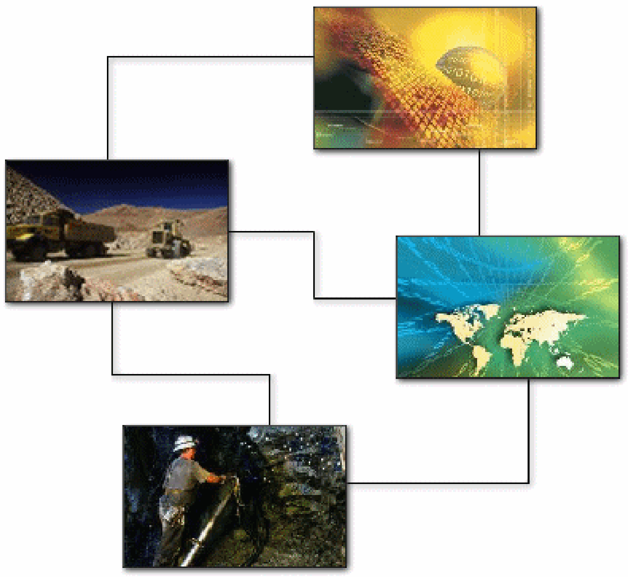
Noise and dust emission from mining activities: a software for measurement management and analysis of suitable reduction techniques

PROCEEDINGS OF THE FOURTEENTH INTERNATIONAL SYMPOSIUM ON MINE PLANNING AND EQUIPMENT SELECTION (MPES 2005) AND THE FIFTH INTERNATIONAL CONFERENCE ON COMPUTER APPLICATIONS IN THE MINERALS INDUSTRIES (CAMI 2005)



MINE PLANNING AND EQUIPMENT SELECTION AND COMPUTER APPLICATIONS IN THE MINERALS INDUSTRIES

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MINE PLANNING AND EQUIPMENT SELECTION AND COMPUTER APPLICATIONS IN THE MINERALS INDUSTRIES

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Foreword

Raj K. Singhal

The basic aim of this conference is to contribute to the development of high-tech methods and technologies for the various segments of the mining and processing industries. A wide range of high quality papers from North and South America, Europe, Australia, Africa and Asia have been attracted. Major topics to be covered at MPES 2005 and CAMI 2005 are: Coal Mining Technologies: Processing Equipment and Quality Control; Open Pit Mine Planning, Design, and Productivity Gains; Underground Mine Planning and Design; Drilling, Blasting and Excavation Engineering; Mining Equipment Selection, Automation and Information Technology; Mine Maintenance and Production Management; e-Maintenance, e-Diagnostics, and Prognostics; Road Headers, Tunneling and Other Excavation Equipment; Case Histories From Coal Mining, Industrial Minerals and Metalliferous Mining; Cost Effective Methods of Mine Reclamation, Mine Closure and Waste Disposal; Rock Mechanics and Geotechnical Applications; Advances in Mine Design, Mine Optimization and Reclamation Planning Technologies; Mine Equipment: Design, Selection, and Real-Time Health and Performance Monitoring; Mine and Machine Automation; GIS, GPS, Telecommunications, Artificial Intelligence, and Internet Application; Rock Mechanics and Geotechnical Applications: Underground and Surface Mine Stability, Groundwater, Tailings and Waste Disposal; Computer Simulation; Real-Time Mine Management Systems; and Computer Applications in Mining Education.

