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Evaluation of the Environmental Impacts of Blasting in Okorusu Fluorspar Mine, Namibia

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ABSTRACT

Blasting is one of the main methods used in the mining industry to fragment hard rock minerals. Blasting is an inherently dangerous activity which can result in serious injury, death, and/or damage if not designed and performed professionally. The work done in this paper is to evaluate these negative factors associated with blasting operations to the mining environment. Four different monitoring places (Mine Offices, Old Crusher, New Crusher and the Mine Hostel) in the mine were selected. Five experimental trial blasts were conducted as from the 14th to 28th November at various pits (D and B Pits) of the mine during the period of field investigation with varying designs and charging patterns. The magnitude of ground vibration and air blast, sound level data evaluated varied between 1.402 and 11.304 mm/s, 0.00354 and 0.0214 Kpa, 104.963 and 120.599 Lp (dB) respectively. Both the magnitude of ground vibration and air pressure were well within the safe limit, however the level of sound generated(120.599 Lp(dB)) from Blast No. 5 near the Old crusher, located at a distance of 771.07 m from the blasting site, it was slightly higher than the maximum safe limit of 120 Lp(dB). This indicates that blasting operations in Okurusu Fluorspar Mine are done without noticeable environmental hazards.

Keywords: *Blasting, Mine, Air blast, Impact, Fly rock*

1. INTRODUCTION

Mining industries and mining practice in particular, are vastly known for their hazardous working conditions and the unstable nature of the earth crust which mineral extraction causes thereby threatening the life and properties of the society (Abubakar et al., 2011). In any surface mines, blasting operation plays a vital role. The extraction of moderately hard mineral such as Diamond, Copper, and Gold etc. requires the use of explosive energy through blasting to free the rock from its in-situ position. Blast operations in mines are usually accompanied by seismic effects which include, ground vibrations, air-blast/overpressure/noise; fly rock, fumes and dusts. Inappropriate planning, design and field operational errors of blasts including unpredictable site conditions, variability of rock mass properties and characteristics of explosives and accessories could cause undesirable impact in the vicinity of blast operation (Akande and Awojobi, 2005). The undesirable known side effects of detonation of explosives are vibration, noise/air over-pressure, flyrock, dust and fumes (Singh *et al.*, 1996).

Air and ground vibration from blasting is an undesirable side effect of the use of explosives for excavation. The actual damage criterion of ground vibration is the Peak Particle Velocity (PPV) of the conducting ground medium or wave acceleration (Mohamed, 2010). The shaking of structure is also directly and linearly proportional to ground vibration amplitude. If the PPV is reduced by half, structural response will be cut in half (Rudenko, 2002). Complete avoidance of superposition and amplification of the vibrations in a larger blast impossible to achieve because the duration of the vibration is always considerably larger than the effective delays used between the charges in smaller blasts (Singh *et al*., 2003; Valdivia *et al*., 2003).

Flyrock being propelled rock fragments by explosive energy beyond the blast area, is one of the undesirable phenomena in the mining blasting operation (Stojadinovic *et al.*, 2011), any mismatch between distribution of explosive energy, mechanical strength of rock mass and charge confinement can be cause of flyrock (Bajpayee et al. 2004). The blasting operation is a potential source of numerous environmental and safety accidents. For instance, the Mine Safety and Health Administration (MSHA, 2006) reports a total of 168 blasting related injuries in the United States between 1994 and 2005. A total of 107 injuries occurred in surface coal, metal and non-metal mining, while 61 injuries were reported for underground mining. Analysis conducted by Verakis and Lobb (2007) shows that in surface mining, 39 accidents were directly attributed to lack of blast area security, 32 to flyrock, 15 to premature blast, nine to misfires, one to disposing and seven to miscellaneous blasting-related accidents. It can be noted that almost 70% of all injuries is directly contributing to the flyrock and lack of blast area security. Study conducted by Lu *et al*. (2000) indicates that almost 27% of demolition accidents in China were contributed to flyrock, while Adhikari (1999) reports that 20% of accidents that were related to flyrock occurred in mines in India.
The aim of this research is to evaluate the environmental impacts namely: Air blast, Sound , ground vibration and flyrock, as a result of blasting operation in Okurusu Fluorspar Mine in Namibia.

