Appendix IR1-07-A
Toxicity Profiles for PM and NO2

Red Mountain Underground Gold Project
IDM Mining Ltd. Responses to
Canadian Environmental Assessment Information Request #1

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1 NITROGEN DIOXIDE

1.1 Inhalation Exposure Limits

1.1.1 Acute Inhalation

Table 1 presents the acute inhalation exposure limits for nitrogen dioxide.

Table 1: Acute Inhalation Exposure Limits for Nitrogen Dioxide

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
ATSDR	-	-	-	-	-	ATSDR 2013
B.C. MOE	1-hour	188	-	-		B.C. MOE 2014
CCME	1-hour 24-hour NAAQO	400 200	-	-	-	CCME 1999
METRO VANCOUVE R	1-hour AAQO	200	-	-	Adopted NAAQO	MV 2011
OEHHA	1-hour REL	470	Respiratory system	Human	CARB, 1992	OEHHA 2008; 2014
TCEQ	-	-	-	-	-	TCEQ 2014
US EPA	1-hour NAAQS	188	Respiratory system	Human	Various	US EPA 2008; 2012
WHO	1-hour	200	Respiratory system	Human	Various	WHO 2006

Clinical studies of controlled human exposure have reported increased airway responsiveness to inhaled allergens in sensitive individuals as a result of acute exposure to nitrogen dioxide while epidemiological studies have correlated ambient nitrogen dioxide exposure with increased respiratory symptoms, emergency department visits and hospital admissions (e.g., US EPA 2008).

The desirable Canadian NAAQOs for NO_2 are 400 µg/m^3 for a 1-hour averaging time and 200 µg/m^3 over 24 hours (CCME 1999). The Metro Vancouver (2011) 1-hour AAQO reflects the Canadian 1-hour desirable NAAQO for nitrogen dioxide. Supporting health-based documentation is not available for the nitrogen dioxide NAAQO values. Canada Ambient Air Quality Standards (CAAQS), defined by Environment Canada (2013) as *health-based air quality objectives for pollutant concentrations in outdoor air*, are being developed for Canada under

the current Air Quality Management System. There are currently no CAAQS for nitrogen dioxide, although work has been initiated by federal, provincial and territorial governments (CCME 2013; Environment Canada 2013).

The OEHHA (2008; 2014) recommends a 1-hour REL of 470 µg/m^3. This REL was equivalent to a NOAEL for increased airway reactivity in asthmatics exposed to nitrogen dioxide for 1 hour (CARB, 1992).

The US EPA (2008, 2012) has implemented a 1-hour NAAQS of 188 µg/m^3 to protect against the respiratory effects of nitrogen dioxide. This standard considers the 3-year average of the 98th percentile of the yearly distribution of 1-hour daily maximum nitrogen dioxide concentrations. B.C. MOE (2014) recommends the same objective (188 µg/m^3) for 1-hour exposure to nitrogen dioxide, with achievement based on the annual 98th percentile of daily 1- hour maximum values, over one year.

In controlled exposure studies, acute effects on the pulmonary function of asthmatics were observed at nitrogen dioxide concentrations levels greater than 500 µg/m^3, with one meta-analysis suggesting an increase in bronchial responsiveness in asthmatics exposed to air concentrations above 200 µg/m^3 (Folinsbee 1992 cited in WHO 2006). The WHO (2006) has therefore set a 1-hour exposure limit of 200 µg/m^3 for short-term exposure to nitrogen dioxide.

Considering the weight of available evidence for airway reactivity of susceptible individuals (e.g., asthmatics) exposed to nitrogen dioxide, the lowest reported exposure limit, US EPA NAAQS of 188 µg/m^3, was selected for use in the acute effects assessment of nitrogen dioxide. Nitrogen dioxide was included in the chemical group for respiratory irritation following acute inhalation exposures.

1.1.2 Chronic Inhalation

Table 2 presents the chronic inhalation exposure limits for nitrogen dioxide.

Table 2: Chronic Inhalation Exposure Limits for Nitrogen Dioxide

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
ATSDR	-	-	-	-	-	ATSDR 2013
B.C. MOE	Annual AAQO	60				B.C. MOE 2014
CCME	Annual Average NAAQO	60	-	-	-	CCME 1999
METRO VANCOUVER	Annual AAQO	40	-	-	-	MV 2011
OEHHA	-	-	-	-	-	OEHHA 2014

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
RIVM	-	-	-	-	-	RIVM, 2001
TCEQ	-	-	-	-	-	TCEQ 2014
US EPA	Annual Average NAAQS	100	Respiratory system	Human	Various	US EPA 2008; 2012
WHO	Annual Average	40	Respiratory system	Human	Various	WHO 2006; 2000