MPES 2005 and CAMI 2005 are supported by a number of organizations. To be noted are: Department of Mining, Metallurgical and Materials Engineering, Universite Laval; Department of Mining and Mineral Process Engineering, University of British Columbia; Department of Mining, Metals and Materials, McGill University; Department of Energy and Geo-Environmental Engineering, The Pennsylvania State University; Laurentian University; Western Australian School of Mines, Curtin University of Technology, Australia; Department of Earth Resources and Mining Engineering, Kyushu University, Japan; Department of Civil and Environmental Engineering, University of Alberta; University of Alaska, Fairbanks; Henry Krumb School of Mines, Columbia University; Department of Earth Sciences, Simon Fraser University; International Journal of Surface Mining, Reclamation and Environment; Faculty of Geoengineering, Mining and Geology, Wroclaw University of Technology; Atilim University, Ankara, Turkey; Rock Engineering, Helsinki University of Technology, Finland; Department of Mining and Nuclear Engineering, University of Missouri-Rolla; The National Technical University of Athens, Greece (NTUA);; Dipartimento di Geoingegneria e Tecnologie Ambientali, Universita degli Studi di Cagliari, Italy; National Mining University of Ukraine, Dnipropetrovsk; CENTEK-International Training and Development Centre, Lulea University, Sweden; Faculty of Mining and Geology, VSB - Technical University, Ostrava, Czech Republic; and Hokkaido University, Mineral Resources Engineering Department, Japan.

The organization and success of such a symposium is due mainly to the tireless efforts of many individuals, authors included. All members of the Organizing Committee and conference chairpersons have contributed greatly. The support of our plenary session and invited speakers and co-chairs is gratefully acknowledged. My greatest appreciation goes to my daughter Dr. Meena Singhal who has worked tirelessly to ensure that proceedings appear on time and who has single-handedly developed the technical program. In addition, particular recognition is accorded to our sponsors, without whose support this conference might not have taken place, Margaret-Anne Stroh for managing administrative functions for CAMI/MPES, Merlene Sparks from Elk Valley Coal Corporation who compiled this CD and Walid Sabbagh of The Reading Matrix Inc. for technical support on the MPES and CAMI website.

This conference is designed to provide a forum for the presentation, discussion and debate of state-of-the-art and emerging technologies in the field of mining and computer applications in the minerals industries. Authors from over 15 countries with backgrounds in computer sciences, mining engineering, research, technology and management representing government, industry and academia concerned with mining and mineral production have contributed to these proceedings. The contents of this volume of proceedings will be of interest to engineers, scientists, consultants and government personnel who are responsible for dealing with the development and application of innovative technologies to the minerals industries. Papers on this CD are available in PDF format and are saved under the authors' last names (Adobe Acrobat is also provided).

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Noise and dust emissions from mining activities: a software for a first approach to the measurement management and selection of suitable reduction techniques

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The paper deals with a research work developed by the Department of Land, Environment and Geotechnologies at "Politecnico di Torino", in cooperation with the IRER Research Center - Regione Lombardia. Its main target was to define and evaluate measurement, analysis and control criteria for the emission of chemical and physical pollutants from non-metal mining industries, with particular reference to noise and airborne particulates.

Any industrial activity needs to be carefully planned and managed, in order to reduce, for workers and neighbouring population, both risks and annoyance phenomena, and these issues are particularly relevant when high population density areas are concerned. But in a sustainable development approach it should be appropriate to go beyond the simple application of laws, often incomplete or not updated (especially referring to the mining sector), and to look for technical and procedural solutions – the so called "good practices" or "best available techniques" – with the final target of minimising the impact on the environment.

Direct assessment of real situations are, of course, essential to point out critical aspects and to derive viable solutions. A quite "simplified" monitoring system has then been proposed and tested, in order to get a first evaluation of the cross references among mining techniques and technologies, pollutant emissions and propagation data. A software-based database was developed to manage detailed info on the mining activities, and to store the measured emission data for any further management. One of the aims of the present work was also the development of a predictive system for noise and dust emission, able to provide a first approach - rough but acceptable - relationships between the different site activities and the pollutant levels.

The output may provide suggestion on the critical situations and possible reduction methods, both at the planning stages, in the mine layout and during the evolution of the mining activities.

Keywords: non-metal non-energy mining, noise and dust, control and reduction of emissions.

1. Foreword

Mining is often a matter of concern of local communities because of the potential impacts on environment and landscape. The exploitation of mineral resources, nevertheless, being an important local source of employment and economic wealth, is so far essential for the needs of our society; as a consequence, an effective balance between socio-economic development and environmental protection must be pursued.

