for some other reason is being eliminated, which later creates great complications, which often lead to human and equipment vulnerability.
In this paper, influence of interlayers coal clay particles was analysed, slope geometry of the opening cut of the OCM RADLJEVO NORTH, as well as on its position in relation to the OCM TAMNAVA WEST FIELD internal dump site.

Reliability Evaluation during Slopes Progressive Failure

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Progressive failure of slopes is a relatively common problem in surface lignite mines. In the present work, a probabilistic methodology that takes into account the inherent geotechnical uncertainty is suggested for the evaluation of a homogeneous slopes' reliability during progressive failure phenomena. The proposed methodology is built upon the reliability index based Point Estimate Method combined with finite elements computations. Shear strength parameters are considered non-correlated random variables following normal distribution. Stability for various safety states, up to the ultimate failure state, is expressed and evaluated in terms of global reliability indices and global probabilities of failure. For illustrative purposes, a typical case example is solved following the suggested methodology. It is anticipated that the established reliability model may be further extended in order to take into consideration slopes' transition failure probabilities during progressive failure.

Avoiding Instability Conditions in Sector 6 of the Southern Field Mine in Northern Greece

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Tectonic structure system crossing the mine benches of Southern Field Mine in Ptolemais basin could activate tension forces towards the open slopes, creating thus possible instability conditions. Detailed study of the geological conditions contributes to detect any instability factors and explain the mechanism of possible failure. Continuous observing, measuring and mapping of tension cracks and deformation movements is of major importance in order safety measures to be taken to avoid any mining failure.

Investigation of the Stability of Deep Excavation Slopes in Continuous Surface Lignite Mines

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The paper investigates the stability of slopes in PPC lignite mines in Greece, where continuous surface mining is applied with excavation depths up to 200m. Experience with the behaviour of such excavations shows that slope instabilities are usually governed by sliding along a sub-horizontal, unfavourably sloping, interface between coal and an underlying stiff, high plasticity clay or marl layer, very close to the bottom of the slope, where shear stresses are largest.

The typical mechanism of such instabilities is triggered by the sharp contrast in stiffness between adjacent lignite and clay/marl layers causing different elastic rebound upon removal of the horizontal confinement during excavation. The resulting differential horizontal strain causes shearing along the lignite-clay interfaces and the development of significant negative excess pore water pressures in the stiff clay. Shearing is larger in deeper interfaces (close to the base of the slope) and increases drastically in cases of unfavourably sloping interfaces (towards the mine). If the shear stresses approach the peak strength of the interface, creep movements become appreciable, gradually reducing the available strength of the interface towards a low residual value. This strength reduction is accelerated by dissipation of the negative excess pore water pressures in the clay, as pore water can drain towards the adjacent lignite (through tension cracks caused by the elastic rebound).

The paper investigates the effect of these parameters on slope stability by a set of parametric analyses. The results are plotted in dimensionless graphs which can be used in preliminary stability analyses of lignite slopes. It is shown that (in addition to height and inclination) the most important parameter is the inclination of the sub-horizontal lignite-clay interface at the base of the slope.

The paper also reviews several slopes in the PPC lignite mines which remained stable despite movements with relatively constant velocities reaching up to 100 mm/day, while others have failed when velocities accelerated abruptly although much smaller. These cases show that the absolute magnitude of slope velocity is not always relevant in predicting slope instability, while slope acceleration (plotted as the inverse of velocity versus time) is a better indicator.

PPC Excavator Production improvement of 20% by iBelt 2D Radar Control

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This paper describes the installation, functions and benefits of the indurad iBelt volumetric conveyor belt measurement solution developed for a Bucket Wheel Excavator at PPC, Greece. The indurad iBelt is a modular conveyor belt control solution based on original indurad radar sensors designed and built for harsh environments. For PPC, iBelt was installed on the E3 excavator boom conveyor belt in the South Field coal mine. iBelt measures the excavated material volume in real time and displays all information in the operators cabin HMI to feed it into the industrial network of the mine. PPC engineers now have the ability to control the productivity of the excavator from a remote engineer station, which has resulted in a 20% increase in average hourly production of the excavator. iBelt is therefore a reliable and highly robust step towards the digitalization of mines and advanced process control.

Gearless Drives for Medium Power Belt Conveyors

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Producers who handle ores, rock, coal and the like are heavily dependent on high-capacity conveyor belt systems that are reliable, efficient and very robust. The hourly cost of a conveyor breakdown can be substantial, so uptime is a parameter of primary importance. ABB has long supplied conveyor systems that meet the stringent demands of producers in a wide range of industries.
ABB's new permanent magnet (PM) motors for medium-power gearless conveyor drives (GCD) reduce production costs and increase competitiveness. A PM motor, combined with gearless technology, also fulfills eco-design requirements, saves energy, reduces failure rates and lowers maintenance overheads.

Mining 4.0 - Our Digital Journey

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Up to 60% of OPEX result in the transportation cost within a mine.[1] There is a trend to use continuous conveying technology as a cost-effective transport method. Increased application of long as well as steep incline systems can be observed in the markets. The demand for a predictive maintenance is rising. Therefore, solutions for a stationary as well as mobile monitoring of conveyor belts is necessary. Data management and analysis are important conditions on the journey for an innovative service provision. Cloud technology represents an interface for data exchange. Digitalization is the basis for new business models.

