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Dust and Noise Environmental Impact Assessment and Control in Serbian Mining Practice

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Received: 30 November 2017; Accepted: 15 January 2018; Published: 23 January 2018

Abstract: This paper presents an approach to dust and noise environmental impact assessment and control in Serbian mine planning theory and practice. Mine planning defines the model of mining operations, production and processing rates, and ore excavation and dumping scheduling, including spatial positioning for all these activities. The planning process then needs to assess the impact of these mining activities on environmental quality. This task can be successfully completed with contemporary models for assessment of suspended particles dispersion and noise propagation. In addition to that, this approach enables verification of the efficiency of suggested protection measures for reduction or elimination of identified impact. A case study of dust and noise management at the Bor copper mine is presented, including the analysis of the efficiency of planned protection measures from dust and noise, within long-term mine planning at the Veliki Krivelj and Cerovo open pits of the Bor copper mine.

Keywords: dust and noise impact assessment and control; air dispersion modeling; AERMOD; noise mapping; SoundPLAN; mine planning

1. Introduction

Adapting the environment to the needs of the social community has consequences that are often unexpected, due to delicate equilibrium of all ecological components. Technogenic impact within the ecosystem can generate a feedback loop to the initiators, causing new conditions and unfavorable effects to the environment and humans. Surface mining and mineral processing, with their salient feature, can pose a threat to the environmental quality. Therefore, activities such as exploration, planning, surface extraction, crushing, milling, flotation, and waste dumping, might cause significant problems for environment protection [1].

The most important parameters for air quality within the area of active surface mines are total suspended particles (TSP) and particles with an aerodynamic diameter smaller than 10 μm (PM10) [2–4]. Dispersion of (airborn) dust is related to all unit operations of surface mining systems [3–6]. It has been established that air dispersion of TSP and PM10 relates to meteorological conditions, besides the technological ones [7–10]. The highest dust concentrations were measured within the area of surface mines, gradually decreasing with distance [9].

Holmes and Morawska [11] analyzed various available dust particles dispersion models, including the Box model, Gaussian plume model, Lagrange-Euler model, and CFD (Computational Fluid Dynamics) model. They concluded that the major shortcoming of particles dispersion modeling was the lack of validation studies, comparing estimated and actual values. Chaulya et al. [12] compared FDM (Fugitive Dust Model) and PAL2 model (Point, Area, and Line sources model) with experimental data during the winter season in the region of a coal mine in India. The results were a correlation coefficient of 0.66 for PAL2 model and 0.75 for FDM. Jaiprakash et al. [13] used AERMOD model and compared modeling results with readings from 20 monitoring stations, and obtained a correlation coefficient of 0.783 for TSP and 0.741 for PM10. NIOSH (The National Institute for Occupational Safety and Health, USA) [14] concluded that the ISC3 model (Industrial Source Complex model) cannot be used for accurate estimation of dust concentration from mining activities, based on a research by Reed [15], since this model was developed for prediction of dust dispersion from stationary sources.

Lilić et al. [16] showed that the AERMOD model can be successfully used for planning measures for reduction of suspended particles impact on air quality in the vicinity of open pit mines.

Beside dust, noise is another major environmental issue in the mining industry. Drill rigs, shovels, trucks, bulldozers, crushers, mills, screens, and other equipment used in mining operations and a mineral processing plant are inherently noisy, and noise as a hazard in the working environment is widely recognized [17,18]. Health risk is higher in working environments where noise exceeds the allowable level. In situations where mining facilities are in proximity of residential areas, as is the case in the Serbian mining experience, the exposed population becomes larger, and hazard is not always limited to on-site employees. The issue of occupational noise becomes the problem of environmental noise, with all its consequences.

Noise in the mines was the subject of research of many authors. Sensogut and Cinar [19,20] developed an empirical model for calculation of noise distribution from different sources based on field measurements in the Tuncbilek open cast mine in Turkey.

Degan et al. [21] directed their research to identification of a simplified but efficient technique for measurement and analysis of noise impact in vicinity of the mine (open cast).

Noise forecasting originating from operation of specific groups of mining machines was in the focus of research of Pathak et al. [22]. Their research resulted in the development of techniques that can be used for assessment of comprehensive sound field in the vicinity of an open cast mine.

Research of Lilić et al. [23,24] related to open cast mines, and resulted in a developed noise mapping model for the definition of measures for reduction of negative noise impact in the vicinity of an open cast mine. Making action plans based on noise mapping and following "what-if" scenarios is a promising path in both environmental noise management and mine activities planning. To prevent environmental noise impact, mine authorities can apply action plans with prescribed measures to actual situations. In addition to being very efficient, noise mapping is also an inexpensive way of solving environmental noise issues. It provides for countless scenarios in creating the best solution for a potentially environmental noise risky situation.

The European Council granted a membership candidate status to the Republic of Serbia (RoS). In accordance with this status, the Government of RoS adopted the National Strategy for Approximation of Environment of the Republic of Serbia, which establishes policies to be achieved for full compliance with EU environmental legislation. Proactive environment management at mining sites and similar industries is now more emphasized, as a result of specific government requirements, including new standards in environment protection, improvement of public awareness, as well as changes and improvements in mining and mineral processing technologies.

This paper presents the approach to dust and noise environmental impact assessment and control in the Serbian mine planning theory and practice. A case study of dust and noise management at the Bor copper mine is presented, including an analysis of the efficiency of planned protection measures from dust and noise within long-term planning of copper ore mining and processing at the Veliki Krivelj and Cerovo open pit mines of Bor copper mine.

2. An Approach to Dust and Noise Impact Assessment and Control in Mine Planning

Emissions of dust and noise can produce a significant environmental impact of the mining industry during all operations related to surface mining, mineral processing, and waste dumping. The contemporary approach to noise and dust emission management in mines includes an understanding of source types, utilization of efficient and contemporary mitigation measures, and application of experiences and best practice in noise and dust management for the reduction of their emission to a level bellow limiting values.