In order to minimize health risks and annoyance problems for the local population, the mining activities must be very carefully planned and managed, especially where highly populated areas are concerned (eg. Lombardia region = 380 inhab/km^2).

With regard to these issues, the approach of the most recent EU documents about the sustainability of extractive activities and the natural resources management point out as necessary actions both the “promotion of extraction and production methods to encourage ecoefficiency” and the “development and implementation of programmes of best practice” (Commission of the European Communities 2000 and 2003).

The research work here discussed deals with such a context, the target being the definition of criteria for the assessment of emissions from mining sites and the identification of control solutions and good practices, applicable to real situations, for the reduction of airborne particulate and noise emissions into the surrounding environment.

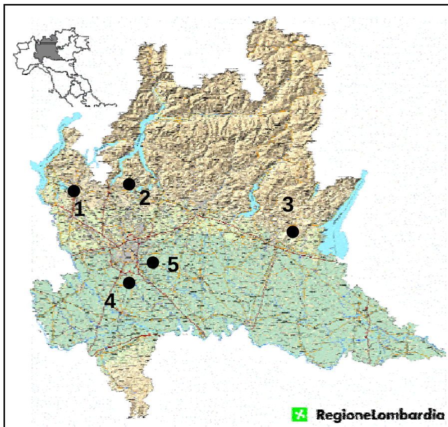
The main step of the research work consisted of on-site measurement campaigns, aimed to a direct data collection for the analysis of the cross references among mining techniques and technologies, pollutant emissions and propagation data, besides testing the applicability of a “simplified” monitoring system and evaluating the effective results of the adopted reduction techniques.

A series of mining sites, different in terms of exploitation technique and general layout, were identified after an in-depth statistical study of the situation in Lombardia Region, and the final selection was carried out in cooperation with the Regional Mining Bureau.

In order to get representative data, the selection considered the following topics, because of their influence on pollutant emissions and propagation:

- features of the material to be extracted (aggregates, natural stones, industrial minerals) and the mining technologies (explosives, mechanical, transports, etc…);
- features and topography of the sites (surface or underground, hillside or flat area quarry, distance from sensitive areas, etc...).

So far, the on-site measurement campaigns have been limited to open cast mines and quarries, selecting five sites representative of the main mining sectors and topographic layouts of the Region (figure 1). Besides, only extraction and first processing phases which take place within the mining site (e.g. crushing and screening) have been analysed. Field data were compared with the output of simplified prediction methods, in order to identify the critical and essential parameters that can be used to correctly simulate and forecast the behaviour of noise and airborne particulate in real situations.



	Municipality and Province	Topographic layout	Exploited Material	Mining technology
1	Ternate (VA)	Hill side	Marl	Explosive + Excavator
2	Costa Masnaga (LC)	Plain	Marl	Ripper + Explosive
3	Botticino (BS)	Hill side	Marble	Diamond wire + Explosive
4	Mediglia (MI)	Plain (wet pit)	Aggregates	Floating grab dredger
5	Peschiera B. (MI)	Plain (wet pit)	Aggregates	Floating suction dredger

Figure 1. Localization of mining sites where measurement campaigns have been done.

As a final result, general criteria upon which evaluate the effectiveness of control measures and simple tools to assess the potential impact of new mining sites have been implemented in a data base, made available for the competent Regional Bureau.

2. On site measurement procedure

the data collection was organized to get detailed info on the selected mining activities, in order to create the first population of the regional database and, above all, to test the prediction software. In each site a detailed inventory of all the sources has been drawn up, collecting also all the available info and data from project documents and machinery manufacturers. In particular, noise emissions were measured along alignments (at least 3 per site), whose location is intended to cover the main propagation directions, from the "core" of the activity/source area toward the closest sensitive areas. Each alignment consisted in at least 3 integrating sound level meters, with simultaneous recording (for a short but representative time) of the noise emission on a suitable recording device (figure 2).

