Musselwhite Mine DPF Installation Project

Being Responsible

MDEC 2017

GOLDCORP

Executive Summary

- **Goldcorp is one of the fastest growing, senior gold producers in the world.**
- **Goldcorp contributes significant economic and social benefits to the communities where we operate and the overall Ontario economy:**
  - o Produces more than 50% of Ontario's Gold.
  - o Established collaboration agreements with all First Nations surrounding our three mining operations.
- **Ontario is an important jurisdiction to Goldcorp – represents roughly 1/3 of a total 3 million ounces produced annually in the Americas.**
- **Goldcorp is currently engaged in an investment to expand the Musselwhite Mine production to extend the mine life and create jobs and associated economic benefits.**

The Challenge

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- **Beginning in the fall of 2013 various areas of the mine had started to become affected by the high accumulation of diesel particulate.**
- **Initially our mechanical shops at 488 meter level had been affected. This had us reduce the shops scheduling to an 8 hour day reducing the throughput of machinery affecting our business partner's availability.**
- **Musselwhite also began to have other areas affected by the DPM which resulted in having other areas become "respiratory fit" mandatory. This affected the working environment and morale for many of our employees.**
- **We struggled with how we were going to deal with the problem as providing additional ventilation was challenging with the mine design, costly, and would not be available within and short time frame.**

The Solution

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- **In 2013 a suggestion from the ventilation department was brought forward that there were DPM filters on the market that could help lower the levels in the mine.**
- **We started working with a manufacturer, Mammoth out of Australia in the fall of 2013. This involved testing the levels of DPM and also emissions to ensure we were not adding another problem such as N02 to our air quality. Testing of filters on the high volume contributors (haul trucks) was done for 3 months to help ensure quality of the product.**
- **The maintenance department investigated and spent the time working on the business case to ensure the investment would be beneficial and responsible. This was done by testing, documenting, planning, and bringing experts to site.**
- **We spent a lot of time with all of the Sites departments to ensure everyone had a voice in the problems and solutions. We held monthly DPM meetings to keep everyone informed. This helped to alleviate false information in work groups, clear any misconceptions and calm personnel issues with long lead times to get the product to site (1yr).**

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- **Prior to the filters being installed there was numerous attempts to improve the shop DPM test results, with different changes to the ventilation and by installing large circular ceiling fans on the back to help move air out of the shop.**
- **Initial testing at 488 Shop resulted in high readings of DPM above the set Ministry of Labour Occupational Exposure Limits (OEL) of 0.256mg/m3. The Goldcorp Industrial Hygiene action limit is set to 0.2 mg/m3 which is 80% of the OEL. Any areas within the mine that had exposure levels above the action limit was designated a "respiratory fit" mandatory area.**
- **The number of samples taken during this testing period was 37 (10.5hrs) from a March 2013-November 2013. A number of other controls were implemented related to changing mine ventilation and dust suppression which had little to no success. The decision was made to reduce the Shop Maintenance shift work hours to (8hrs) reducing the exposure of DPM on the workers (samples taken from Nov2013-Nov2014).**

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- The trial filters were installed on a truck and scoop (cat AD45 and R2900G) for a trial period of one year prior to installing the Mammoth filters on the rest of the fleet (trucks and scoops).
- Once the filters arrived the maintenance team made a plan to execute the installation. This involved generating a “base line” before and after installs for future reference.
- The Mammoth filters were installed on all scoops and haulage trucks which significantly decreased the levels of DPM well below the Occupational Exposure Limit and the corporate Action Limit.
- The results after the changeover from Standard exhaust to Mammoth Filters was almost instantaneous. DPM results at 488 level shop came in below the MWM threshold acceptable levels in the first set of test results.
- Other mine levels that were restricted “respiratory fit” mandatory were also tested and were relieved of the restrictions within the first 2 weeks after installation. These were big wins to the mine site as they improved the health and morale of all workers underground.
- The results have been extremely positive and sustainable, but the filters are “maintenance intensive” and require a coordinated team effect along with investment to keep them performing.