Noise and dust emission management during the planning of mining operations and mineral processing is a complex procedure, due to numerous parameters related to emission and dispersion of air-born dust, as well as noise propagation. Most recent approaches to management of noise and dust include the application of a dust dispersion assessment model, i.e., noise propagation model, as well as approaches based on a Global Information System (GIS) platform, which provides for acquisition of relevant information required for undertaking necessary environmental mitigation measures. Environmental management must be modelled by cross-disciplinary studies. This requires a system-oriented approach based on functional abstraction rather than structural decomposition [25].

Dust and noise impact identification, assessment, and control are part of an integrated and holistic impact assessment and management process, with many interacting and competing activities. Modern trends usually rely on a generic process enacted in ISO 14001 Environmental Management Systems Standard [26]. Linking environmental impact assessment and environmental management systems to various theoretical approaches has been proposed [27–30]. The objective of the environmental impact assessment procedure is to predict and mitigate the impact of mining projects at the planning and design stage. The environmental management system enables mining organizations to manage the environmental impact that occurs on a daily basis during the development and operation of mining projects. In accordance with the system approach to impact identification and evaluation, both tools could provide focus on significant impacts, identifying them at an early stage in project planning [27].

The conceptual framework for integrating dust and noise impact identification, assessment, and control with an environmental management system is shown on Figure 1.

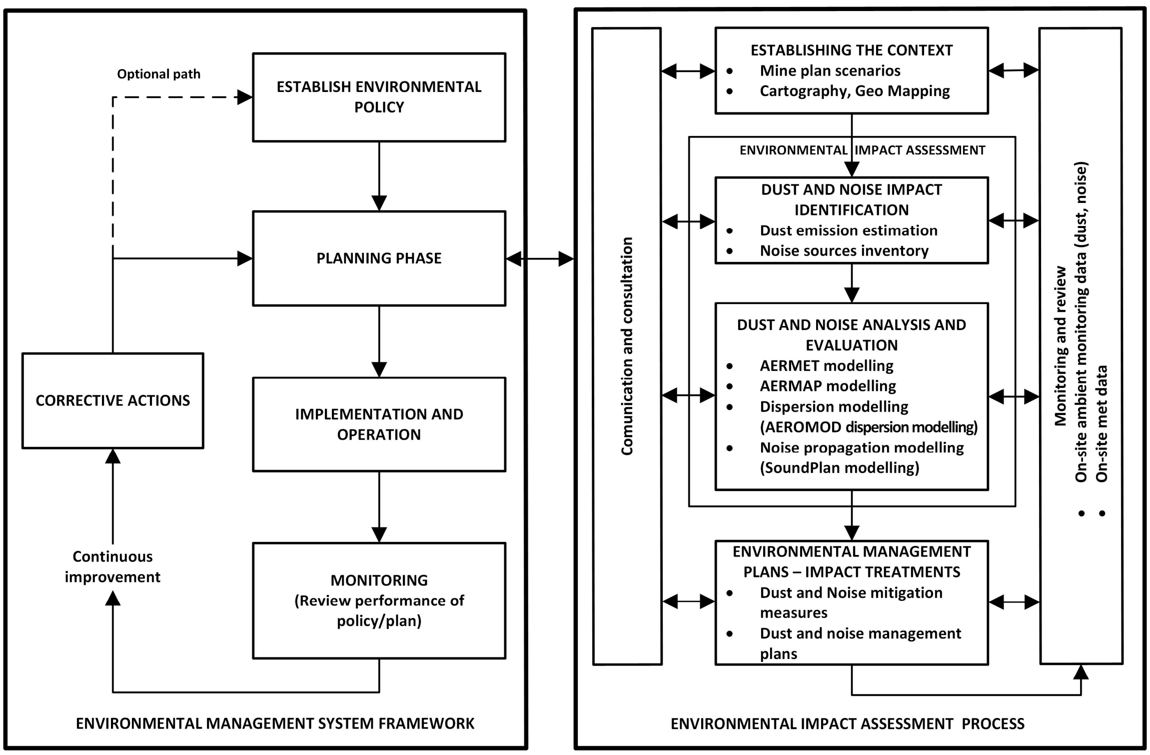

Figure 1. The conceptual framework for integrating dust and noise impact assessment and control with an environmental management system (approach modified from Ecceleston and Smythe [31] and Fitzmaurice and D'Abreton [32]).

Mine planning defines the model of mining operations, production and processing rates, and ore excavation and dumping scheduling, including spatial positioning for all these activities. The presented approach for dust and noise impact assessment and control (Figure 1) enables environmental impact assessment of planned mining activities and verification of suggested mitigation measures.

Dust dispersion modeling is a mathematical estimation of impact of suspended particles emission from various sources in the analyzed area of a mine. There are numerous parameters related to emission and transport of suspended particles in the atmosphere, including meteorological conditions, configuration of the terrain, pollution emission properties, etc.

The presented approach for dust dispersion assessment is based on the AERMOD model, which is used for research on air quality [33]. Dust dispersion analysis process with the AERMOD model encompasses the following:

- processing of meteorological data with AERMET software [34],
- processing of terrain elevation digital data,
- final characterization of location with complete information on sources and receptors,
- terrain data pre-processing for AERMOD model with AERMAP software [34],
- application of AERMOD model for obtaining distribution of suspended particles over analyzed area (plume forecast),
- visualization of results for analysis and decision-making.

Successful noise management in the Serbian mining experience requires showing in advance that a mine activities scenario will have an acceptable noise impact [35]. Doing this by common noise measurement is not possible, because it is not a real-time situation but a potential one. In such situations, the noise mapping process can offer a possible solution. Regarding noise mapping, noise measurements may be appropriate and valuable, especially in the phase of a model validation. However, noise maps are not usually performed by measuring with a sound level meter, but rather created by calculation using a sophisticated computer modelling software.