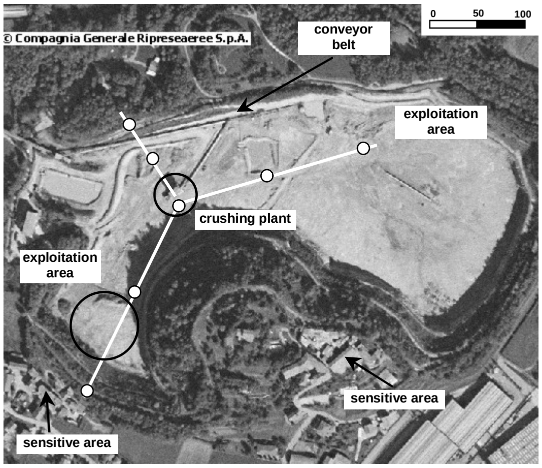


Figure 2. On the left, aerial photo of the site n°2 (marl mine); the alignment and the microphones locations used for the noise survey are reported. On the right, a recording station in the site n°1.

To test the repeatability of the procedure, the measurement campaigns were repeated in different situations - operating machinery and specific operations performed - showing a good stability of the measured noise levels.

Where dust emissions are concerned, the mass concentration of air dispersed particulate has been measured. battery operated active monitoring systems have been adopted (4-5 devices), simultaneously working for a period of at least 5 hours per day, located with the aim of intercepting the dust “plume” created by mining activity, considering also the position of potential sensitive areas.

Finally, it is important to underline that the aims of the on-site measures were the following:

- to test the feasibility and reliability of a procedure which can be performed in a relatively short time, at reasonable costs and without interferences with the regular mining activities;
- to get direct data of emission levels from different types of mining site, in order to populate the regional data base;
- to test the results of some predictive models;
- to directly assess the efficiency of some emission reduction practices.

3. The software for the management of the measurement results

In order to make available to the Regional Mining Bureau a tool for the management of measurement results, a software-based database has been purposely developed.

The database, designed with Visual Basic ®, is organised in numbered input-forms but without a fixed input order, so that the different files can be filled as the data get available (figure 3).

The requested info is grouped into homogeneous classes, to which correspond the different input sheets of the software (14 in total): sheets number 1 to 5 deal with general industrial data (industrial size, mining exploitation methods, work organization); sheets number 6-7 with adopted technologies, equipment, machinery and main fittings, with their technical characteristics in terms of emissions; sheets number 8-10 and 12-13 with pollution levels, both at workplaces and toward the surrounding areas (here are also collected, where available, the data from previous noise and dust measurement campaigns); sheets number 11 and 14 with pollutant sources identification and description, and the already adopted control measures.

