

## Environmental problems at the underground limestone Baltar mine, São Paulo, Brazil

S.M. Eston, W.S. Iramina & W.T. Hennies

Escola Politécnica, Universidade de São Paulo, Brazil

R.T. Nakamura

S.A. Industrias Votorantim, São Paulo, Brazil

**ABSTRACT:** Baltar mine is the largest Brazilian underground limestone producer. The mining method is sublevel longhole stopping, with empty stopes averaging 110 x 40 x 200 meters. The first production panel has main haulage levels up to 150 meters of depth and ventilation problems are minor and easily solved. Development of ramps and access drifts for the second panel, at depth of 300 meters or more, has generated environmental problems related to fresh air quantity, dust and thermal comfort conditions. An environmental data survey was carried out and results indicated that the old ventilation system could not support further deepening of the mine, and thus new fans, main and auxiliary, are required.

### 1 INTRODUCTION

Votoran Cement plant is located at Santa Helena, close to Votorantim town about 120 km from São Paulo. Limestone has been mined for decades and present cement nominal production is 7700 metric tons per day and limestone may be consumed up to a maximum of 4 million tons per year.

The three main mines are the open pits of Placa and Pastinho, and Baltar which is an underground mine.

The Baltar limestone deposit has a lenticular shape, northeast direction and dips to the southeast. Mine openings started in 1975 and production began in 1981. The initial mine layout was defined by Outtokumpu Oy company.

### 2 MINE LAY-OUT

The main access to the stopes is a ramp of 1850 m long, cross-sectional area of 7,5 m by 5 m and grade of 12,4%. This ramp has an entrance at level 616 and connects the surface to level 397, where several important operations such as crushing and equipment maintenance are performed. From this area a new ramp has been developed, with 1100 m long, cross-sectional area of 6,5 m by 5,5 m and inclination of 12,5 %. This secondary ramp is the main access to the second level of mining panels that will be mined in the next years.

Crushed ore haulage to the surface is done by belt conveyor, using a straight ramp that has surface entrance close to the main access ramp, as shown in Figure 1.

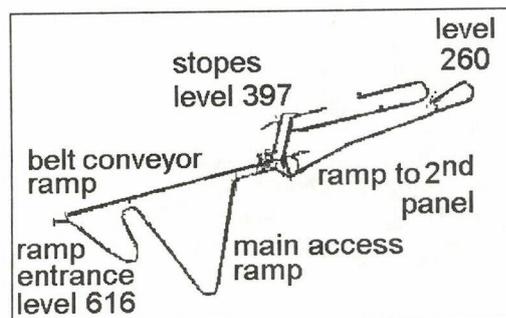


Figure 1 – Top view of main ramps of Baltar Mine.

### 3 MINING METHOD

Mining method is longhole stopping, with rooms averaging 40 m width, 200 m length and 110 m height.

Production drilling is performed in 3 sublevels drifts and pillars between rooms average 32 to 40 m. Explosive is ANFO and ore haulage is performed by front end loaders and 35 t trucks to feed the un-

derground crusher. Figure 2 presents a sketch of a production stope.

The first panel is at an average depth of less than 200 m and is composed by several developing and production rooms. A second panel below the first one is being developed and production should start in a couple of years. The access ramp to this second panel is already completely opened.

#### 4 UNDERGROUND ENVIRONMENTAL PROBLEMS

No serious environmental problem was encountered during the first panel development and production phases. However the secondary ramp development and the second panel will require a new ventilation plan since depth over 300 m will be attained. The main problems are associated with thermal comfort, gas removal and dust.

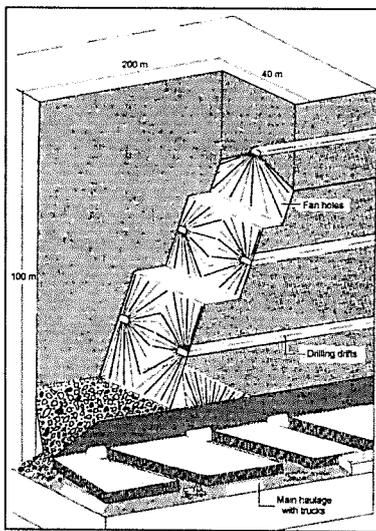


Figure 2 - Drilling and haulage at production stope.