Session 5: Health & Safety, Environment

Control of Social and Environmental Risks During Opencast Lignite Mining

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The opening and development of large opencast lignite mines with complex continuous mining systems is subject to a large number of environmental and social risks. The impact of the mines is constantly increasing, therefore monitoring and adjusting to changes are becoming a priority for the managers of mining companies.
The process of controlling social and environmental risks, which could temporarily or completely stop lignite mining production on opencast mines, is based on the analysis and determination of the probability of occurrence, the operation reliability of the opencast mine, the necessary safety reserves of lignite and the required costs for minimizing the impact of the risk to a minimum.
Social risks are related to sustainable development, harmonization with the local community and government legislation. Environmental risks can be controlled, when it comes to sustainable mining, and partially uncontrolled, in relation to natural disasters. Together they represent a serial stochastic process with probabilities which define the reliability of the opencast mine production as a whole.
The set methodological approach allows for practical interactive control of the social and environmental risks during opencast lignite mining in real space and time, and is the basis for optimizing the process of sustainable mining.

A Review of the Effectiveness of Health & Safety Management Systems according to OHSAS 18001 Standard at PPC's Lignite Mines

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PPC's Mining Business Unit in seeking to achieve free from injury and disease lignite mines' workplaces, in collaboration with PPC's Department of Health & Safety at Work, works to lead and coordinate efforts to prevent workplace death, injury and disease. For the Public Power Corporation S.A respect for the society and the environment, it's not just a legal obligation but a fundamental corporate goal, a key part of the broader business policy and a cornerstone of corporate social responsibility. Mining Business Unit has integrated the planning, management and performance evaluation of health & safety issues through the development of a Health & Safety Management System according to international standard OHSAS 18001 at its workplaces (mines and support units). The objective of this paper is to review the effectiveness of this system in Lignite Centers' operation and to show the gains and the simplicity of development and implementation, the lessons learned and the opportunities of further development and continual improvement. Occupational health & safety system performance is not easily measured. The complexity of occupational health & safety is such that simple quantified measures are often inadequate and does not represent the overall performance of the System or its impact on organisation's safety culture. Increased attention has been given to positive performance indicators and audit tools as measures of some aspects of health & safety management system performance.

Innovative Approaches to Coal Surface Mine Sites Rehabilitation: A Case Study of Megalopolis Lignite Fields

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Coal surface mining can have significant effects on environment, related to both physical disruption of land morphology, habitats and ecosystems. It can also affect substrate factors such as ground/surface water quality. More significantly however, coal mine sites could leave behind a legacy of secondary detrimental effects due to permanent land form alterations. Traditionally, mine site rehabilitation should return sites to safe and geotechnical and geochemical stable conditions where, land forms, soils, hydrology, habitats and flora and fauna are self-sustaining and compatible with surrounding land uses. To this end coal mine sites are usually returned to their pre-mine uses, which, for the majority of mines is agriculture, wildlife habitat or forestry.

However, new ethos in mine closure plans is the repurposing of mine sites i.e the identification of a creative, successful and economically sustainable future use taking advantage of the existing infrastructure and being the result of a successful collaboration of mining companies, regulators, land-use planners, investors, and citizens to identify the most beneficial use.

This paper examines some rehabilitation practices, leading to repurposing of mine sites on some mostly typical lignite and coal mines worldwide. Some good national examples are also used to point out how mine closure plans can be drafted before mine activity closure, leading to the creative and successful re-use of decommissioned mines.

The case study presents a rehabilitation plan of Megalopolis lignite fields, where continuous surface mining has been applied.

Impact of Environmental Policies on Lignite Plants Generation In the Greek Wholesale Electricity Market

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Lignite is a significant and essential part of the Greek electricity generation mix. Historical data demonstrate the critical contribution of lignite plants throughout the years. EU energy policies are currently focusing, among other targets, to the decarbonization of European electricity market. Greece, as an EU member state follows the EU trend by adopting all relevant regulation at national level. Scope of this paper is to investigate the impact of environmental EU and national policies into the generation output of lignite plants in Greece. The measures of the EU Emissions Trading System (EU ETS) and the Transitional National Emission Reduction Plan (TNERP) are presented and their impact on lignite plants generation in the Greek Wholesale Market between 2013 and mid 2018 is discussed.

Alkali Activating of Low-Alumina Mine Tailings for more Sustainable Raw Material Supply

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Each year, the mining industry generates a significant amount of mine tailings. Disposal of mine tailings (MT) has environmental impacts such as air pollution from dust emissions and release of heavy metals to surface and underground water. The EU funded project 'Integrated mineral technologies for more sustainable raw material supply (ITERAMS)' as a part of its aims is trying to develop an alkali activated materials from low-Aluminium mine tailings from the Kevitsa mine in northern Finland using different alkali activator solutions investigated firstly the compressive strength of the final products. Based on the final strength of the prepared samples, the selected activator (sodium silicate here) was subsequently used for the further experiments. The alkali activated mine tailings (AAMT) were prepared by mixing different concentrations of sodium silicate solution, water and the MT powder. The MT contains X-ray amorphous material in addition to Quartz, Tremolite, Dolomite, Forsterite and Enstatite. Using a curing temperature of 40 °C led to strengthened and dense materials. The structure and morphology of the alkali activated products was determined by Scanning Electron Microscopy (SEM) which also confirmed the presence of phases leading to an increase in the compressive strength. It should be noted that the alkali activation of MT constitute new and novel materials with potential environmental protection applications such as low permeability covers for surface deposits of tailings to seal the surface tailings disposal area. Alkali activation involves the manipulation of materials within the tailings to change the properties of the resulting material. The water penetration and the permeability of oxygen are crucial factors for proper functionality of the installed covering layer.