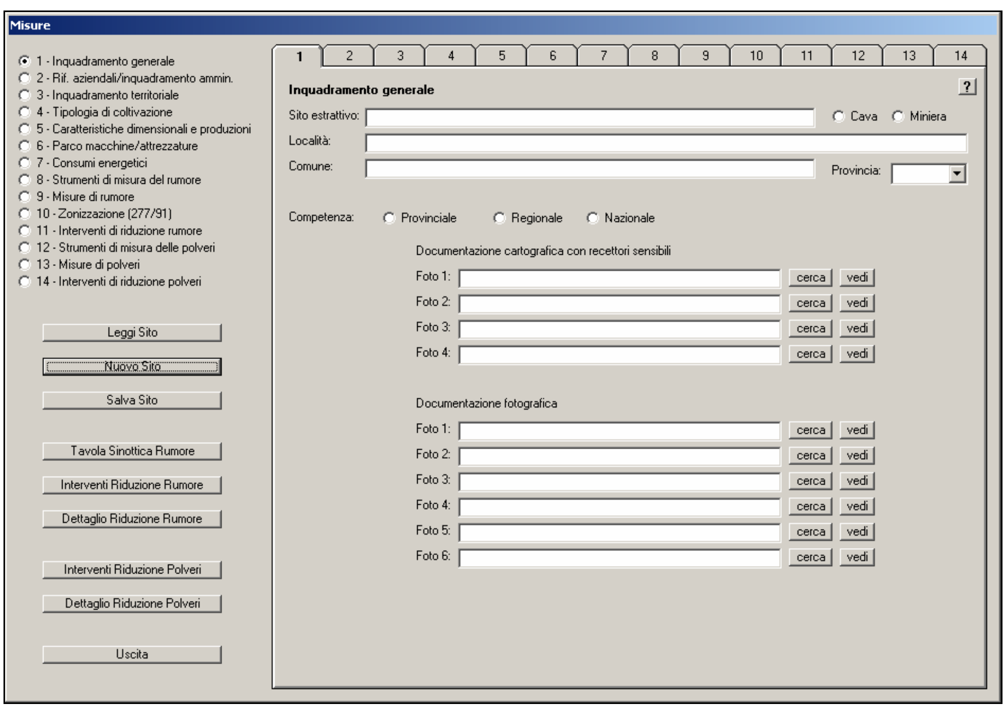


Figure 3. The input form number 1: text and graphical (pictures, CAD plans, etc…) data have to be inputted to give the general outline of the mining site.

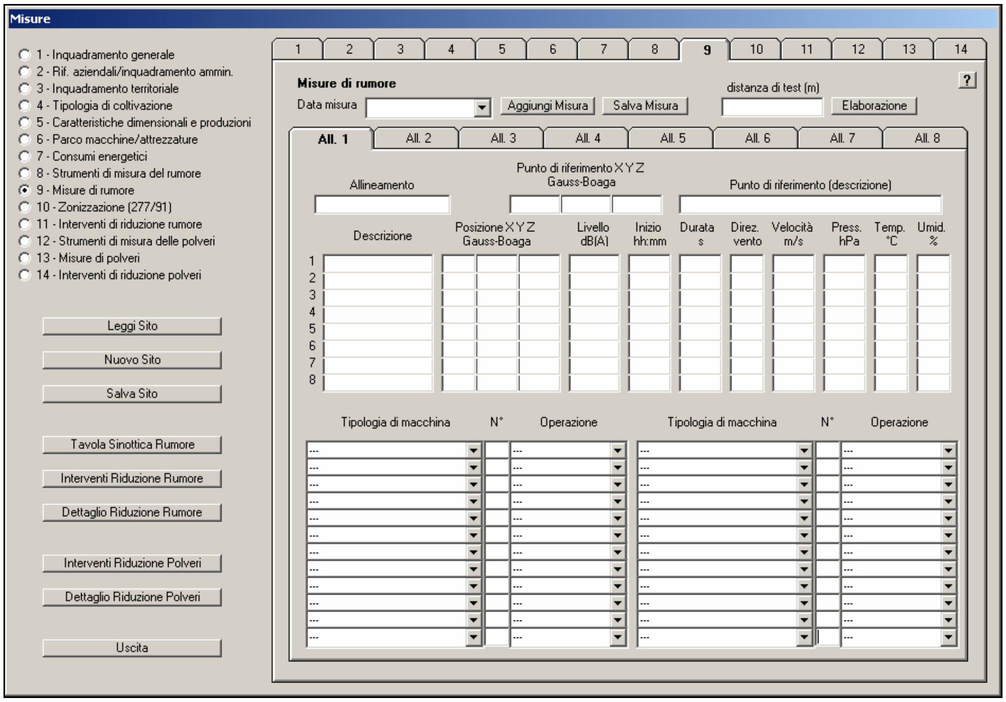


Figure 4. The data collection form for noise measurement campaigns.

The database results in a collection of upgradeable option sets, so that it is possible to insert new parameters and to carry out further analyses where required in the future. Due to the interaction between the different parameter sets during the data processing, and to avoid meaningless results, most of the data are inputted through pre-set lists and "check" buttons. In this way the data input can be performed even by relatively unskilled operators, since mistakes or incoherencies are automatically detected by the system. The data related to each on-site measurement are saved in different and independent files, linked to the file which describes the general features of the site, so that it is easy to share them among different users.

The software is not just a data storage, but it mainly consists in a simple predictive system for noise and dust emissions, able to provide a rough preliminary relationships between the different site activities and the pollutant levels, and movement patterns around the site.