A consulting company was hired to design the new ventilation system and the Mining Engineering Department of the Polytechnic School of the University of São Paulo was authorized to perform independent work to verify and compare the old and new conditions underground.

During the months of January through June 1999 dozens of monitoring visits were done, with several parameters being measured. These parameters included wet and dry bulb temperature, moisture, air

velocity, pressure, cross-sectional areas of openings, gas and dust concentrations.

Several difficulties were encountered to analyze the ventilation old conditions, the main one related to the fact that fan operation constantly changed, due to tests that were weekly performed. An average condition was adopted considering 6 fans, 5 operating under exhaust conditions and one under blowing condition.

These fans were located at ventilation shafts and fresh air entered the first panel by the main ramp and one shaft, a condition considered inappropriate as soon as the secondary ramp giving access to the panel below began to be opened.

#### 5 AIRFLOW

Table 1 summarizes the location and characteristics of the old system operating fans, all 6 being axial type fans manufactured by Hightec-Chicago Blower.

The only fan operating under blowing conditions was installed at the shaft that connected the surface to the south end of level 530.

Four fans operated under exhaust conditions and were installed at 3 shafts connecting the surface to the north portion of levels 420, 500 and 530.

Table 1. Old system fan location and characteristics. Nominal airflow refers to expected values.

Shaft location	number	pressure (Pa)	airflow (m <sup>3</sup> /s) nominal
N530 South	1	61	43,2
N420	2 (parallel)	741	27,8
N530 / N500	2 (parallel)	681	28,5
crush ex-hauster	1	246	30,6

Airflow distribution in the first panel was analyzed by surveying the air velocities at ramps, drifts and shafts, measuring velocities at 9 points in each section. Table 2 summarizes the airflow at the shafts and ramp.

A first set of measurements was taken in order to compare real air distribution with the nominal expected airflow (table 1). Expected total fresh air was 155,8 m<sup>3</sup>/s and measured total fresh air is presented in table 2.

For the first panel the total fresh air influx was of 163,8 m<sup>3</sup>/s, measured at main ramp entrance and

blowing shaft. Total air exiting was measured at exhaust shafts and was 148,1 m<sup>3</sup>/s. The difference in measured values was less than 10%, an acceptable result.

Expected flow value of 155,8 m<sup>3</sup>/s lied between both measured values, indicating that the old ventilation scheme was operating under reasonably good conditions.

Table 2. Measured airflow for old ventilation scheme for the first panel.

Location	airflow (m <sup>3</sup> /s)	observation
access ramp entrance - P1	111,6	30% difference due to losses associated with connecting drifts to conveyor ramp
access ramp end - N420 - P2	81,8	
N420 north - exhaust 1	67,8	
N530 north - exhaust 2	55,4	
N500 north - exhaust 3	24,9	
N530 south - blower 1	82,0	

Measurements at main access ramp entrance and bottom indicated a difference in airflow of about 30%, due to leakage associated with drifts connecting the main ramp and the conveyor belt ramp. This is considered too much and leakage should be diminished.

A second set of measurements included psychrometric parameters and gas concentrations. All measurements indicated compliance with legal standards. The only exception was in the truck repair shop where NO<sub>x</sub> concentration would be above legal standards when all engines were working together.

Fresh air quantity which was adequate for the first panel turn out to be inadequate as soon as the secondary ramp to the second panel began to be developed. There were complaints about thermal comfort, dust and gas. The total fresh air delivered by the old scheme was clearly not enough for the mine expansion.

## 6 NEW VENTILATION SYSTEM

Due to problems with the old ventilation scheme a new one is being tested, involving 7 fans, all operating by exhaustion at several shafts.

Fresh air will enter the mine through two ramps, the main access ramp and a recently reopened tunnel (TAB). All polluted air will leave the stopes and

rooms and will be directed to the closest ventilation shaft.