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Goldcorp Musselwhite Mine - TWAs and Action Levels (July 2013)

(as per O. Regs. 833/90; 854/90 and 490/09 - shift adjusted by Brief and Scala Model)

Agent	TWA			Action Level (80% of TWA)		
	8 hour	10.5 hour	12 hour	8 hour	10.5 hour	12 hour
arsenic (As)	0.01 mg/m3	0.0064 mg/m3	0.005 mg/m3	0.008 mg/m3	0.0051 mg/m3	0.004 mg/m3
cadmium (Cd)	0.01 mg/m3	0.0064 mg/m3	0.005 mg/m3	0.008 mg/m3	0.0051 mg/m3	0.004 mg/m3
carbon disulphide	1 ppm	0.64 ppm	0.5 ppm	0.8 ppm	0.51 ppm	0.4 ppm
carbon monoxide (CO)	25 ppm	16 ppm	13 ppm	20 ppm	13 ppm	10 ppm
carbonyl sulphide	5 ppm	3.2 ppm	2.5 ppm	4 ppm	2.6 ppm	2 ppm
cobalt (Co)	0.02 mg/m3	0.013 mg/m3	0.01 mg/m3	0.016 mg/m3	0.01 mg/m3	0.008 mg/m3
copper (Cu) - dust	1 mg/m3	0.064 mg/m3	0.5 mg/m3	0.8 mg/m3	0.51 mg/m3	0.4 mg/m3
copper (Cu) - fume	0.2 mg/m3	0.13 mg/m3	0.1 mg/m3	0.16 mg/m3	0.1 mg/m3	0.08 mg/m3
dimethyl disulphide	0.5 ppm	0.32 ppm	0.25 ppm	0.4 ppm	0.26 ppm	0.2 ppm
dimethyl sulphide	10 ppm	6.4 ppm	5 ppm	8 ppm	5.1 ppm	4 ppm
DPM - elemental carbon	0.308 mg/m3	0.197 mg/m3	0.154 mg/m3	0.246 mg/m3	0.158 mg/m3	0.123 mg/m3
DPM - total carbon	0.4 mg/m3	0.256 mg/m3	0.2 mg/m3	0.32 mg/m3	0.2 mg/m3	0.16 mg/m3
ethyl mercaptan	0.5 ppm	0.32 ppm	0.25 ppm	0.4 ppm	0.26 ppm	0.2 ppm
hydrogen sulphide (H2S)	1 ppm	0.64 ppm	0.5 ppm	0.8 ppm	0.5 ppm	0.4 ppm
isocyanates	0.005 ppm	0.0032 ppm	0.0025 ppm	0.004 ppm	0.0026 ppm	002 ppm
lead (Pb)	0.05 mg/m3	0.032 mg/m3	0.025 mg/m3	0.04 mg/m3	0.026 mg/m3	0.02 mg/m3
manganese (Mn)	0.2 mg/m3	0.13 mg/m3	0.1 mg/m3	0.16 mg/m3	0.1 mg/m3	0.08 mg/m3
mercury (Hg)	0.025 mg/m3	0.016 mg/m3	0.013 mg/m3	0.02 mg/m3	0.013 mg/m3	0.01 mg/m3
methyl mercaptan	0.5 ppm	0.32 ppm	0.25 ppm	0.4 ppm	0.26 ppm	0.2 ppm
n-butyl mercaptan	0.5 ppm	0.32 ppm	0.25 ppm	0.4 ppm	0.26 ppm	0.2 ppm
nitric oxide (NO)	25 ppm	16 ppm	13 ppm	20 ppm	13 ppm	10 ppm
nitrogen dioxide (NO2)	0.2 ppm	0.13 ppm	0.1 ppm	0.16 ppm	0.1 ppm	0.08 ppm
respirable dust/fume	3 mg/m3	1.9 mg/m3	1.5 mg/m3	2.4 mg/m3	1.5 mg/m3	1.2 mg/m3
silica - cristobalite	0.05 mg/m3	0.032 mg/m3	0.025 mg/m3	0.04 mg/m3	0.026 mg/m3	0.02 mg/m3
silica - quartz	0.1 mg/m3	0.064 mg/m3	0.05 mg/m3	0.08 mg/m3	0.051 mg/m3	0.04 mg/m3
silica - tripoli	0.1 mg/m3	0.064 mg/m3	0.05 mg/m3	0.08 mg/m3	0.051 mg/m3	0.04 mg/m3
silver (Ag) - dust/fume	0.1 mg/m3	0.064 mg/m3	0.05 mg/m3	0.08 mg/m3	0.051 mg/m3	0.04 mg/m3
styrene	35 ppm	22 ppm	18 ppm	28 ppm	18 ppm	14 ppm
sulphur dioxide (SO2)	2 ppm	1.3 ppm	1 ppm	1.6 ppm	1 ppm	0.8 ppm
tungsten (W) - metal	5 mg/m3	3.2 mg/m3	2.5 mg/m3	4 mg/m3	2.6 mg/m3	2 mg/m3