As it was already mentioned, this is particularly important in noise action planning, where a possibility of cost-benefit analysis of various options is invaluable to the process of making a final decision in mine planning. Noise mapping in a specific area is a procedure for estimation of exposure to level of noise, due to the existence of various sources [23,24].

The first step of noise mapping is preparation of genuine input data, which is the most critical task of the process, mainly because of the lack of the proper form of such type of data. After collection of all required data, they are represented in a model. This usually implies numerous adjustments within the model, both regarding geometry of the source and adjustments of acoustic data. Occasionally, due to its iterative nature, the process requires repeated measurements and verification of the noise sources operation regime.

The validation process is a very sensitive part of noise modelling. It is usually performed in two steps [36]: validation of sources, and full validation of the model. Both are based on comparison of measured and calculated values, from a different set of receptors.

Depending on availability of noise modelling software, the calculation method can be selected in such way to suit various methods and standards. The most common method for industrial sources is the one defined by standard ISO 9613 [35]. Nowadays, several widely accepted noise models exist, supporting a varying number of standards all over the European Union: SoundPlan, NoiseMap, Predictor-LimA, CadnaA, etc.

3. Baseline Characterization

The assessment of noise and dust impact and selection of mitigation measures during the planning stage of mining and processing of copper ore will be presented in the case study of the Bor copper mine. The analyzed area encompasses two open cast mines at a small distance, with planned mining activities for a production rate of 10.6 million tons of copper ore at the Veliki Krivelj open pit mine and 5.5 million tons of ore at the Cerovo open pit mine. Mining of copper ore at these open pits is based on drilling and blasting, and shovels for loading. Trucks are used for the haulage of ore to the processing facilities (crushing, milling, and floatation). Overburden is dumped on waste dumps and into the old open pit. Tailings are deposited into the Veliki Krivelj tailing pond. The locations of these mining facilities are shown on Figure 2.

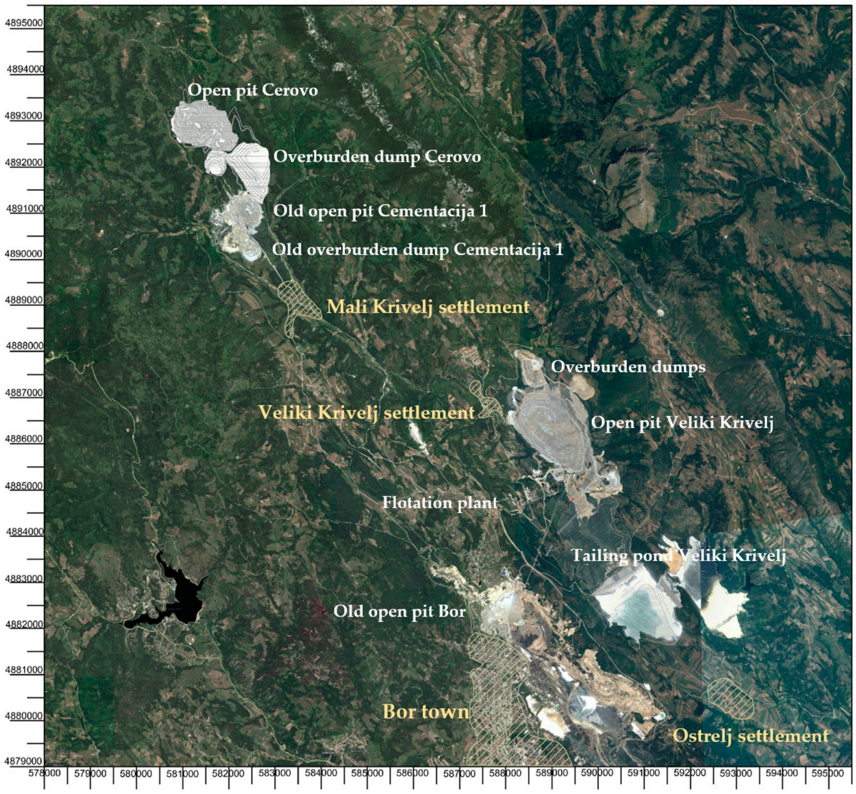

Figure 2. Locations of mining facilities in the area of the RTB Bor copper mine.

Bor town and its surroundings are characterized by continental climate. The mountains Crni Vrh and Čestobrodica represent climate boundaries. The climate in lower areas is moderately continental, being transformed in the highest mountain zones into mild mountain climate. The summers are characterized by rather stable weather circumstances, comprising long sunny and short rainy periods. In winter, weather circumstances are characterized by low temperatures and intense snowing. Meteorological data for the territory of Bor are continuously recorded in the meteorological station on the mountain Crni Vrh.

The wind rose for the period 2011–2015 is shown on Figure 3 [37]. As can be seen, most frequent winds for this period were from the north-west and south-east directions.

Rainy seasons are spring and autumn. Maximum annual precipitation is 693.6 mm/year. Average annual precipitation is 560.4 mm/year. Maximum daily precipitation is 75.2 mm/day, and average daily precipitation 1.5 mm/day.

Annual average level of clouds in the sky above Bor is about 55%. The largest cloud level, over 70% of the sky, appeared in November and January, and the smallest, below 40% of sky, from July to September. The average annual humidity is 74.5%. In July, August, and September (89.2 days), the humidity is below 50%. In November, December, and January (106.3 days), humidity is higher than 80%. The transition from one extreme value to the other is abrupt.