Occupational Accidents in Turkish Energy Sector

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In a developing world, the spreading and progress of industry, agriculture and social service is a necessity. Such a progress is often associated with an increase of occupational accidents. Unfortunately, occupational accidents are destined to reiterate itself and the reasons are in very case the same (human mistake, poor regulatory enforcement, etc.). There are 2.78 million deaths per year and 374 million non-fatal work related injuries and illnesses each year. The human rate of this daily adversity is high and the economic onus of not enough occupational safety and health practices is assessed at 3.94 per cent of global Gross Domestic Product each year. Work accidents occur in Energy sector as other sectors with the difference that happens more often. Petroleum and Natural Gas sector play the most crucial role in the world in power generation. Many accidents happen in Petroleum and Natural Gas fields and the negative outcomes affect the surroundings. In this attempt, the official statistics on Turkish crude petroleum and natural gas sector are analyzed for the period between 2011 – 2016. All studied data are taken from Social Security Institution of Turkey (SGK), which includes the fatalities, serious injuries, minor injuries and working population for Turkish Petroleum Industry for the period 2011-2016. Fatal Accident Rate (FAR), Serious Injuries Rate (SIR) and Individual Risk (IR) are calculated together with F-N curve analysis. Moreover, OSHA incident rate (based on lost workdays) is also calculated. Furthermore, some recommendations are made in order to take the necessary preventative measures to decrease all the necessary rates related with occupational accidents. It should be mentioned that his method of analysis could be applied to chemical-petrochemical activities and surface mining activities (continuous and non-continuous) for the exploitation of coal deposits.

Adaptation of Fruit Crops in Rehabilitated Old Mines Soils in West Macedonia Lignite Centre

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The primary purpose of rehabilitation in post mine area in West Macedonia Lignite Centre, Northern Greece is the recovery of the nature and ecosystem, and the creation of a self-sustaining land surface. However, the effective utilization of post mine area for the productive uses such as agricultural crops and other potential economic have been taken into consideration in recent years. About 1,000 ha of these land are already covered annually with cereal crops, but require specific treatment if they are to be rehabilitated for fruit land production. A 5ha orchard and a vineyard were established by the Public Power Corporation SA in an old mine to evaluate the adaptability of 12 fruit trees species in this specific environment. In 2001 were planted 15 apple, 9 pear, 10 cherry, 3 walnut, 9 peach, 1 nectarine, 1 plum, 4 grapevine, 1 quince, 1 jujube, 1 raspberry, 1 gooseberry and 2 persimmon varieties. After 15 years of cultivation several problems recorded regarding adaptation on soil or climatic conditions. Success of crop adaptation was judged on the basis of yield, blossom set, incidence of disease and survival rates in comparison to adjacent control orchards. Grapevine, cherry, walnut, apple and jujube trees responded quite well while persimmon, plum, peach, raspberries pear and quince trees revealed severe adaptation problems. Fruit yield in rehabilitated soils did not exceed 60% of control orchards yield while tests for heavy metal did not show significant differences compared with local market fruits.

Evaluation of Honey Producing Potential of Robinia Pseudacacia in Reforested Old Lignite Mines in West Macedonia

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Opencast mining is important for local and global economy, but this operation mostly and inevitably leads to substantial environmental damage. Potential future use of the post-mining lands basically depends on the nature of the land, soil conditions, and communal structure of nearby surrounding to be rehabilitated by technical, biological, agricultural means or forestry applications. Vegetation cover has significant functions on post-mining landscapes so, in order to reduce the probability of negative impacts, selection of suitable plant material, which may be preferably native but also introduced plant species, is critical. In West Macedonia Lignite Centre, about 1,500 ha of these land have already reforested by the Public Power Corporation S.A., with Robinia pseudacacia L., one of the most criticized non-native tree species in Europe, because its rootstocks spread into neighbouring areas, repressing native species. The tree is an excellent species for revegetating poor or damaged soils and its fast-growing nature, makes it popular for former lignite mine reclamation, reforestation and erosion control. Robinia forests represent a valuable nectar and pollen source in late spring for many insects, especially Hymenoptera, such as Apis mellifera. That has increased dramatically the regional honey producing potential. In this study, the annual potential honey production of 1,500ha black locust forests established in reforested old mines land, was estimated from 50,000 to 70,000 kg honey, depending on the year, which is sufficient for up to1,000 bee hives to survive for one year. For the efficient utilization of this valuable honey producing source by the beekeepers, a plan should be developed, to facilitate accessibility to the region and proper beehives dispersion.