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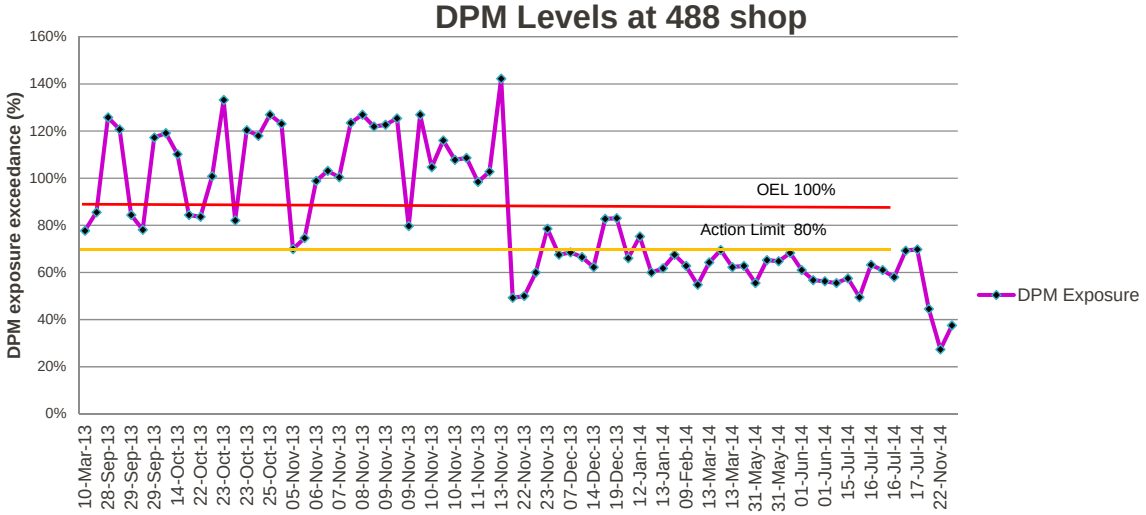
DPM Levels at 488 shop