Results of air quality measurements, done by a certified laboratory, around the facilities of Bor copper mine are provided for better understanding of pollution in this area, and proper impact assessment of copper ore extraction and processing facilities. Measurements were taken at 17 locations in the vicinity of all facilities of Bor copper mines, and included particle deposition levels, analysis of the liquid phase, and analysis of the solid phase (sampling carried out for each month during the monitoring year). Results of particle deposition levels are shown in Figure 4.

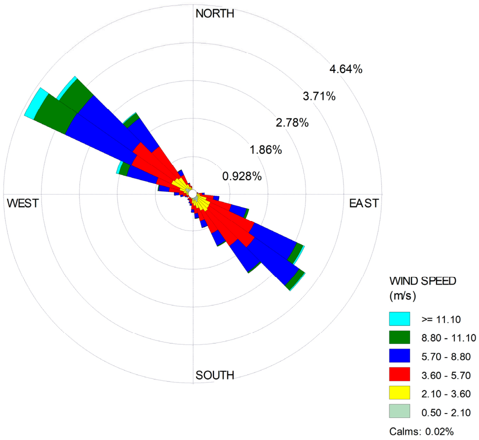

Figure 3. Wind Rose for Bor, period 2011–2015.

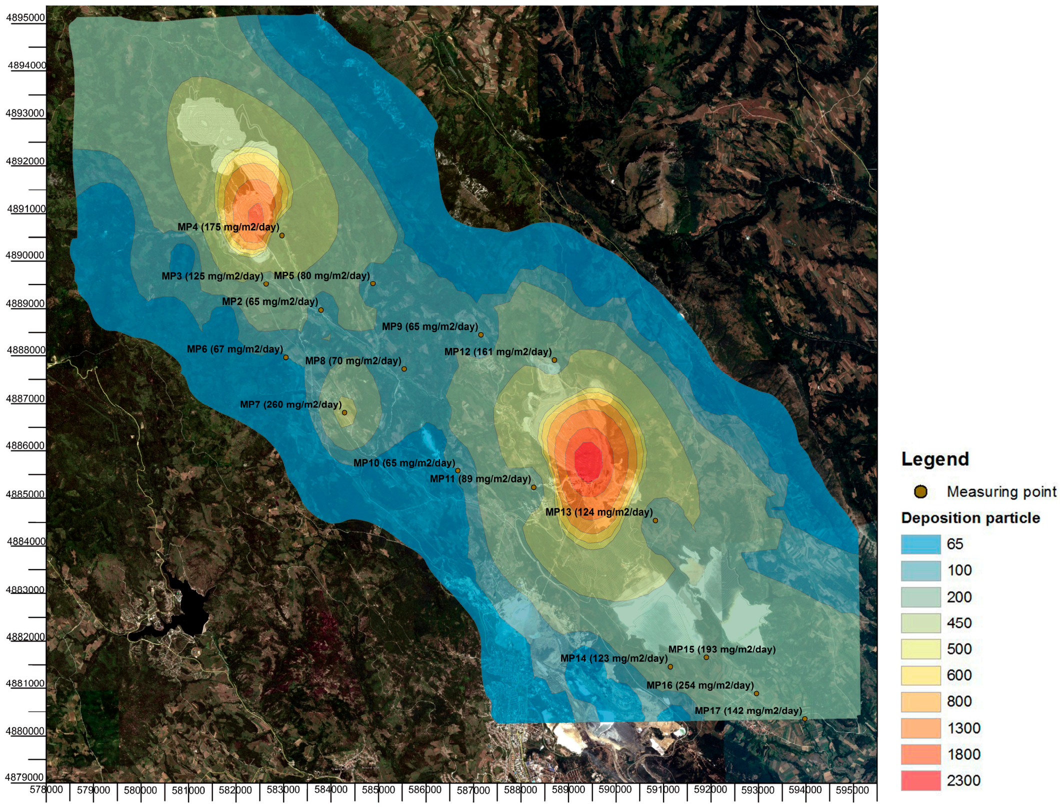

Figure 4. Measurement results of particle deposition levels in vicinity of Bor copper mines in 2016.

Results of air quality monitoring, as shown in Figure 4, indicate that average annual values of particle deposition levels ranged from 71 mg/m^2/day (measuring point 8) to 280 mg/m^2/day (measuring point 16). The elevated average annual value of particle deposition level (over the maximal limit of 200 mg/m^2/day) was detected at measuring points 7 (228 mg/m^2/day) and 16 (280 mg/m^2/day). Average annual values of Pb ranged from 2.1 µg/m^2/day (measuring point 12) to 26.6 µg/m^2/day. Average annual values of Cd ranged from 0.01 µg/m^2/day (measuring point 12) to 0.67 µg/m^2/day (measuring point 15). Average annual values of as ranged from 1.4 µg/m^2/day (measuring point 12) to 15.5 μg/m^2/day (measuring point 17), and average annual values of Ni ranged from 1.5 μg/m^2/day (measuring point 12) to 10.1 μg/m^2/day (measuring point 17).

Periodical environmental noise measurements are also performed in the vicinity of Bor copper mine. Measurements are performed in accordance with national regulations and generally accepted standards ISO 1996-1 and ISO 1996-2 [35].

Last performed noise measurements by a certified laboratory are given in Table 1. Measurements are performed at the location of an isolated village household at the southern access road to the Veliki Krivelj village, at a distance of 550 m from the south-western rim of the Veliki Krivelj open pit mine. According to national legislation related to environmental noise and spatial designation of the area [35], location of the household belongs to the 3rd acoustic zone, i.e., residential areas with maximal allowed limit of 55 dB(A) during the day and evening and 45 dB(A) during the night. Allowed noise levels in specific rooms of the house (living room, bedroom) with closed windows, according to the same legislation, are 35 dB(A) during the day and evening, and 30 dB(A) during the night. The same legislation divides 24 h of the day into three referent time intervals, where the day lasts 12 h (from 06:00 to 18:00 h), and the evening lasts 4 h (from 18:00 to 22:00 h) and the night lasts 8 h (from 22:00 to 06:00 h of next day).