Sustainable Development Analysis of Lignite Mining, by Coupling Environmental, Economic and Social Indicators

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Energy sufficiency is a primary target for all countries worldwide. Fossil fuels lie at the top of the list of resources that must be exploited to accomplish this target. Continuous surface mining occupies the highest proportion of the category of coal/lignite production, thus holding a leading role both in the energy and financial markets. In addition, these large-scale operations extend to more areas of human life with various environmental, social and economic impacts. All the above, constitute the evaluation and assessment of a lignite deposit, in terms of sustainable exploitation, a particularly complex process. This paper attempts to contribute on this field by presenting an indicator for sustainable development called "TOSDIMA" (TOtal Sustainable Development Indicator for Mining Activity) and by implementing it in a lignite deposit in Greece. TOSDIMA is synthesized by three Environmental, four Economic and two Social sub-indicators which are directly linked with the sustainable development assessment. The proposed method includes the analysis and quantification of the sub-indicators and their synthesis for estimating the TOSDIMA value for the lignite deposit. The proposed framework can constitute a useful tool for planning exploitation strategies, managing mining activities, supporting and validating research and operational objectives, by always taking into consideration sustainability standards and viable development perspectives.

Technological and environmental upgrading of lignite from Amynteon and Ahlada deposits, in Northern Greece, via selective grinding

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Lignite plays a dominant role for energy production in Greece, covering over 50% of the demand for electricity generation. Energy crisis requires, additionally to alternative energy sources, an increase in energy supply from both old and new deposits. Due to the low quality of mined lignite, methods of upgrading in terms of power plants' efficiency and environmental performance need to be applied. In this work, the technique of Selective Size Reduction (SSR) was adopted for two deposits in North Greece, Amynteon and Ahlada, in order to improve lignite quality through reduction of its mineral matter content. The variation of the qualitative characteristics of the grain fractions produced by SSR provided useful information on both the suitability of these fractions for combustion in the power plants of the area, as well as on the emissions of greenhouse gases. The results have shown that fractions, which were produced from the first stage of crushing, with a recovery between 83% and 95%, had lower ash by 18-27% than the raw material and were of acceptable quality for combustion in the power plants of the area. Beneficiated fractions could give energy efficiency between 34 and 36%, while a reduction in CO_2 emissions up to 29%.

Session 6: Land reclamation

Moving from Energy Depletion to Energy Crops in Exhausted Continuous Surface Mines

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Agriculture is a sector that can provide considerable quantities of biomass to be used in regional biomass power facilities. Agricultural residues represent an attractive alternative source to fossil fuels in Greece and the considered available quantities have been evaluated up to over $4.5x10^6$ dt/yr (dry tones/year, dt=tn). In this study, an analysis and cost evaluation for the development of an agricultural biomass supply chain is conducted regarding energy crops. It concerns the tillage, collection, processing and storage of perennial herbaceous biomass, to be cultivated in the depleted Continues Surface Mines in Ptolemaida (PCSM) area that belongs to the Public Power Corporation (PPC), and is scheduled to be restored and rehabilitated after mine's exhaustion. This is for the full compliance with the environmental terms set by the Ministry of Environment that allocate 37% (5.471 hectares), of the total restoration area for cultivation. The residues that are produced from the cultivation of Cynara Cardunculus L (Cardoon), have been investigated and analyzed in terms of quantities, energy potential and spatial distribution, in an attempt to identify and determine the ability of this particular feed stock to support district heating or electricity production either by itself or by co-firing with lignite in the neighboring PPC's Power Generation plants. Moreover the economic viability of this particular feedstock, from the investor's point of view is also examined, by comparing the costs of the different harvesting, transporting and storing methods in conjunction with proprietary or hired equipment. The results revealed that, the most cost-effective harvesting method is in bulk; the machinery equipment used for harvesting and transporting the crop are proprietary; the personnel employed in harvesting transport and storage are in an employment relationship with the collector, and that storage is more economical when it is bulk windrows in open space with cover to protect against weather conditions. Moreover the thermal content of the biomass itself can easily support district heating or power generation up to a certain extent.

Towards a New Deal for the Lignite Industry in Western Macedonia

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Having reached its peak in 2004, the production of lignite and lignite power accordingly has been steadily declining in Western Macedonia, coming to a mere 50% of its corresponding production in 2004. Estimates for the next 15 years indicate that this decline will continue towards the end of this period, resulting in lignite production in the region dropping to 1/3 compared to that of 2004. In this paper, there is documentation by quantitative indicators of the heavy negative impact that will be brought on the Western Macedonia economy by the escalation of the decommissioning of lignite units, both in terms of Gross Added Value and in terms of income generation for the wider region, unless simultaneous large-scale development actions and substantial employment support are promptly implemented. In addition, the paper presents the basic parameters of a New Deal for the lignite utilization as a raw material in the production of high added value products, along with its use in power generation, creating a secure and viable bridge for the transition of Western Macedonia to the post- lignite era.