Table 3 presents the characteristics of the new ventilation system, as proposed by the contractors and which will operate with an estimated total airflow of 228 m<sup>3</sup>/s. This is in accordance with the contractors estimate of the required airflow of 224 m<sup>3</sup>/s.

Table 3. New ventilation system fans.

location	sublev-els connected	shaft length h (m)	num-ber of fans (50HP)	airflow in one fan (m <sup>3</sup> /s)	total airflow (m <sup>3</sup> /s)
R4B north	420-600	210	2	32	64
R5B north	530-600	70	1	30	30
inv 1	530-600	70	2	32	64
inv 2	530-600	70	1	35	35
inv 3	530-600	70	1	35	35
total airflow in the min = 228 m <sup>3</sup> /s					

## 7 FRESH AIR REQUIREMENTS ANALYSIS

The new required fresh airflow was analyzed according to the criteria involving combustion engines operating underground, dilution of the gas generated by detonation and thermal comfort at the deepest drifts and stopes.

### 7.1 Combustion engines

Airflow requirement calculation considered 60 m<sup>3</sup>/s of fresh air for each megawatt of power underground. Table 4 presents the values obtained for each machine and the total calculated airflow of 236,4 m<sup>3</sup>/s. This value is somewhat greater than the value adopted by the contractors.

Table 4. Air flow requirements due to combustion engines.

Machine	Power (MW) and number of machines	Total power (MW)	Fresh airflow required (m <sup>3</sup> /s)
small truck	0,067 (2)	0,134	8,0
truck	0,082 (2) / 0,097	0,261	15,7
truck	0,324 (5)	1,62	97,2
loaders	0,280 (2)		
	0,127 (3)	0,929	55,74
Jumbo drill	0,056 (2)	0,112	6,7
auxiliary equipment	0,112	0,112	6,7
drill	0,043 (2)	0,086	5,2
new trucks / drills	0,216 (2)		
	0,127 (2)	0,686	41,2
total required airflow = 236,4 m <sup>3</sup> /s			

### 7.2 Detonation gases

Detonation generally occurs at lunchtime, between 12 AM and 1 PM or after 5 PM. Normal dilution time is 60 minutes but sometimes delays in blasting preparation makes necessary to dilute gas in 30 minutes.

Adopting the value of 0, 57 m<sup>3</sup>/s of fresh air for each kg of explosive, with an average blast with 200 kg of explosive, an airflow of 114 m<sup>3</sup>/s will be required. This value is far below the requirement due to combustion engines.

### 7.3 Thermal comfort

Measurements of psychrometric parameters at several locations in the first panel indicated that effective temperatures were all below 27° effective grades, confirming that thermal comfort was not critical at the first panel. Measurements in the second panel should start as soon as the first stope in this second panel is developed. Table 5 presents some psychrometric parameters measured in the first panel.

Table 5. Example of thermal comfort parameters in the first panel.

Location	Tbn (°C)	Tbs (°C)	V air m/min	P kPa	moist ure (%)	Tef °
N420 access ramp (ambulatory)	16,5	20	210,6	99,2	75,5	14
N420 -ramp split at access for levels N330 e 280	16	19,1	82,2	99,2	74,1	15
N420 - main haul- age drift	17,4	21,2	115,8	99,1	74,9	17
access ramp en- trance to level N460	18,6	20,7	31,8	98,3	78,3	19
level N500 en- trance	18,6	21,4	51,6	98,1	78,4	18
level N530 en- trance	18,2	22	27,6	97,8	70	20

## 8 CONCLUSIONS

The old ventilation scheme worked satisfactorily for the first panel of rooms and stopes. Expected and measured fresh airflow values were reasonably close and above fresh air estimated requirements. Workers complaints were not significant and thermal comfort and gas concentrations were below legal values.

The development of a secondary ramp to a second panel of stopes below the production ones indicated that the old ventilation system was not enough

to meet gas, thermal comfort and dust concentration standards. Workers complaints corroborated the need for a new ventilation system.