The household analyzed was subjected to the noise emitted from the open pit mine, in any given moment. Noise was generated by following activities:

- operation of crushing facility—comprising of primary and secondary crushers, which are operating 24 h a day, with occasional stoppages depending on ore supply;
- excavation and loading of ore and waste—shovels, which are operating 24 h a day, with occasional stoppages caused by loading and haulage;
- ore haulage to the crushers and waste haulage to the waste dumps—dump trucks, driving along non-paved roads between the mine, and crushing facility and waste dumps.

At the time of measurement, all of the above-mentioned equipment operated at full load.

Table 1. Results of noise measurements in vicinity of the Veliki Krivelj open pit mine.

Measurement Location	Rating Level L_{RAeqT}, dB(A)		Maximal Allowed Level, dB(A)	
	Day and Evening	Night	Day and Evening	Night
Yard of the house	48	44	55	45
Living room	27	26	35	30

According to this environmental noise measurement generated by mining activities at the Veliki Krivelj open pit mine, it can be concluded that the residential object was not subjected to the highest level of environmental noise.

4. Status of Dust and Noise Emissions Estimation

Quantification of TSP and PM10 emissions, i.e., dust emission factors for various activities of copper ore extraction and processing, was performed according to (Environmental Protection Agency) EPA recommendations (US EPA AP-42, Compilation of Air Pollutant Emission Factors) and National Pollutant Inventory (Emission Estimation Technique Manual for Mining and Processing of Metallic Minerals, 2012) [38,39]. The EMEP/EEA air pollutant emission inventory guidebook [40] was used for verification and calibration of TSP emission during mining activities, more specifically, the chapter "Quarrying and mining of minerals other than coal".

Dust emission factors by activity types and equipment, related to natural and technological conditions of Bor copper mine, be given in Table 2.

Table 2. Dust Emission Factors for Various Operations at Mines [27,28].

Operation/Activity	Units	Emission Factor	
		TSP	PM_{10}
Drilling	kg/hole	0.59	0.31
Shovels	kg/t	0.025	0.012
Bulldozers	kg/h	17.0	4.1
Graders	kg/VKT	0.19	0.085
Wheel generated dust from unpaved roads	kg/VKT	4.23	1.25
Trucks dumping	kg/t	0.012	0.0043
Primary crushing	kg/t	0.01	0.004
Miscellaneous transfer points (conveying)	kg/t/trans point	0.00032	0.00015

Conducting infield measurement in order to quantify the dust emissions is pretty difficult. The main reason is the fugitive nature of dust. Therefore, site-specific mining dust emissions are often unavailable. As opposed to dust emission, it is much easier to define sources of noise as well as their emissions. Noise emission data for the actual plant and machines are primarily supplied by equipment manufacturers. As an alternative, wherever it is possible and suitable, noise measurements data of the actual plant and machines in operation on site should be used. This approach was followed during the process of noise mapping. Noise source data presented in Table 3 originate from manufacturers' documentation and catalogues, as well as from infield measurements.

Table 3. Noise levels of mining, auxiliary, and other equipment.

Equipment	Noise Level (dB(A))
Trucks	114
Shovels	103
Bulldozers	116
Drilling rigs	95
Graders	106
Primary and secondary crushers (ore)	110
Crushers (overburden)	104
Belt conveyor for ore	65

5. Air Quality Assessment and Control

Sources and levels of dust emission are identified and established during development of long-term plan for production of 10.6 Milt of copper ore at the Veliki Krivelj open pit and 5.5 Milt of ore at the Cerovo open pit. Analysis of dust emissions from production operations in these open pits included drilling (drilling rigs), loading (shovels), and haulage (dump trucks), as well as facilities for primary and secondary crushing and floatation. Special attention was given to dust emission sources on waste dumps and tailing ponds.

The AERMOD View^{TM} model [34] was used for assessment of air quality as a function of PM10 particles concentration distribution, where accepted dust emission parameters are given in Table 1. Results represent maximal daily concentration values of PM10 particles (μg/m^3) for defined emission sources, specific time interval and receptors. Meteorological conditions were modeled according to data for the 2011–2015 period (NOAA National Climatic Data Centre) [37].

Model calibration was performed according to recommendations established by the US Environmental Protection Agency (EPA) [33] for air quality control. Monitoring data of deposition particles concentration in the area of Bor copper mine, as given in Section 3, was used for model calibration. This approach ensured reliable quality analysis, as well as quantitative analysis at acceptable level.

Distribution of PM10 (μg/m^3) particles concentration around the Veliki Krivelj and Cerovo open pits, without dust suppression and mitigation measures, is shown in Figure 5. Distribution of PM10 particles concentration indicates a significant impact of dust in the vicinity of open pits, waste dumps, and tailing ponds due to mining operations. In the wider area around the mines, concentration of suspended particles decreases from 1351 μg/m^3 (immediate vicinity of sources—open pit mines) down to 75 μg/m^3 in the zone of Oštrelj village, i.e., near Krivelj village.