Backfilling and Securing of abandoned Small Scale Coal Mines in Mongolia with Coal Combustion By-Products (CCB's) - the BASMIC Project

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In Mongolia more than 500.000 t of "Coal Combustion By-products" (CCB's: Fly Ash, Bottom Ash, Boiler Slag) are generated by 5 Power Plants. Most of these CCB's are usually disposed to special designed ponds without any environmental or social benefits. Particularly the pozzolanic material behaviors qualify CCBs as stable construction material, e.g. for backfilling operations in underground mines.
In Nalaikh - 30 km southeast of Ulaanbaatar - hundreds of small scale miners are digging for coal, leaving behind a multitude of unsecured surface openings and unclear branches towards the subsurface. During the peak season in winter up to 2.000 Nina-miners work in around 200 mine shafts. Nalaikh's coal counts to about 70% of the 1 Mio. t coal burned every year in UB's ger district.
The abandoned small scale mines, over time, often pose a permanent threat to humans in the neighborhood. Stabilization of these mine sites is a crucial part of a rehabilitation concept that has been developed at GMIT for the Nalaikh mining area.
The aspect of rehabilitation in mining areas is becoming more and more important in society. For the bigger mine sites in Mongolia rehabilitation concepts are available. For the smaller mine sites and especially for the Ninja-mines of Nalaikh such concepts are not yet available, even if the necessity is given and commonly accepted.
Currently the "German Mongolian Institute for Resources and Technology" (GMIT) is starting a project "Backfilling and Securing of abandoned Small Scale Coal Mines with Coal Combustion By-Products (CCB's) generated at Power Plant Sites and with Domestic Coal Combustion By-Products generated at Ger District Sites" (BASMIC) to improve both, the sustainable usage of CCB's and the stability of abandoned small scale mines.
BASMIC analyses CCB's and CCB's in combination with other materials to determine their suitability as backfill material for abandoned mining sites. The abandoned small scale coal mines should be backfilled with CCB's, to ensure ground support and regional stability.

Land reclamation planning of continuous surface lignite mines in closure phase: A risk-based investigation

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The exploitation of a continuous surface lignite mine is a complex framework that requires high capital and operational expenditures, resources and use of excavating, transporting and dumping equipment for several decades. When the lignite mine enters the closure phase, the land reclamation and remediation of any environmental damage caused in the wider exploitation area constitute a multidisciplinary intervention of high impact for the lignite and energy producers as well as local societies. This paper investigates the critical technical, socio-economic, environmental and permitting issues and associated operational risks involved with the environmental management of a lignite field into mine closure phase, based on empirical evidence and managerial practices followed in relevant projects. The selection of a low risk reclamation technology is analyzed as a critical decision-making problem for lignite mining organizations and environmental stakeholders to achieve cost effective and environmentally acceptable reclamation options. Recommendations and proposals for development of a risk-based multi-criteria methodology advised, perceived as a tool for efficient control of risks in managing projects of lignite mines land reclamation.

A Multi-Criteria Methodology for Low-Risk Evaluation of Mine Closure Restoration in Continuous Surface Lignite Mining Projects

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The restoration of continuous surface lignite mines that fuel mine-mouth located thermal power plants is a complex, long-term and multidisciplinary initiation, particularly in the case of mines that have been operating for many decades and now enter the closure phase. Various environmental, technical, economic, social and engineering factors have to be early considered during the assessment and evaluation of alternative restoration technologies of which reclamation is the most critical. This context inserts critical decision-making risks, since projects of this nature have considerable environmental and social impacts. Therefore, the project decision makers have to select the most appropriate and lower risk solution among a set of several restoration/reclamation alternatives. The paper identifies the decision-making problem and suggests a multi-criteria methodology combining the AHP (Analytical Hierarchy Process) and TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) techniques with a case study for ranking of the lower risk restoration/reclamation alternative in a closing lignite mine. The methodology is suggested as a low cost and easy development tool for lignite mining operators, reclamation project managers and environmental stakeholders.

Session 7: Water management - Environmental monitoring

Planning of Mavropigi and Kardia Mines Depressurization Systems by Three Dimensional Groundwater Flow Numerical Modeling

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Mavropigi and Kardia lignite mines, located on western margins of South lignite bearing Ptolemais basin (NW Macedonia, Greece), have an annual lignite production of $15*10^6$ tones available, to provide it as partial contribution to the 3000 MW Power Plants' Electric System.
The confined loose water bearing formations under lignite seams, in fact can be extremely dangerous as water may enter the excavation area after piping or heaving the mine bottom and benches.
In present paper there is an effort to simulate in three dimensions the underneath lignite seams aquifer's groundwater flow into the loose Neogene sediment's porous media, in order to implement a depressurization water well's system of appropriate magnitude and other dewatering of mine measures or acts to be dimensioned only to confront heaving and piping effects.
The studied part of this aquifer was simulated in two layers of 1086 nodes each one, which lie in a square grid with a distance of 300 m between them. The simulation was performed on FREEWAT MODFLOW-2005 application in cooperation with Q-GIS open source that held all geological and hydrological information. The results of 3 stress periods model running revealed that is feasible the decompression of the aquifer under approximately 1500 m^3/h average pumping rate in both mines. The afterwards decompression, dewatering of free aquifer is not included to present investigation, because the appropriate ground water lowering to ensure slope stability is not geotechnical investigated yet.
The possibility of an artificial recharge on the decompressed aquifer is prospected to be simulated in future by the same numerical model. Thus it will be a further future investigation, going to the right direction of regional water resources rational management.