A consulting firm proposed a new ventilation scheme with estimated fresh air requirement of 224 m<sup>3</sup>/s and a fan system operating with 228 m<sup>3</sup>/s.

Analysis of airflow requirements indicated that combustion engines would require at least 236,4 m<sup>3</sup>/s, not considering thermal comfort in the second panel production stopes.

The authors suggest that the new ventilation system should operate with a larger fresh air influx in order to allow for leakage and future thermal comfort requirements. The new system should consider 250 m<sup>3</sup>/s as minimum fresh airflow. Future monitoring will permit to check the second panel working conditions. Leakage should be decreased to below 10% in the main ramp.

## REFERENCES

- BRASIL. Ministério das Minas e Energia. Departamento Nacional da Produção Mineral. Ventilação em minas subterrâneas. Brasília, DNPM, 1986.
- DASYS, A., HARDCASTLE, S.G; Mine ventilation management "expert system". [on line]. In: 6<sup>th</sup> Mine Ventilation Congress, Pittsburgh, USA, May 17-22, 1997. Disponível: [http://icewall.vianet.on.ca/comm/eei/mine-sim\\_doc.html](http://icewall.vianet.on.ca/comm/eei/mine-sim_doc.html). [Accessed July 21, 1998].
- HARDCASTLE, S.G.; LEUNG, E.; DASYS, A., Integrated mine ventilation management systems. [on line]. Ontário, CANMET. Disponível: [http://icewall.vianet.on.ca/comm/eei/ventmgmt\\_doc.html](http://icewall.vianet.on.ca/comm/eei/ventmgmt_doc.html). [Capturado em July 21, 1998].
- HARTMAN, H. L. Introductory mining engineering. New York, John Wiley, 1987.
- LACASEMIN TECHNICAL REPPORT MI/587 - 03/93. Análise da rede de ventilação forçada da mina subterrânea de Ipueira III, Lavra de Cromita, Bahia. 3o Relatório. EPUSP
- VOTORANTIM: 5 km de túneis para chegar ao calcário. Minérios: Extração & Processamento. N. 18, julho de 1978. p. 24-8.

PROCEEDINGS OF THE SIXTH INTERNATIONAL CONFERENCE ON ENVIRONMENTAL  
ISSUES AND MANAGEMENT OF WASTE IN ENERGY AND MINERAL PRODUCTION  
SWEMP 2000/ CALGARY/ ALBERTA/ CANADA/ MAY 30 – JUNE 2, 2000

# Environmental Issues and Management of Waste in Energy and Mineral Production

*Edited by*

**Raj K. Singhal**

*Federal Government of Canada & Université Laval, Québec, Canada*

*International Journal of Surface Mining, Reclamation and Environment*

**Anil K. Mehrotra**

*University of Calgary, Department of Chemical and Petroleum Engineering, Calgary, Alberta, Canada*

OFFPRINT



A.A. BALKEMA / ROTTERDAM / BROOKFIELD / 2000



FROM THE SAME PUBLISHER

90 5809 126 0

**Tailings and mine waste '00** – *Proceedings of the seventh international conference, Fort Collins, Colorado, USA, 23-26 January 2000*

2000, 25 cm, 576 pp., EUR 95.50 / \$99.00 / £63

The proceedings present state-of-the-art papers on mine and mill tailings and mine waste, as well as current and future issues facing the mining and environmental communities. This includes subjects related to technical capabilities and developments, regulations, and environmental concerns. Papers include topics related to tailings and mine waste dealing with reclamation and remediation, protective liners and covers, barriers, design and operation, ground water and surface water quality and modeling, geotechnical and geochemical aspects, reprocessing, utilization and treatment, mine waste regulations, case histories, and disposal issues.