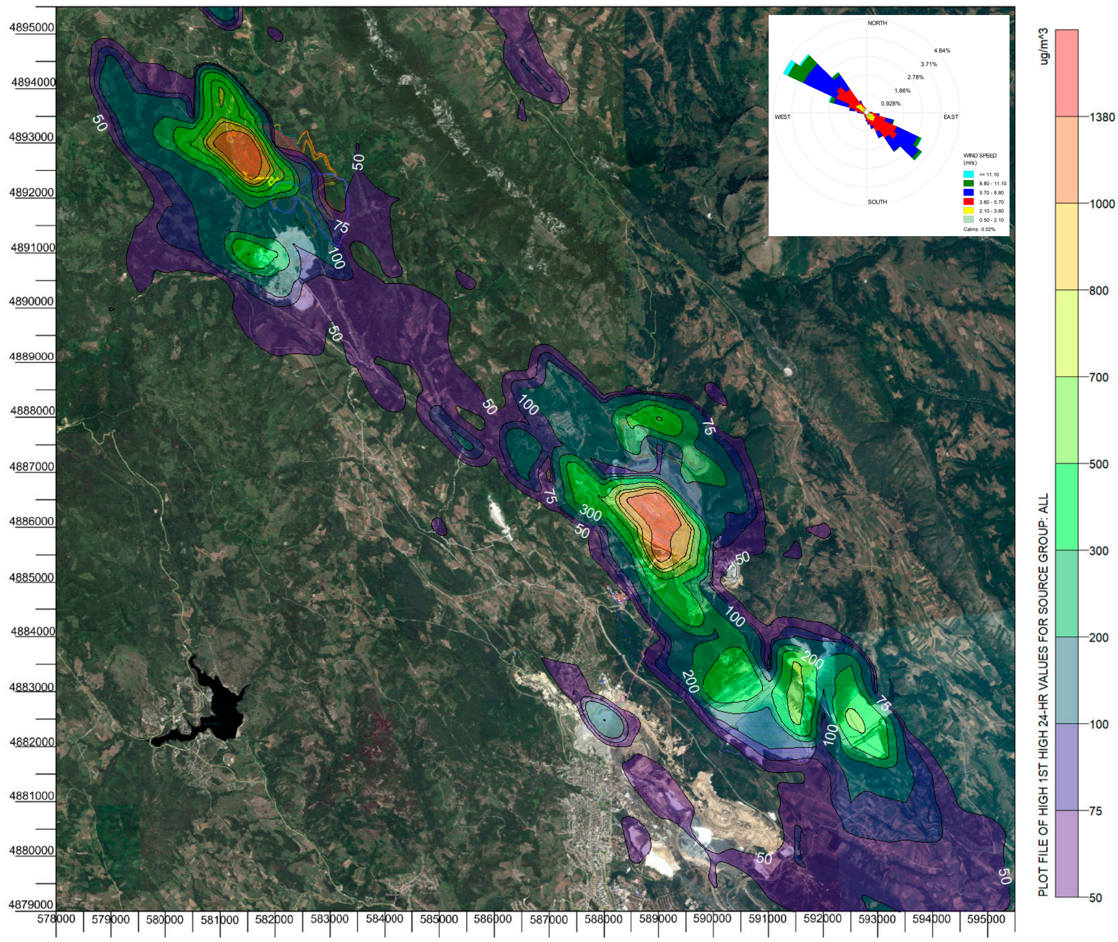

Figure 5. Distribution of PM10 (μg/m^3) particles concentration around the Veliki Krivelj and Cerovo open pits, without dust suppression and mitigation measures. PM10, particles with an aerodynamic diameter smaller than 10 μm.

Research conducted during development of Feasibility Study on Exploitation of copper ore deposits Veliki Krivelj, Kraku Bugaresku, and Cerovo also included the analysis and suggestions of measures for prevention and reduction of environmental impacts. According to the EPA (AP-42) [38] and National Pollutant Inventory [39] data, dust particles emission from various sources in an open pit mine can be reduced by more than 50% by using water spraying for dust suppression or maceration of excavated ore. Having in mind estimated dust concentrations in the zones of mining operations at open pits, waste dumps, and tailing pond, in relation to protection from dust in the working environment, research suggested measures for suspended dust suppression by using techniques of ore/waste maceration and water spraying. These techniques will also reduce emission of suspended particles into the atmosphere of the wider area of the open pit mines, resulting in the improvement of air quality.

Distribution of PM10 (μg/m^3) particles concentration around the Veliki Krivelj and Cerovo open pits, with dust suppression and mitigation measures, is shown in Figure 6. This assessment indicates that the effect of all suggested measures for dust suppression will ensure that PM10 suspended particles concentration will be within the limits prescribed by regulations, i.e., concentrations will be lower than 50 μg/m^3.

This approach in modeling dust dispersion with application of protection methods and procedures (Figure 6) ensured verification of suggested measures and therefore enabled reliable planning of efficient mitigation measures.