3.1 The simplified approach selected and the reasons for such a decision

The simplified approach is based on fundamental laws of applied acoustics and on experimental relationships which describe the dust diffusion at sites characterised by a simple layouts; relying on these simplification, the software allows the evaluation of active sources at a given distance from mining site.

All data concerning the measurement campaigns are inputted in a suitable form of the database (figure 4), with detailed info about measuring parameters, environmental conditions and active sources. The list of active machinery is requested together with the actual operation they were performing during each measurement.

As far as noise emissions are concerned, some of the experimental data show a decay similar to the one typical of free field propagation conditions [1]

$$SPL = SWP - 20 \cdot \log(r) - 11 \qquad [1]$$

where:

SPL = Sound Pressure Level (dB); SWP = Sound Power Level of the source (dB); r = distance (m)

while in other situations the presence of secondary sources or the spatial distribution of the main sources themselves can make very difficult the definition of a precise decay pattern: a problem to be carefully taken into account when provisional models are used.

According to these premises, for a simplified prediction of the emissions, the obtained results are plotted comparing the experimental data with theoretical noise propagation patterns, and a rough estimation of sound levels at a different distance form the extraction site is given, based on best-fit curve obtained from experimental data (figure 5).

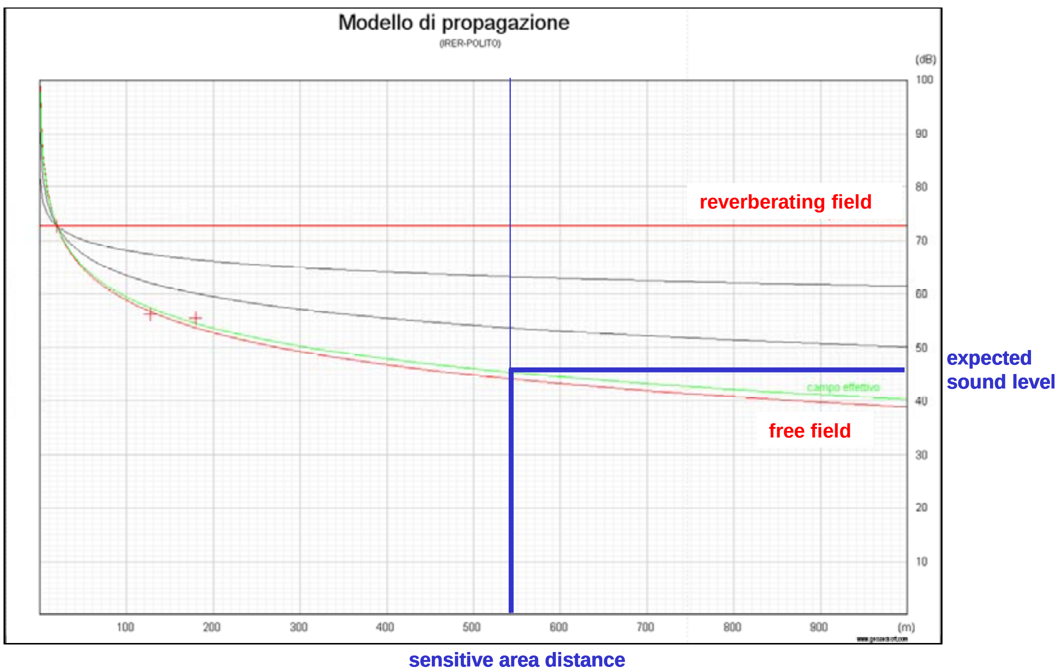


Figure 5. Example of data processing: estimation of the noise level at a specific distance.

Where the airborne particulate pollution is concerned, a Gaussian dispersion model, appropriately modified to recognise plume depletion through particulate fall-out depending on wind turbulence, is confirmed to well describe the dust diffusion at sites characterised by a simple topography and constant climatic factors.