1.1 Site Location and Geology

The Okorusu Fluorite Mine is situated to the north of Otjiwarongo, Namibia. The Mine is owned by Okorusu Fluorspar (Pty) Ltd, a subsidiary of the Solvay S.A Group. The Mine produces acid-grade fluorspar of 97% purity, with full mineral processing facilities on site. Fluorite is associated with an alkaline igneous-carbonatite ring dike complex. The complex is of early Cretaceous age, which intruded into late Pre-cambrian Damara Series metasedimentary rocks. The metasedimentary rocks have been thoroughly fenitized in the vicinity of the igneous intrusives to fine-grained sodic fenites. The early main intrusion of carbonatite (sövite) is fine grained and consists almost entirely of calcite.

Figure 1: View of the Okorusu Fluorspar mine

2. METHODOLOGY

Five trial blasting were done and four monitoring points were used namely; Old Crusher (Plant), New Crusher, Main offices building and Hostel. Generally, Empirical approach was adopted in evaluating the various disasters associated with blasting operation. The following formulas were used to calculate selected blasting associated disasters and the results presented thereafter in tables.

1. Air blast (kPa)

$$P = K\left[\frac{R}{Q^{0.33}}\right]^{-1.2} \quad (1)$$

Where: P is pressure (kPa), K is state of confinement, Typical K factors :*Unconfined= 185* , *Fully confined= 3.3*

Q is maximum instantaneous charge (kg), R is plane distance from charge/ blasting location (m)

2. Sound level

$$Lp = 20log\left[\frac{P}{20\times 10^{-9}}\right] \quad (2)$$

Where: P is pressure (kPa)

3. Maximum particle vibration

$$V = K\left[\frac{R}{Q^{0.5}}\right]^{B} \quad (3)$$

Where: V is peak particle velocity (mm/s), K is site and rock factor constant, Typical K factors: *Free face – hard or highly structured rock = 500, Free face average rock = 1140, heavily confined= 5000*, Q is maximum instantaneous charge (kg), B is constant related to the rock and site (usually -1.6), R = distance from charge (m)

3. RESULTS

The results obtained during the first to five trial blasts are shown in Tables 1-5 below respectively.

Table 1: The air blast, sound level and ground vibration generated during the first blast trial.

Monitoring point	Distance from the blasting location to the monitoring point .(m)	Air Blast (kPa)	Sound level Lp(dB)	Ground Vibration (mm/s)k =1140	Fly rocks
Old crusher(Plant)	981.53	0.016266633	118.2053534	7.276386101	Not observed
New Crusher	992.67	0.016047822	118.0877218	7.14617464	Not observed
Main offices building	1381.68	0.010791778	114.64126	4.210265727	Not observed
hostel	1887.3	0.007422887	111.3908568	2.55632435	Not observed

Table 2: The air blast, sound level and ground vibration generated during the second trial blast.

Monitoring point	Plane distance from the blasting location to the monitoring point .(m)	Air Blast (kPa)	Sound level Lp(dB)	Ground Vibration (mm/s)k =1140	Fly rocks
Old crusher(Plant)	911.36	0.01274708	116.0876141	4.182643475	Not observed
New Crusher	923	0.012554419	115.9553324	4.098567264	Not observed
Main offices building	1312.11	0.008231412	112.2888874	2.334545786	Not observed
hostel	1729.77	0.005908165	109.4084526	1.500283771	Not observed

Table 3: The air blast, sound level and ground vibration generated during the third trial blast.

Monitoring point	Plane distance from the blasting location to the monitoring point .(m)	Air Blast (kPa)	Sound level Lp(dB)	Ground Vibration (mm/s)k =1140	Fly rocks
Old crusher(Plant)	1064.42	0.011283705	115.0284343	3.715659716	Not observed
New Crusher	1105.37	0.010783957	114.6349628	3.497876713	Not observed
Main offices building	1494.77	0.007507548	111.489362	2.158230268	Not observed
hostel	1956.51	0.005435116	108.6835772	1.402960555	Not observed

Table 4: The air blast, sound level and ground vibration generated during the fourth trial blast.

Monitoring point	Plane distance from the blasting location to the monitoring point .(m)	Air Blast (kPa)	Sound level Lp(dB)	Ground Vibration (mm/s)k =1140	Fly rocks
Old crusher(Plant)	732.26	0.00838814	112.4527137	1.499566855	Not observed
New Crusher	917.19	0.006401959	110.1056577	1.045912692	Not observed
Main offices building	1218.08	0.00455463	107.1484616	0.664276717	Not observed
hostel	1502.12	0.003541755	104.96377	0.475010189	Not observed

Table 5: The air blast, sound level and ground vibration generated during the fifth trial blast.