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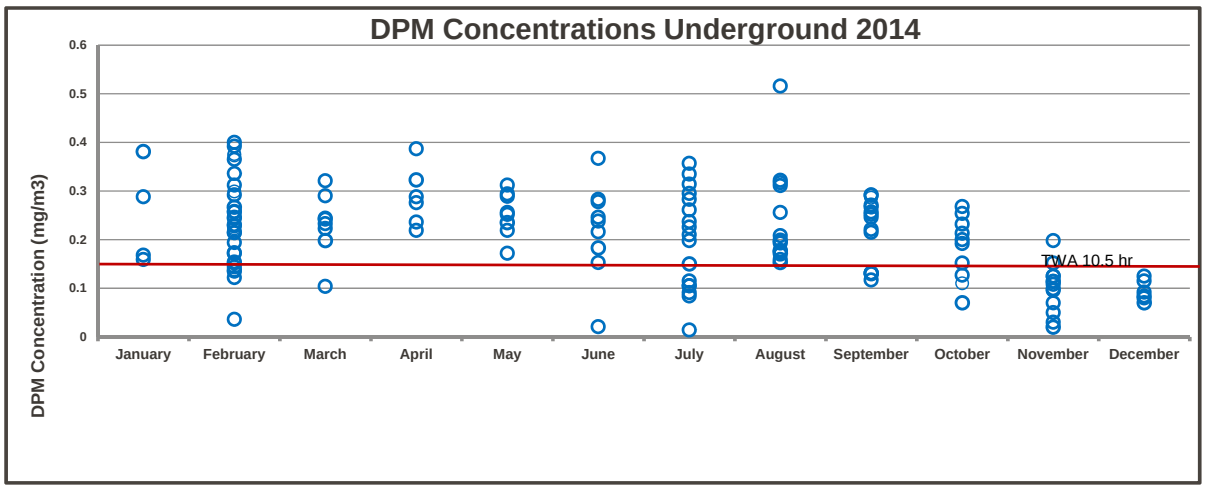
DPM Concentrations Underground 2014



This graph represents all testing done underground from January to December 2014.

Chart showing Nov 7 th – 8 th survey.

GAS MONITORING SUMMARY — Ventilation Survey Nov 7th & 8th, 2014

NO_2 TESTING			CO TESTING		
104	readings	<0.8 ppm (<50% TLV)	104	readings	<7 ppm (<50% TLV)
1	readings	>= 0.8 to < 1.20 ppm (50%-75% TLV) **	0	readings	>= 7 ppm (50% TLV)
0	readings	>= 1.20to < 1.46 ppm (75%-90% TLV)	0	readings	>= 10.5 ppm (75% TLV)
0	readings	>= 1.46 to < 1.6 ppm (90%-100% TLV)	0	readings	>= 12.6 ppm (90% TLV)
0	readings	>= 1.6 ppm (exceeding TLV)	0	readings	>= 14 ppm (exceeding TLV)
105		NO_2 readings taken	104		CO readings taken
0	readings	>= 5 ppm (exceeding stel)			

Breakdown of the NO2 Readings				Breakdown of the CO Readings		
31	readings	at 0.0		56	readings	at 0.0
0	readings	at 0.1	59 % below 0.2 NO2	0	readings	1
31	readings	at 0.2		8	readings	2
25	readings	at 0.3		28	readings	3
7	readings	at 0.4	41 % above 0.2 NO2	9	readings	4
8	readings	at 0.5	1145,1095,1080, 657	3	readings	at 5
1	readings	at 0.6	1120	0	readings	6
1	readings	at 0.7	720 lynx mucking	0	readings	7
1	readings	at 0.8	720 lynx mucking	0	readings	8
0	readings	at 0.9		0	readings	9

Chart showing Nov 27 to 29 th Survey.

GAS MONITORING SUMMARY — Nov 27 to 29th , 2014

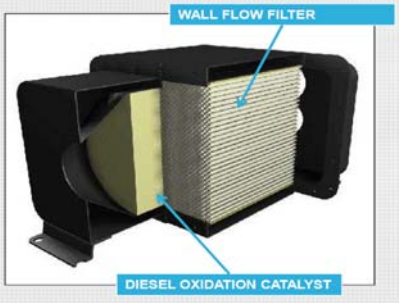
NO_2 TESTING			CO TESTING		
138	readings	<0.8 ppm (<50% TLV)	137	readings	<7 ppm (<50% TLV)
0	readings	>= 0.8 to < 1.20 ppm (50%-75% TLV) **	0	readings	>= 7 ppm (50% TLV)
0	readings	>= 1.20to < 1.46 ppm (75%-90% TLV)	0	readings	>= 10.5 ppm (75% TLV)
0	readings	>= 1.46 to < 1.6 ppm (90%-100% TLV)	0	readings	>= 12.6 ppm (90% TLV)
0	readings	>= 1.6 ppm (exceeding TLV)	0	readings	>= 14 ppm (exceeding TLV)
138		NO_2 readings taken	137		CO readings taken
0	readings	>= 5 ppm (exceeding stel)			