Improvement Methods of Pumping Station Function in Coal Mines of Western Macedonia Lignite Centre

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Lignite mines dewatering efficiency in Western Macedonia Lignite Centre is based on a complex pumping system with appropriate capacities. This paper discusses the results of two series of water and sludge samplings from pumping stations of mines in Western Macedonia Lignite Centre. These samples were analysed in order to identify the water quality of mine pumping stations. Particularly, physicochemical parameters and the concentration of suspended particulates solids were tested. The results showed that the pumped water quality of Western Macedonia Lignite Centre mines is within the limits set by the local authorities for the protection of the aquatic receiver of mine water discharges. Many samples meet even the EU standards for the suitability of drinking water. Consequently, the pumping system of these mines is characterized sufficient enough. Moreover, sludge samples were tested via X-ray powder diffraction (XRD) analytical technique. The analyses results showed that the mineralogical composition of sludge samples is similar to the geoenvironmental profile of the greater mining area. The paper concludes by outlining some methods for the mine pumping station upgrade.

Alfeios River Sectional Diversion for the Expansion of the Continuous Surface Mining Operations of Megalopolis Mines in the Peloponnese Peninsula, Greece

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Strategic planning and operation of continuous surface mining projects are in many ways influenced by the Geological, Geotechnical, Hydrogeological and Hydrological conditions of the mineral deposit and the mining field. The Hydrological conditions prevailing in lignite deposits with extensive horizontal spatial distribution often relate to streams or rivers which are mainly associated with the formation of the deposits. They have a significant effect on: (a) the long term planning and mining sequence from the initial cut to the depletion of the mine, (b) the boundaries of the mining field which may change during planning and operations processes, (c) the slope stability of the excavations, (d) the mine closure and land reclamation.

This paper investigates the hydrological conditions related to the development of Megalopolis continuous surface mines, in the Peloponnese Peninsula, Greece. The analysis is focused on the successive diversions of Alfeios River for the expansion of the lignite mining activities and the corresponding risk factors. Alfeios is the longest river in the Peloponnese. The river is about 110.00 km long, flowing through the regional units of Arcadia and Elis. Its origin is located close to the village of Dorizas, about halfway between Tripolis and Megalopolis, in the highlands of Arcadia.

Emphasis is placed on the considerations, the methodology and the final design for the planned sectional diversion of Alfeios River, for the extension of the boundaries of the Choremi mine. In order for the mining activity to expand towards the south-most part of the Megalopolis Mine Complex (Choremi mine), it is necessary for a section of approximately 2.70 km of the Alfeios River channel to be relocated further to the south. The study for the abovementioned diversion takes into consideration the Hydraulic, Geotechnical and Structural aspects of the complete project.

Particularly, as far as the Hydraulic design is concerned, a detailed hydrological analysis was conducted for the calculation of the flood runoff, using the Soil Conservation Service (SCS) unit hydrograph method. The design flow values were estimated for design periods T of fifty (50) years and one hundred (100) years. The

flow of Alfeios River was simulated using one-dimensional, step by step, steady flow analysis for open channels.

Furthermore, for the verification of the overall design, all the necessary Geotechnical considerations were addressed. Detailed, long-term, steady state seepage models were constructed, both for non-ruptured and ruptured lining, in order to determine the maximum possible level of the water table due to the hydraulic load in the channel. In addition, extended stability analyses were performed for the diverged channel slopes, the embankments and the southern mine slopes, taking into account the pore water pressure conditions dictated by the aforementioned steady state seepage analysis. The performance of the clay lining was estimated and special erosion control measures were prescribed considering the flow conditions in the channel.

Finally, the energy dissipation works at the confluence of Alfeios River and two significant secondary streams in the area (Kserilas Stream and Ag. Giannis Stream), were designed and verified by specific structural analysis, according to Greek and European Codes.

Surface Mining in Western Macedonia, Greece: PM10 Emissions and Dispersion

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The operation of large open-pit lignite mines represents a significant source of fugitive dust emissions connected to energy production. In the process of extracting and handling excavation materials (overburden, lignite, waste material), a series of fugitive dust emission sources are recorded. The quantification of the emissions of each individual source and the investigation of atmospheric dispersion are subjects of great interest, because of the specificity of diffuse emission sources and the wide range of the particular characteristics of the excavation and handling materials. They constitute the foundation for the development and implementation of the environmental management and decision-making system that aims to avoid exceedance of air quality limits in the neighbouring residential areas. In this study, the contribution of the surface mining on the air environment of Western Macedonia, an industrial area in NW Greece, is investigated. Four open lignite mines (South field, Kardia, Mavropigi, Amyntaio) feed the lignite power plants operating in this area, contributing to the atmospheric pollution of the region. This study is referred to the PM10 emissions, emitted from the newer of the above mines (Mavropigi). Specifically, the percentage of the contribution of each individual activity – emission of fugitive dust over the period of one year is calculated. Furthermore, the dispersion of PM10 emitted from the whole mines operating in the area is simulated. For this purpose, emission factors were used that were calculated specifically for the mines of the Western Macedonia region in the context of the THEOPHRASTOS project, funded by the Lignite Centre of West Macedonia / Public Power Corporation SA. Specifically, the contribution of the individual PM10 emission sources recorded in the continuous and non-continuous extraction method was quantified and particularly by the following activities - PM emission of the Mavropigi mine: shovel excavation and loading, hauling and dumping, moving vehicles on unpaved haul road, bucket-wheel excavators, excavator's head, stacker head, multiple cross point. At the same time, there was an effort to investigate the dispersion of air pollutants emitted from each individual mine (South field, Kardia,

Mavropigi, Amyntaio) and source activity and assess the contribution of the mining activities to the air quality of the surrounding areas, by using a three-dimensional, nestable, prognostic meteorological, and air pollution model. The results can contribute to the implementation of measures and scenarios for the air quality management in the area.