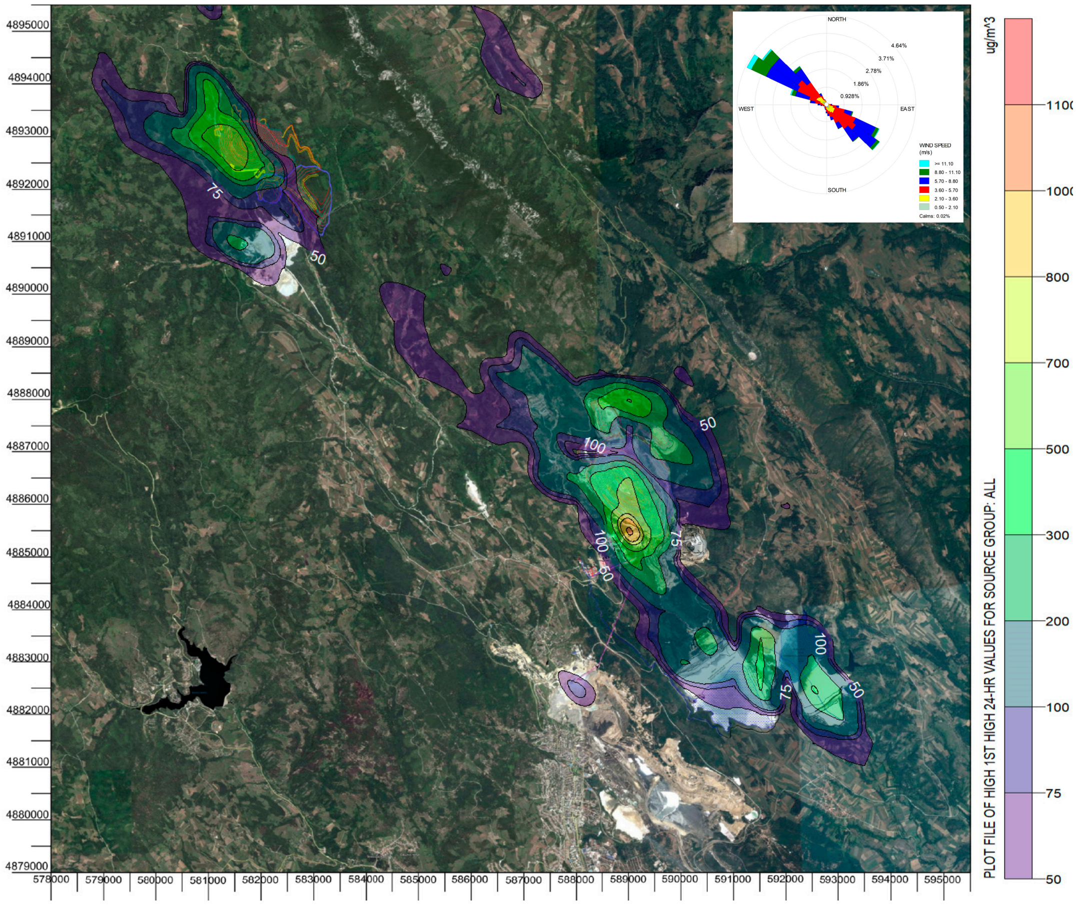

Figure 6. Distribution of PM10 (μg/m^3) particles concentration around the Veliki Krivelj and Cerovo open pits, with dust suppression and mitigation measures.

6. Noise Assessment and Control

Noise management in general supports the standpoint that one should always be "one step ahead" of the potential problem, which might generate elevated noise emission both in the working and the living environment. In the long-term, the life cycle of a mine depends on numerous parameters, which calls for its development in stages, according to specific scheduling. Typical for each stage is level of equipment engagement, location, and number of working faces. Equipment is mainly the same in all of stages, but the number of machines and their place of engagement can significantly vary in relation to the development stage of the mine, but also in relation to dynamics of operations within the same stage. In such conditions, it is difficult to make effective and efficient decisions in real time. Therefore, being "one step ahead" of potential noise issues requires the analysis of any number of potential situations, thus preparing timely and suitable solutions for any of those issues.

In the case of the Veliki Krivelj open pit, this included modeling of noise propagation for two possible and typical scenarios of mining operations. Differences between those scenarios are in engaged equipment and their locations. Scenario 1 (Figure 7) includes engagement of four bulldozers, two graders, two shovels, 20 dump trucks (four on the ore and 16 on waste, according to production scheduling), four drilling rigs, primary and secondary crushers for ore, and a belt conveyor for ore. Scenario 2 (Figure 8) is more favorable regarding the threat to residential objects. Number and locations of engaged equipment are somewhat different than in the previous scenario, however, this scenario includes a system for waste haulage located opposite the residential objects. Sources of noise in Scenario 2 are: four bulldozers, two graders, two shovels, 26 dump trucks (eight on ore and 18 on waste), four drilling rigs, primary and secondary crushers for ore, a crusher for waste, a belt conveyor for waste, and a belt conveyor for ore. Noise maps based on the scenarios were generated based on the SounPlan noise model [41].

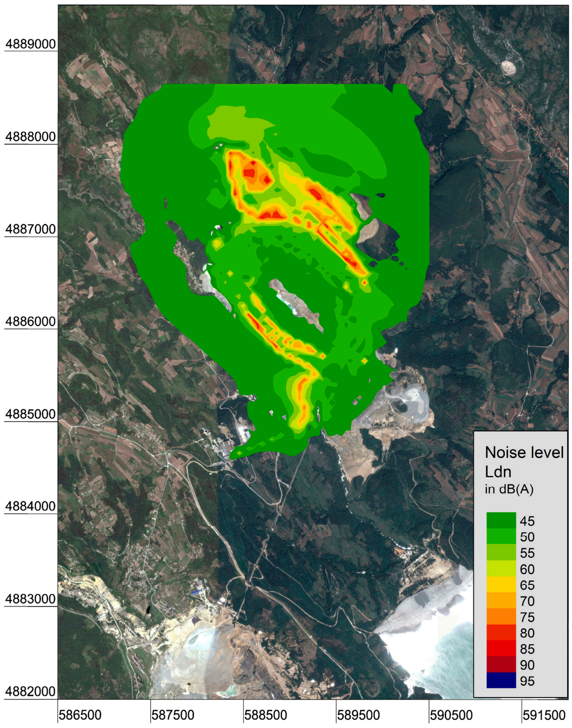

Figure 7. Estimation of noise level around the Veliki Krivelj open pit, Scenario 1.

Noise propagation analysis from mining operations at the Veliki Krivelj open pit mine for both scenarios (Figures 7 and 8) shows that the nearest residential object, some 550 m from the south-western border of the mine, will not be endangered by noise from mining activities. This conclusion is fully supported by noise measurements in the previous period, data of which are shown in Table 1.

Therefore, as presented by analyzed scenarios, noise management measures should be mainly related to control and noise reduction in the working environment. These measures would result in additional benefit related to noise propagation outside the boundaries of the mine.