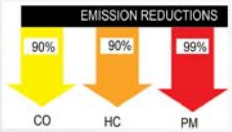
Breakdown of the NO2 Readings				Breakdown of the CO Readings		
8	readings	at 0.0		47	readings	at 0.0
0	readings	at 0.1	52 % below 0.2 NO2	0	readings	1
65	readings	at 0.2		12	readings	2
32	readings	at 0.3		40	readings	3
32	readings	at 0.4	48 % above 0.2 NO2	25	readings	4
1	readings	at 0.5		12	readings	at 5

NO2 readings only elevated by 4% after installation.

DPF SNAPSHOT

The passive regeneration ZERO filter is a very efficient cleaning system of diesel exhaust. This DPF removes up to 99% of diesel particulates. The system consists of an oxidation catalyst upstream of the wall flow filter substrate. The highly durable ZERO filter is available to suit most heavy diesel equipment.





Zero

Visual

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Original OEM

Mammoth Filter

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- **MWM has purchased and now are using FSX filter cleaning system.**
- **This helped us to lower the cost of cleaning and shipping of filters.**
- **This has also helped us to ensure we are tracking and protecting our investments.**

Additional equipment Improvements

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- **We are currently working with Mammoth on new designs for different applications.**
- **Boom trucks have been one of the higher contributors of DPM but are very hard to eliminate because of the nature of the machine, running up and down the ramp and extended idling in cold weather on surface.**
- **We are currently trying heat blankets to help the filters regenerate.**
- **We currently have 2 Boom trucks with Stratus 8.1 DPF Systems. Initial results show improved results.**

2 year trend (2016 – 2017)

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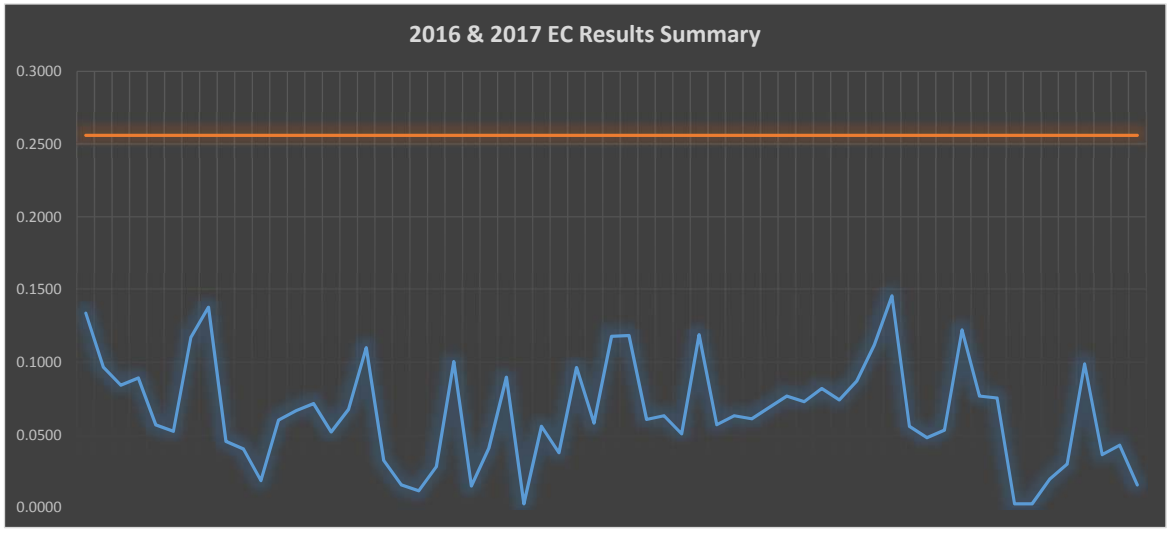

Statistical analysis 2013 vs current

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