A first prediction of the expectable dust concentration at different distances from the source, along the prevailing wind direction (wind speed must not exceed 0.5 m/s), can be obtained from the following experimental relationship (Occella 1970) [2]:

$$c = A \cdot r^{-B} \qquad [2]$$

where: c = airborne dust concentration ($\mu g/m^3$); r = distance from the source (m)

A = 15000; B = 2.17 according to Sutton;

A = 3200; B = 1.50 according to Pearson;

A = 1000; B = 1 according to Zurlo-Frigerio, this being the most conservative.

Once selected the curve that best fits to the locally collected data, the software provide an assessment of the expectable concentration at each given distance from the mining site (eg. data recorded at the site n. 1 well fit to the curve proposed by Sutton - figure 6).

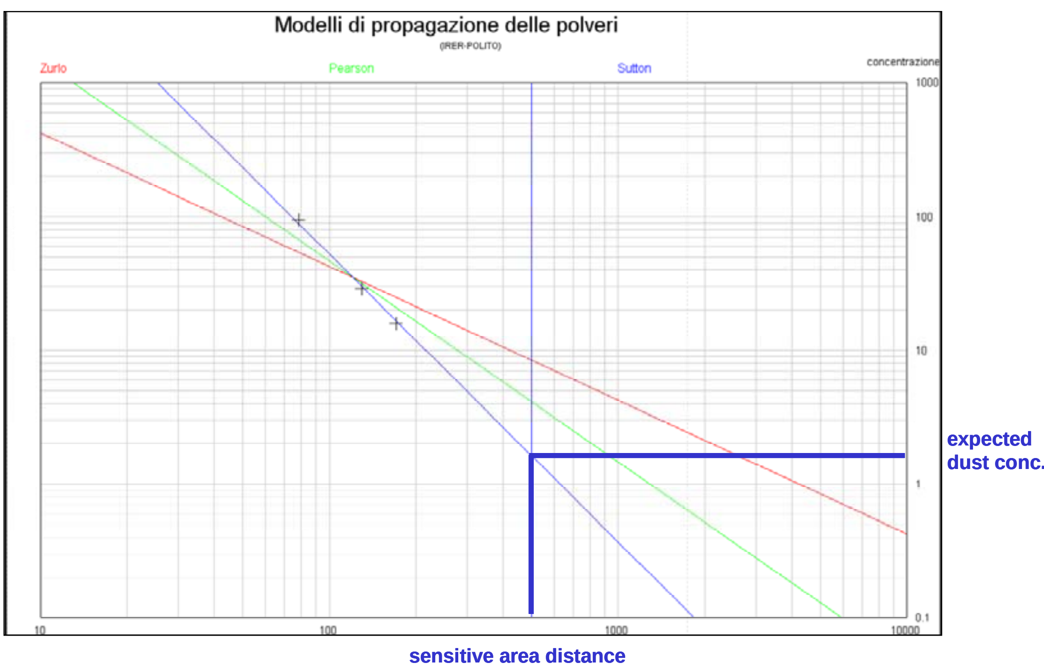


Figure 6. Example of data processing: estimation of the dust concentration at a specific distance.

In order to get effective environmental progresses of the mining sector, it is necessary to combine the identification of the most suitable technologies and mining methods with the adoption of effective control and reduction measures of pollutants.

Once roughly assessed the noise and dust propagation pattern in order to estimate the emissions level towards sensitive areas, another step is requested, that is the identification of best control practices, proper to the different real situation. The last phase of the research dealt with this issue, leading to the issuing of a "good practices" guideline on technical and organizational solutions aimed to the reduction of dust and noise emissions. A section of the software is dedicated to these aspects, in fact two input forms (organized in eight sub-forms) contain a series of possible control measures grouped as follows: design solutions; control measures on the pollutant source; control measures along the propagation path of the pollutant; organizational solutions and procedures (figure 7). For each reduction measure adopted, the user has to associate the obtained pollutant reduction (in terms of noise level or dust concentration at a given distance).