Pasamehmetoglu, A.G. & A. Özgenoglu (eds) 90 5410 956 4

**Environmental issues and waste management in energy and mineral production** – *Proceedings of the fifth international symposium SWEMP '98, Ankara, Turkey, 18-20 May 1998*

No rights India

1998, 25 cm, 770 pp., EUR 100.00 / \$116.00 / £70

Topics: Sustainable mineral and energy resources development; Environmental regulations; Environmental management, risk assessment; Environmental impact assessment, monitoring and waste characterization; Health and safety; Petroleum production and environment; Coal combustion byproduct and mine waste management and utilization; Coal processing and utilization technologies for a cleaner environment; Wastewater treatment and cleaning; Emerging mineral processing technologies; Mine site closure, acid mine drainage, decommissioning and rehabilitation; Role of computer and geographic information systems (GIS) in solving environmental problems.

Sêco e Pinto, P.S. (ed.)

90 5809 006 X

**Environmental geotechnics** – *Proceedings of the third international congress, Lisbon, 7-11 September 1998*

1998, 25 cm, 1400 pp. 4 vols, EUR 179.50/\$209.00/£126

Topics covered: Presentation of TC5 activities report; Environmental problems in the Iberian Peninsula; Environmental problems in the East European countries; Environmental problems of the New Tagues bridge; New perspectives in management of operating and abandoned mining waste deposits; Landfills for solid and liquid wastes; Remediation of polluted land and abandoned landfills; Re-use of by-products; Risk analysis, quality assurance and regulations; Education in environmental geotechnics; Professional practice; etc.

Haigh, Martin J. (ed.)

90 5410 793 6

**Reclaimed land - Erosion control, soils and ecology**

2000, 24 cm, 400 pp., EUR 85.00 / \$88.00 / £56

No rights India

This volume covers an array of key issues within current thinking on the conservation of land that has been reclaimed after surface mining for coal. The book contains work connected to the search for self-sustainability in reconstructed landscapes and seeks strategies for the creation of the landforms, soils, drainage-channels and vegetation systems that will protect the land from degradation and survive through the long term. It also contains work connected to the stabilization of newly reclaimed lands, so that long-term self-sustainable systems may become established.

Lecomte, Paul

90 5410 784 7

**Polluted sites – Remediation of soils and groundwater**

1999, 24 cm, 218 pp., EUR 55.00 / \$58.00 / £37

No rights India

Translation of *Les sites pollués: traitement des sols et des eaux souterraines*, 2nd edition, 1998, Paris. The author proposes a rigorous and organized approach comprising different phases: diagnosis, risk assessment, remediation of site. The 'remediation' aspect is particularly emphasized by considering two specific media: soil and groundwater. The book presents a complete summary and includes all aspects of the process of rehabilitation: financial and regulatory aspects as well as the factors relating to insurance. In this second edition Paul Lecomte presents an update of the technologies and the regulatory framework in this fast developing field.

Singhal, R.K., A.K.Mehrotra, K.Fytas & J.-L.Collins (eds.)

90 5410 079 6

**Environmental issues and management of waste in energy and mineral production** – *Proceedings of the second international conference, Calgary, Alberta, Canada, 1-4 September 1992*

1992, 25 cm, 1487 pp., 2 vols, EUR 214.50 / \$252.00 / £151

Atak, S., G.Önal & M.S.Çelik (eds)

90 5809 013 2

**Innovations in mineral and coal processing** – *Proceedings of the 7th international mineral processing symposium, Istanbul, Turkey, 15-17 September 1998*

1998, 25 cm, 922 pp., EUR 98.00 / \$114.00 / £69

The papers represent a spectrum of diverse areas such as comminution, sizing, gravity, magnetic and electrostatic separation processes, flotation fundamentals and technology, industrial minerals, hydro- and bio-hydro metallurgy, processing of gold and silver, coal preparation and utilization technologies, agglomeration, dewatering, modeling, simulation and control, environmental issues, recycling and waste treatment.

*All books available from your bookseller or directly from the publisher:*

*A.A. Balkema Publishers, P.O. Box 1675, NL-3000 BR Rotterdam, Netherlands (Fax: +31-10-413-5947)*

*For USA & Canada:*

*A.A. Balkema Publishers, Old Post Rd, Brookfield, VT 05036-9704 (Fax: 802-276-3837)*