Monitoring point	Plane distance from the blasting location to the monitoring point .(m)	Air Blast (kPa)	Sound level Lp(dB)	Ground Vibration (mm/s)k =1140	Fly rocks
Old crusher(Plant)	771.07	0.021429641	120.5996978	771.07	Not observed
New Crusher	1003.73	0.015616625	117.8511435	1003.73	Not observed
Main offices building	1275.28	0.011716578	115.355416	1275.28	Not observed
hostel	1654.37	0.0085737	112.6427657	1654.37	Not observed

4. DISCUSSION

Air blast

The levels of air overpressure recorded from different blasts varied between 0.00354 and 0.0214 Kpa. The Internationally accepted damage levels due to blast-induced air blast/overpressure are shown in Table 6.

Table 1: The Internationally accepted damage levels due to blast-induced air blast/overpressure

Overpressure (dB)	Overpressure (KPa)	Air Blast Effects
177	14.00	All windows break
170	6.00	Most windows break
150	0.63	Some windows break
140	0.20	Some plate glass windows may break and rattle
136	0.13	USBM interim limit for allowable air blast
126	0.05	Complaints likely

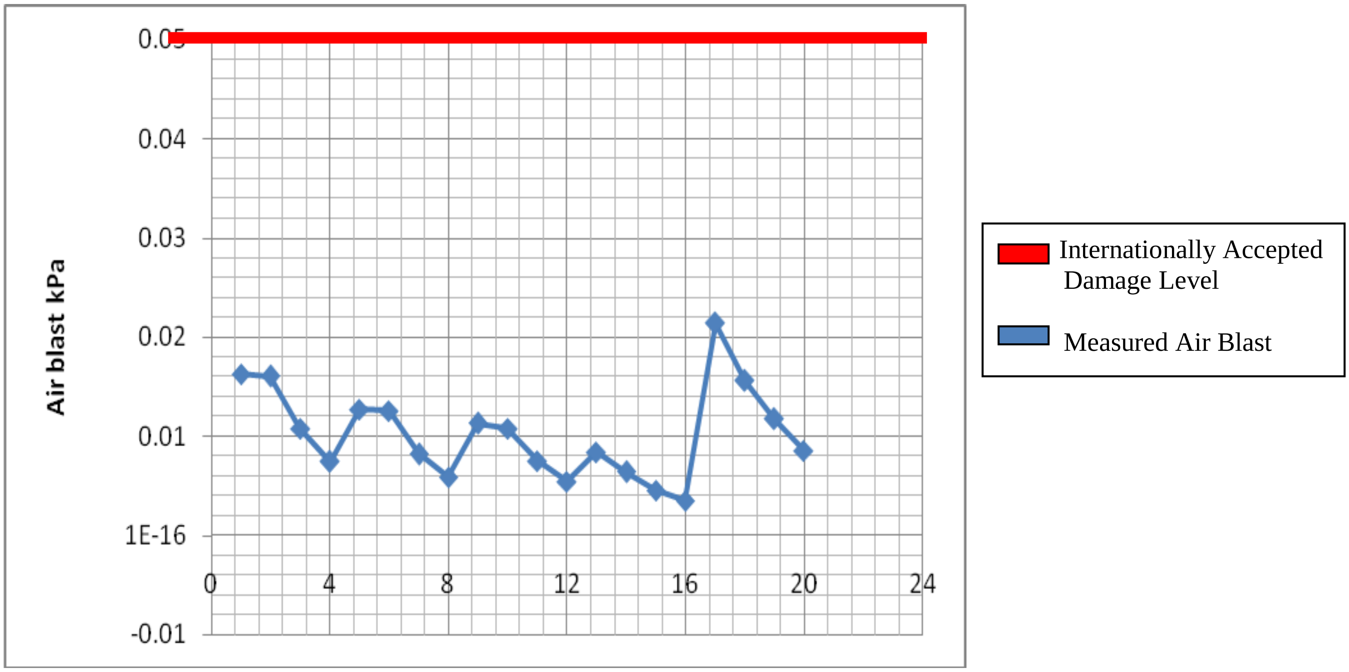

Figure 2: Plot of air blast / air over-pressure (kPa) at different locations

The graph in Figure 2 shows the air blast / air over-pressure (kPa) at four different monitoring places (New Crusher , Old crusher(Plant), Main offices building and hostel) during the five experimental trial blast.

From Table 6 and Figure 2, it is discovered that the levels of air overpressure recorded during experimental trial blasts were well within the safe limits of the Internationally accepted damage levels due to blast-induced air overpressure.