The desirable annual average NAAQO for NO_2 is 60 µg/m^3 (CCME 1999) which is the same as the B.C. MOE annual air quality objective for NO_2 (B.C. MOE 2014). No supporting documentation was available for these objectives. The WHO (2000, 2006) established an annual average guideline value of 40 µg/m^3 for NO_2. In the absence of a particular study or set of studies that clearly support an annual average guideline, the WHO considered background ambient levels of 15 µg/m^3 and evidence of a 20% increase in respiratory illness in primary children with an increase of 28 µg/m^3 nitrogen dioxide indoors (averaged over 1 year) (WHO 1997). The annual AAQO recommended for nitrogen dioxide by Metro Vancouver (2011) reflects the WHO (2000, 2006) guideline.

The US EPA (2012) annual standard for NO_2 is 100 µg/m^3. This exposure limit is based on limited evidence to support a link between long-term exposure to nitrogen dioxide and adverse respiratory effects, particularly for persons with pre-existing pulmonary dysfunction (US EPA 2008).

Considering the available evidence for respiratory illness in children and individuals with pre-existing pulmonary dysfunction following long-term exposure to NO_2, the lowest WHO guideline of 40 µg/m^3 was selected for the assessment of chronic inhalation exposure to NO_2.

2 PARTICULATE MATTER

2.1 Inhalation Exposure Limits

2.1.1 Acute Inhalation

Tables 3 and 4 present the acute inhalation exposure limits for fine PM (≤2.5 µm in diameter; PM2.5) and coarse PM (≤10 µm in diameter; PM10) respectively.

Table 3: Acute Inhalation Exposure Limits for Fine PM (≤2.5 µm in Diameter)

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
ATSDR	-	-	-	-	-	ATSDR 2013
B.C. MOE	24 hour AAQO	25	-	-	-	B.C. MOE 2013
CCME	24-hour CWS/CAA QS	27-30	Population mortality and morbidity	Human	Various	CCME 2012; 2000
CARB	24 hour AAQS	-	-	-	-	CARB 2009
METRO VANCOUVER	24 hour AAQO	25	-	-	-	MV 2011
TCEQ	-	-	-	-	-	TCEQ 2014
US EPA	24-hour	35	Population mortality and morbidity	Human	Various	US EPA 2012; 2009
WHO	24-hour	25	Population mortality and morbidity	Human	Various	WHO 2006

Table 4: Acute Inhalation Exposure Limits for Coarse PM (≤10 µm in Diameter)

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
ATSDR	-	-	-	-	-	ATSDR 2013
B.C. MOE	24 hour AAQO	50	-	-	-	B.C. MOE 2013
CCME	-	-	-	-	-	CCME 2012; 2000
CARB	24 hour AAQS	50	Population mortality and morbidity	Human	Various	CARB 2009
METRO VANCOUVER	24 hour AAQO	50	-	-	-	MV 2011
TCEQ	-	-	-	-	-	TCEQ 2014
US EPA	24-hour	150	Population mortality and morbidity	Human	Various	US EPA 2012; 2009
WHO	24-hour	50	Based on PM2.5	Human	Based on PM2.5	WHO 2006

The CCME (2000) developed a 24-hour Canada Wide Standard (CWS) of 30 µg/m^3 for fine particulate matter ($PM_{2.5}$). The CWS is based on the 3-year average of the annual 98th percentile of the 24-hour average concentrations. The $PM_{2.5}$ CWS was based on the weight of available evidence for an association between acute exposure to ambient fine particulate matter and increased population mortality and morbidity, particularly related to the cardiovascular and respiratory systems, reported in numerous epidemiological studies from the US, Canada,Britain and Europe (WGAQOG 1998; Health Canada 2000; US EPA 2009).

The available data (e.g., epidemiological studies of large populations) have not identified a threshold concentration below which adverse effects do not occur; therefore, actions to reduce ambient $PM_{2.5}$ concentrations are considered an improvement in air quality that will be beneficial to human health (CCME, 2000; WHO 2006). In addition to the CWS for fine particulate matter, the CCEM (2000) provides guidance for i) continuous improvement and ii) keeping clean areas. This guidance is intended to reinforce the health benefits of lowering ambient $PM_{2.5}$ air concentrations and dissuade actions that could result in "polluting up" to the CWS in areas where ambient $PM_{2.5}$ concentrations are low.