Statistical Analysis and Spatial Distribution of Trace Elements Contained in Clays Excavated in Western Macedonia Continuous Surface Mining Complex

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Twenty one clay samples of Pliocene – Pleistocene age were collected from five active and three inactive mines of Western Macedonia Lignite Centre and were tested by the INAA and ICP-OES methods to determine the concentrations of 10 major and 39 trace elements. The content of clay samples in carbon and sulphur and the loss of ignition were also determined.

According to the results of a statistical processing that was conducted, the comparison of trace elements concentrations of clay samples collected from the entire lignite-bearing Neogene basin of Ptolemais as well as the comparison of the same concentrations with the mean values of the Earth's crust, preliminary conclusions have been drawn concerning the spatial (horizontal and vertical) distribution of trace elements concentrations in the clays contained in overburden and intercalate waste of the lignite deposit. Furthermore, useful information has been gathered about the behaviour of trace elements contained in clay layers during lignite combustion - utilisation processes.

The average concentrations of all the analysed major elements are similar to the MVEC. Regarding trace elements, Co, Cs, Hf, Rb, Sc, Th, U, La, Ce, Nd, Sm, Eu, Tb, Yb, Lu, Cu, Pb, Zn, Ni, Cd, Ba, Sr, Y, Sn, Zr, Be and V exhibit enrichment factors that vary from 0.5 to 3.0 among the different mines of the examined area, while the highest enrichment factors exhibit the elements Sb (3.5 ppm), Ag (4.1 ppm) and Cr (4.6 ppm) (average values in the entire Ptolemais – Amynteon basin). Nevertheless, the elements of greatest environmental concern (As, Se, B, Cd, Hg, Mo, Pb) are present in clays in low concentrations.

Taking into consideration the alkaline pH values of the surface water, groundwater and soils of Ptolemais basin, the probability to occur severe pollution incidents due to toxicity caused by the trace elements contained in the clays of the lignite deposit is negligible.

Session 8: Geological exploration, quality control, homogenization

Structural Geology of the Lignite Mines in the Ptolemais Basin, NW Greece

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The active, opencast, lignite mines in the Ptolemais Basin, NW Greece, provide world-class outcrops for characterising and understanding normal fault systems from km- down to mm-scale. We have visited and mapped these mines 26 times at ca. 3 month intervals since October 2009. The data collected during each fieldwork campaign were structural measurements, interpretations, various resolutions of photographs and GPS locations for all exposed faults and related structures observed in each mine. Part of this unique dataset has been imported within a fully georeferenced 3D structural interpretation package and has been used for fault and horizon interpretations. Our motivation for this work is to advance our generic understanding of the structure and development of normal faults, but in this contribution, we focus on some of our findings that might be of more general interest to mine planners and designers.

Structural Analysis of Greek and Bulgarian Coals by Solid-State 13C Nuclear Magnetic Resonance (NMR) Spectroscopy

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In the present study, lignites and sub-bituminous coal samples from Greece and Bulgaria are characterized through high-resolution, solid-state 13C Nuclear Magnetic Resonance Spectroscopy (NMR). Solid state 13C Nuclear Magnetic Resonance (NMR) spectroscopy is a very powerful tool for determining the chemical structure of complex organic substrates such as coals of various ranks and the effects of this structure on conventional pulverized coal combustion. Additionally, from an environmental point a view, 13C-NMR spectroscopy technique is widely used to investigate the possible link between Balkan Endemic Nephropathy (BEN) – a form of interstitial nephritis which can cause irreversible kidney failure, affecting rural people in Croatia, Bosnia and Herzegovina, Serbia, Romania, and Bulgaria but not in Greece – and the leaching of toxic organic compounds from Pliocene lignites in the Balkans by groundwater. Hence, the intention to shed light on the relationship between BEN disease and the organic functionality of coals by means of the solid-state 13C Nuclear Magnetic Resonance (NMR) spectroscopy is also embedded in this research work.

Energy Efficiency by Ecological Coal Quality Management in EPS and Its Benefits

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Production of electric power in a power plant from the coal excavated in Kolubara mines lasts more than 50 years.
Besides the significant resources that are still available within the Kolubara basin, and continuance in the coal exploitation, it is necessary to fulfil the following: very strict requirements for environmental protection and preservation, demands from power plants regarding quality of coal, required sustainability in coal production, demands for securing stabile and reliable existence for inhabitants from local communities etc.
Among others, afore mentioned are the reasons for implementing Coal Quality Management System (CQMS), and through its development and implementation the rational use of coal deposit and excavation of all parts with changeable and lower quality will result in constant quality.
Particular and specific solutions in CQMS project are reflected, not only in the definition of work during coal exploitation, but in the immediate benefits as well.
Those benefits will be seen in the coal mine production-as a supplier and power plant-as a consumer, during the production of energy.