Sound level (Noise)

The levels of noise recorded from different blasts varied between 104.963 and 120.599 Lp (dB). The Internationally accepted Minimum levels quoted AS 2187.2 – 1993 are given in Table 7.

Table 7: The Internationally accepted Minimum/ accepted levels quoted AS 2187.2 – 1993

Sound level effects	Minimum levels [dB(lin)]
Human discomfort	120
Onset of structure damage, or historic buildings where no specific limit exists	130

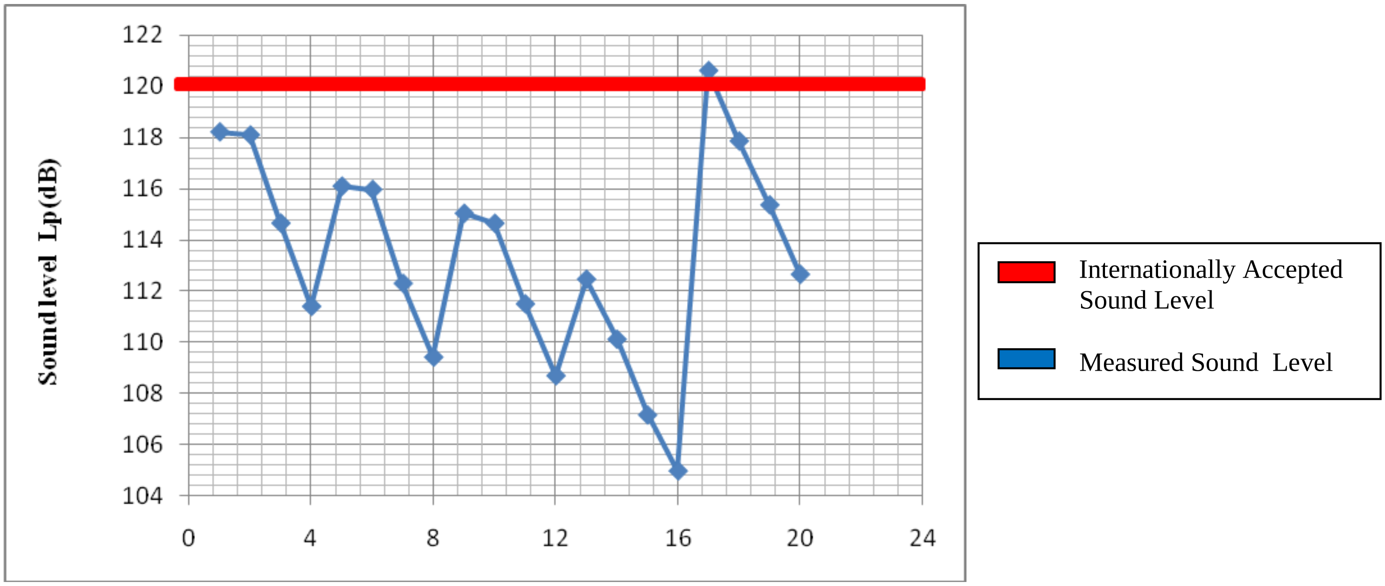

Figure 3: Plot of sound level (noise) Lp (dB) at di9fferent locations

Figure 3 shows the sound level (noise) experienced at four different monitoring places (New Crusher , Old crusher(Plant), Main offices building and hostel) during the five experimental trial blast.

From Table 7 and Figure 3, it is shown that the sound levels recorded during experimental trial blasts were within the safe limits of the Internationally accepted Minimum/ accepted sound(noise) levels quoted AS 2187.2 – 1993 except for people working at the new crusher who affected by the noise produced during the 5th blast, because the sound level at the old crusher due to the blast five, is 120.5996978 Lp(dB) which is slightly higher than the minimum sound level of Human comfort.

Ground vibration (Peak Particle Velocities)

When an explosive is detonated in a blast hole, a pressure wave is generated in the surrounding rock. As this pressure wave moves from the borehole it forms seismic waves by displacing particles. The particle movement is measured to determine the magnitude of the blast vibration.

The likely peak vibration amplitude is referred to as Peak Particle Velocity (PPV) and is used as a basis for damage limiting criteria together with blasting frequency. For various distance from the blasting site to the area of concern, Vibration has several negative impacts to the mining environment. The peak particle velocity from different blasts varied between 1.402 and 11.304 mm/s. The Internationally accepted and recommended maximum Peak Particle Velocities (AS 2187.2 – 1993) are given in Table 8.