The Cerovo open pit mine has a low population density in its surroundings, with just few residential objects: isolated village type households at a distance from 550 to 700 m, on the west and the south-west. Besides this, the configuration of the mine and the surrounding terrain represent natural sound barriers. In such case, modeling is usually performed for the worst-case scenario, which includes most intensive mining operations at unfavorable locations in relation to receptors—surrounding residential objects. Hence, the same approach was accepted for noise propagation modeling at the Cerovo mine. The model included all engaged machines on this mine as noise sources: three bulldozers, one grader, two shovels, one loader, 20 dump trucks (five on the ore and 15 on waste, according to the production dynamics), two drilling rigs, primary and secondary mobile crushers for ore, and a crusher for waste. Listed equipment is identical to the one engaged at the Veliki Krivelj open pit, whose noise levels are given in Table 2. These machines were placed as near as possible to the terrain surface, i.e., most of those machines were located above the base terrain elevation, with strongest potential impact on few surrounding residential objects.

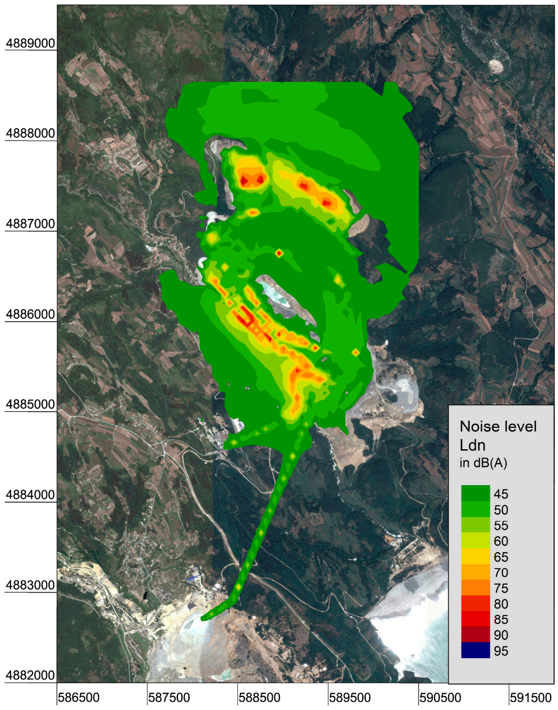

Figure 8. Estimation of noise level around the Veliki Krivelj open pit, Scenario 2.

Noise propagation modeling for mining operation condition presented in Figure 9 shows that no negative noise impact should be expected at nearest residential objects.

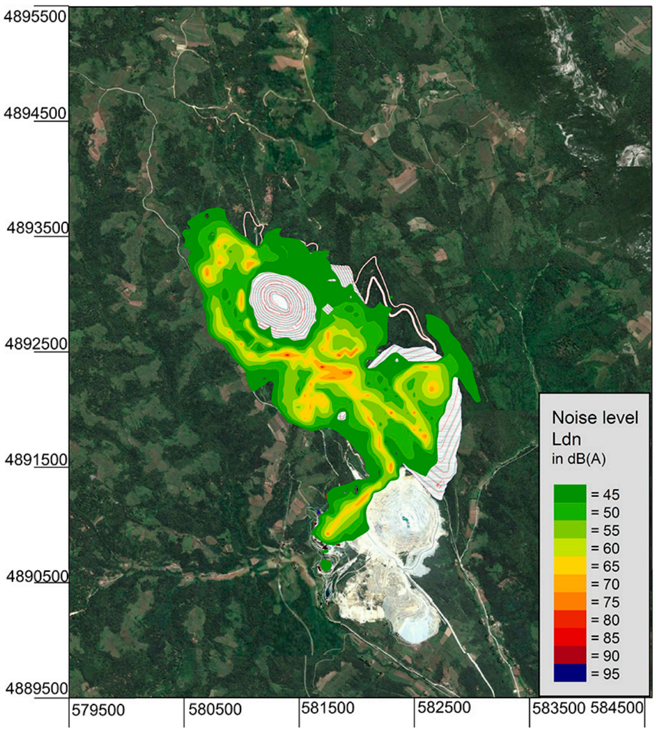

Figure 9. Noise propagation assessment around the Cerovo open pit mine.

As in case of the Veliki Krivelj mine, noise management measures would be mainly related to the control and reduction of noise in the working environment, with additional benefit related to noise propagation outside the boundaries of the mines.

Model calibration for both mines, depending on available data, was performed according to the environmental noise measurements and measurement of working environment noise.

7. Conclusions

Surface mining operations and mineral processing can generate impact on environmental quality. Significant environmental impact of mining industry includes emissions of dust and noise during all unit operations of surface mining, mineral processing, and waste dumping.

Dust and noise impact identification, assessment, and control are part of an integrated and holistic impact assessment and management process, with many interacting and competing activities. Modern trends usually rely on a generic process enacted in ISO 14001. In accordance with the system approach to impact identification and evaluation, environmental management system and environmental impact assessment could provide focus on significant impacts, identifying them at an early stage in project planning.

Noise and dust emission management during the planning of mining operations and mineral processing is a complex procedure, due to numerous parameters related to emissions and dispersion of particulate matters, as well as noise propagation. Best practice in noise and dust management implies the application of models for assessment of suspended particles dispersion and noise propagation.

The presented integral approach for dust dispersion assessment incorporates the AERMOD model for air dispersion modeling, which is used in air quality research. According to the proposed approach, noise maps were created using computer modelling software SoundPlan [41].

Research conducted during development of the Bor copper mine project included an analysis and proposal for mitigation measures, besides a review of possible impact of mining activities on environmental quality. Therefore, modeling of suspended particles dispersion and noise propagation was successfully used for efficiency verification of suggested measures.

Acknowledgments: Research described in this paper was performed during development of the project "Improvement of lignite opencast mining technology in order to increase energy efficiency and occupational safety" (TR33039). Development of this project is financed by Ministry of Education, Science and Technological Development of Republic of Serbia, for period 2011–2017.

Author Contributions: U.P. and A.C. did the modelling; D.K. and V.M. analyzed the data and contributed analyses and assessments; N.L. wrote the paper.

Conflicts of Interest: The authors declare no conflict of interest.

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