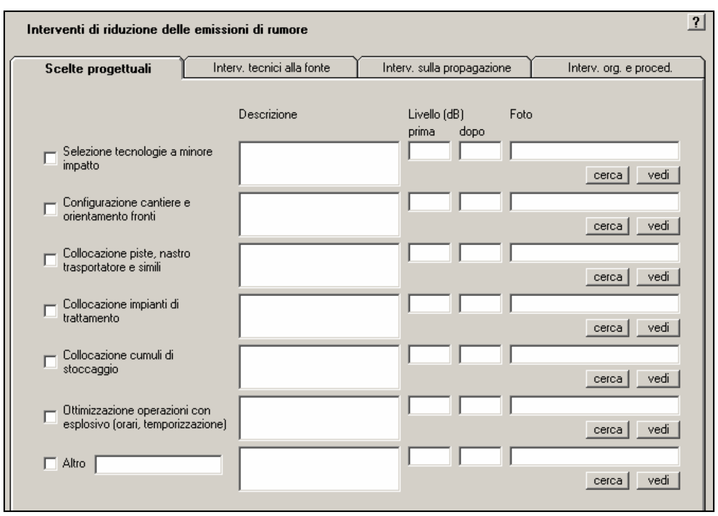


Figure 7. The input form dedicated to the "design solution" aimed at reducing noise emissions.

All stored data are grouped and analyzed according to the characteristics of the mining sites, and a number of tables are plotted, graphically showing the real efficiency of control measures as function of extraction site features and exploitation methods.

When completed with a larger number of input data from different extraction sites (and also from literature) the software will provide useful suggestion both at the planning stages, on the mine layout and technology selection, and during the evolution of the mining activities, on the critical situations and possible reduction methods.

It must be underlined that, of course, different methodologies are available nowadays to study pollutant emissions from industrial activities; in particular, for noise and dust emissions a number of complex provisional computer-based methods can be used to estimate the propagation of pollutants from a specific source.

It can be observed that in general, to give reliable results, these methods need a very detailed set of input data (about the source, its position, site topography, features of all surfaces along the path of propagation, etc...) in order to take into account all parameters involved in noise and airborne particulate behaviour; but being mining exploitation a continuously evolving activity - both sources and field can noticeably and quickly change – the high quality results achieved can result inefficient to describe the general situation.

Hence, given the experimental character of the measurement campaign, aimed to provide rough preliminary data, it has not been considered essential to carry out measures complying with all the prescriptions of the national laws about environmental noise and dust monitoring: obviously the same are mandatory in a following step, where detailed analysis of the situation is required.

4. Concluding remarks

Pollutant emission, dispersion patterns and impacts are difficult to predict due to the wide range of mining activities that may rise them, and often to the lack of reliable emission factors, together with the decisive influence of local climatic and topographic features.

The unavoidable uncertainties, due to the simplified approach described, can be overcome by the process of continuous updating of the proposed database, in order to link experimental measurement data with typical features of the site, used technologies, extracted material, etc… An advantage of the proposed method lay on the possibility of carrying out simple, repeatable and low cost measurement campaigns and analysis, in order to check the emissions trend during the time.

Reduction measures for chemical and physical pollutant from extractive sites must be included in the general management process of the activities, and effective results are easier to be achieved if all the critical aspects are considered since the planning stage and controlled along the "life cycle" of a mining site:

- assessment of existing baseline emission level, independently of the mining activity;
- identification and characterisation of mining emission sources; measurement or prediction of the emission levels expectable near the mine site and evaluation of the potential to affect human health and the environment;
- analysis of the local parameters that can affect (positively or negatively) the emission impact;
- identify and implement the most suitable mitigation measures and site design modifications;

- assess the achieved results through predictive models and verify them through a monitoring program.

The proposed database is intended to support both the Public Administration and private operators in their choices and decisions, because when it will be populated by a wider range of extraction site typologies and repeated measurement campaigns during the time, it can help to forecast emission levels in similar situations, and to point out the critical aspects that should be controlled. Moreover, a list of “good practices” and reduction measures, which can be adopted according to the different layout of the mining sites, is also provided, quoting an assessment of the mitigation that can be gained. A further step of the research should include the economical assessment of the reduction measures and of the expectable results, in order to supply an improved basis to sustainable policies.

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