Table 8: Recommended maximum Peak Particle Velocities (AS 2187.2 – 1993)

Type of structure/ vibration effects	Maximum Peak Particle Velocities PPV (mm/s)
Lower limit for damage to plaster walls	13
Lower limit for dry wall structures	19
Commercial and industrial buildings or structures of reinforced concrete or steel constructions	25
Minor damage	70
>50% chance of minor damage to structures	140
50% chance of major damage	190

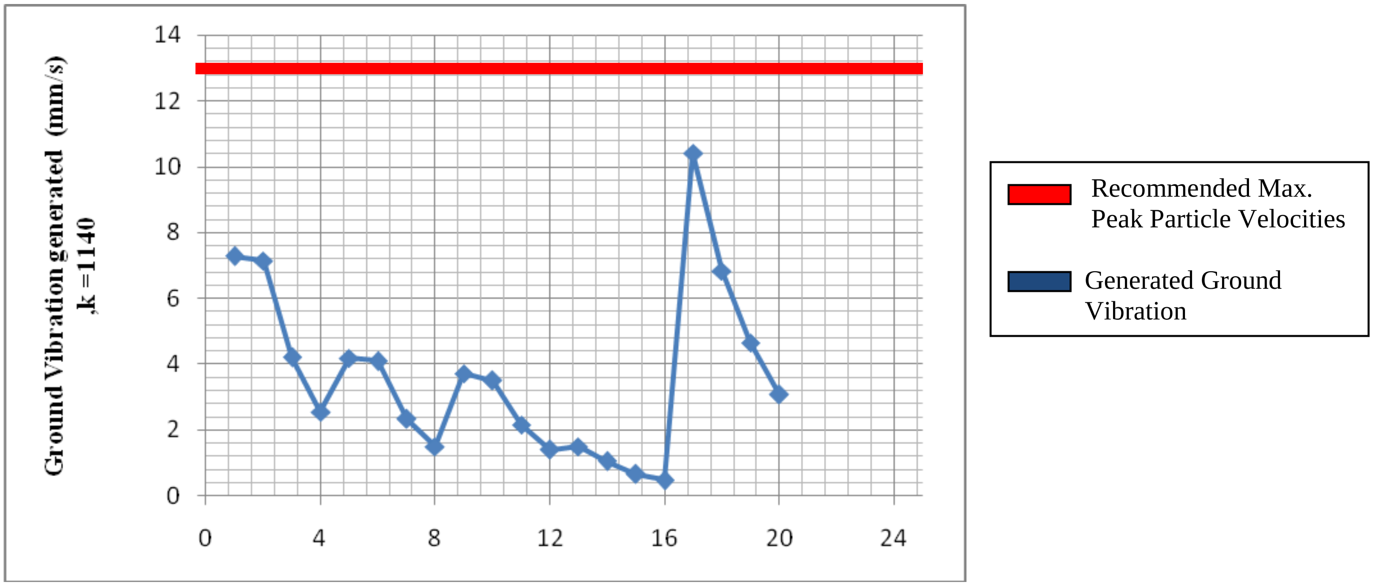

Figure 4: Plot of Ground vibration (Peak Particle Velocities) (mm/s) at different locations

The graph in Figure 4 shows the Peak Particle Velocities at four different monitoring places (New Crusher, Old crusher (Plant), Main offices building and hostel) during the five experimental trial blasts. From Table 8 and Figure 4, it is clear that the Peak Particle Velocities (Ground vibration) at the four monitoring places during the five experimental trial blasts were all within the safe limits of the internationally accepted / recommended maximum Peak Particle Velocities (AS 2187.2 – 1993).

Fly rocks

During the five experimental trial blasts, there were no fly rocks observed at all the monitoring places. This shows that accurate blasting controlled was carried out during the five blast experimental trial.

5. CONCLUSION

This study revealed that the blasting operation in Okorusu mine followed the internationally acceptable standards except in a location during the fifth trial blast where the sound level was slightly higher than the recommended level.

Generally, it can be concluded that blasting operation at Okurusu mine is within the international Standard and this fault the general belief that mining operation cannot be carried out without accompanying environmental hazards.

However, training of personnel involved in blasting operations would continually update the workers on the improved methodologies of blasting from time to time especially in areas of preventing environmental and safety accidents, implementing work practices that meet specified legislation and standards, identifying strategies for monitoring and updating safety information and effective safety communications.

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