Morphology, Mineralogy, and Chemistry of Fly Ash from the Ptolemais Power Stations, Northern Greece, and its potential as partial Portland cement substitute

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Morphological, mineralogical, and chemical properties of three composite Fly Ash samples from Agios Dimitrios, Amyntaio and Kardia lignite-fired Power Stations, Northern Greece, were studied applying Scanning Electron Microscopy (SEM), X-ray Diffraction (XRD) and X-ray Fluorescence (XRF) methods. The -45 μm fraction of each sample was also analyzed. Morphologically, fly ash consists mostly of silica coated plerospheres, cenospheres, and calcic-sulphuric agglomerations. Fiber shaped silica phases were found in the fly ash sample from Amyntaio Power Plant. The fly ash samples are mainly composed of anhydrite, lime, calcite, gehlenite, and quartz. Differences in the mineral and the chemical composition between the bulk sample and the -45 μm fraction were noticed. Fly ash samples picked up from Agios Dimitrios and Kardia are mainly calcareous while in Amyntaio Fly ash silica oxides prevail. The potential of the fly ash samples as a pozzolanic additive to Portland cement was examined on the basis of the ASTM C311 standards.

Open Pit Mine 3D Geological face mapping perspectives obtained by a fully automated, terrain following, rotary-wing UAVs mission

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Geological face mapping is perhaps the most significant method of mining benches imaging, as it maps out the stratigraphy, the existing geological structures and helps understand the geology of the mine in order to efficiently plan the exploitation of the deposits. This paper presents how new perspectives are being created in open pit mining with the use of a small commercial rotary-wing UAV performing geological face mapping in a fully automated terrain following mission.

Investments in Geological Exploration and Affectation on Mining Operating Cash Costs at Lignite Open Pits Kolubara (Lazarevac), Serbia

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This paper presents a brief overview of the spent funds on geological explorations in the past few decades of the Kolubara mining basin. The results of the performed surveys are extremely important. They reflected in the following: 1.1B t lignite mined out. On four active surface mines, at the exploitation stage is more than 1B t of lignite. The next 1B t is in the phase of final geological exploration, design and investment in future mining technological processes. The last 1B t of useful mineral raw materials is still in the form of mineral resources. In addition, several hundred million tons of quartz sands of Pliocene and Quaternary gravel within the lignite deposits, for now, are still only in the form of mineral resources, and represent additional opportunities to increase total profits of open pits. This paper presents a summary of costs, natural and combined factors and indicators of realized geological exploration on selected lignite deposits in the Kolubara coal basin.
By the end of 2017, the total geology research costs barely reach 1.2 euros cent / tonne of lignite, which is extremely low and does not burden the costs of investments, expropriation, excavation-exploitation, processing and transhipment of coal. The commercial sales price of coal to thermal power plants is 1.74 € / GJ (reference selling price).

Do Coal Combustion Products Affect the Groundwater Quality Around Power Plants Area of the Lignite Ptolemais Basin?

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The West Macedonia Lignite Center (WMLC) is located in Ptolemais basin and constitutes the largest coal-mining district in Greece. The power plants (PPs) in Kardia and Ag. Dimitrios are in operation today, whereas the Ptolemais PP has ceased operations since 2014. This paper examines the influence of the lignite combustion products (fly-ash) on groundwater quality near PPs, by evaluating data from: a) wells' lithological sections, b) water table measurements, c) pumping tests and soil permeability tests, d) soil and fly-ash chemical analyses, e) Soulou stream water and groundwater, chemical analyses and f) land uses.

The hydrogeological conditions between the three areas are different. The presence of ultra-mafic rocks of Vermion Mt. influences groundwater recharge and quality at Ag. Dimitrios region. Groundwater depth varies from 7.5 in Ptolemais PP up to 102 m Ag. Dimitrios. Permeability of the sediments of the basin (k) ranges between $1.55x10^{-3}$ and $7x10^{-6}$ m/sec. Soil permeability (k) of the vadose zone varies between $1.2x10^{-5}$- $4.7x10^{-7}$ m/sec. The geochemical environment (alkaline) is not conducive to mobilize metals in groundwater. Heavy metals and trace elements (As, B, Ba, Cd, Co, Cu, Mn, Ni, Pb, Se, Sb, Sr, V, Zn) are recorded in low concentrations, under the limits of WHO (2011), in most of the groundwater and surface water samples. Elevated values of Cr_{tot} (up to 137.89 μg/l) in groundwater were measured only near Ag. Dimitrios PP, although Kardia and Ag. Dimitrios fly-ashes have similar composition and similar deposition conditions. In the wider area of Ag. Dimitrios PP, soils are highly enriched in serpentine, comparing to the soils of the other two PPs, due to the occurrence of ultra-mafic rocks in Vermion Mt. Agricultural activities are extensive (fertilizers, pesticides, etc.) in Ag. Dimitrios area, as indicated by NO_3^- concentrations (up to 139 mg/l) in groundwater. The geological environment influences significantly the quality of the groundwater of the basin, with agricultural activities and the use of fertilizers playing locally an important role as well. The contribution of fly-ash to groundwater quality is of minor significance.