In May 2013, the Canadian Ambient Air Quality Standards (CAAQS) for $PM_{2.5}$ were published in the Canada Gazette (Vol 147, No. 21). The CAAQS replaced the existing CWS for fine

particulate matter, based on amendments to the Canadian Environmental Protection Act in 2013. In keeping with the intent for continuous improvement of air quality, the 24-hour $PM_{2.5}$ standard to be achieved by 2015 was be 28 µg/m^3 with a slightly more stringent standard of 27 µg/m^3 recommended for 2020 (CCME 2012). The CAAQS is based on the 3-year average of the annual 98th percentile of the 24-hour average concentrations. The CCME (2000, 2012) have not established standards specific to coarse particulate matter (PM_{10}) as the management of $PM_{2.5}$ was considered to result in the greatest health benefits and reductions in fine particulate matter are expected to reduce concentrations of coarse particulate matter (CCME 2000).

The California Air Resources Board (CARB 2009) have established an acute ambient air quality standard of 50 µg/m^3 (24-hour average) for PM_{10}. The acute health effects noted for coarse particulate matter exposure include worsening symptoms of asthma and acute bronchitis, particularly in the elderly and very young, as well as increased mortality or risk of hospitalization due to respiratory illness and lung disease (CARB 2009).

The US EPA (2012) implemented a 24-hour primary standard (NAAQS) of 35 µg/m^3 for $PM_{2.5}$ based on the 3-year average of 98th percentile concentrations. This standard is intended to increase protection against adverse health effects associated with acute exposure to respirable particles, including cardiovascular and respiratory effects and premature mortality (US EPA 2009). The US EPA (2012) also recommend an acute NAAQS of 150 µg/m^3 for PM_{10} which is not to be exceeded more than once per year over a 3-year average. Similar to $PM_{2.5}$, this standard is based on evidence of a causal relationship between acute exposure to coarse particulate matter ($PM_{10-2.5}$) and cardiovascular effects, respiratory effects and mortality. The evidence for these associations was limited in comparison to the evidence for $PM_{2.5}$ and these associations were only apparent for short-term (not long-term) exposures to $PM_{10-2.5}$ (US EPA 2009).

The WHO (2006) recommends a 24-hour guideline of 25 µg/m^3 for $PM_{2.5}$ and a 24-hour guideline of 50 µg/m^3 for PM_{10}. The 24-hour guidelines refer to the 99th percentile of the distribution of daily values (i.e. the fourth next highest value of the year). The acute PM guidelines are intended to protect against peaks of pollution that could result in excess morbidity or mortality. The acute $PM_{2.5}$ guideline was established based on relationships between the distributions of 24-hour means and annual average PM concentrations. The acute guideline for PM_{10} was developed using $PM_{2.5}$ as an indicator of potential health effects and applying a $PM_{2.5}/PM_{10}$ ratio of 0.5, which represents the approximate ratio of $PM_{2.5}/PM_{10}$ observed in urban areas. It is noted that the WHO (2006) prefers the use of the $PM_{2.5}$ guideline for the evaluation of PM exposure.

Similar to the WHO (2006), the B.C. MOE (2013; 2009) also recommend 24-hour guidelines of 25 µg/m^3 for $PM_{2.5}$ and 50 µg/m^3 for PM_{10}, which have been adopted by Metro Vancouver (2011).

The WHO (2006) also recommend three interim 24-hour target levels as a stepped approach for countries as they develop abatement measures to move towards eventual compliance with the guidelines. The highest interim targets are 75 and 150 µg/m^3 for $PM_{2.5}$ and PM_{10}, respectively. These targets are associated with an approximate 5% increase in short-term

mortality risk, relative to the short-term mortality risk at the recommended air quality guidelines. The next interim targets of 50 µg/m^3 for $PM_{2.5}$ and 100 µg/m^3 for PM_{10} are associated with ~2.5% increase in short-term mortality risk compared to the guidelines. The lowest interim targets of 37.5 and 75 µg/m^3 for $PM_{2.5}$ and PM_{10}, respectively, are associated with ~1.2% increase in short-term mortality. These risk estimates were determined using published risk coefficients from multi-centre epidemiological studies and meta-analyses (WHO 2006).

The lowest recommended 24-hour guidelines of 25 µg/m^3 for $PM_{2.5}$ and 50 µg/m^3 for PM_{10} (WHO 2006) were selected for the assessment of potential health risks following acute inhalation exposure to fine and coarse particulate matter, recognizing the health benefits of maintaining ambient $PM_{2.5}$ air concentrations as low as possible.

$PM_{2.5}$ and PM_{10} were included in the population mortality/morbidity group for acute (24-hour) inhalation exposures.

2.1.2 Chronic Inhalation

Tables 5 and 6 presents the chronic inhalation exposure limits for PM2.5 and PM10 respectively.

Table 5: Chronic Inhalation Exposure Limits for PM2.5

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
ATSDR	-	-	-	-	-	ATSDR 2013
B.C. MOE	Annual Average AAQO	8 (objective) 6 (goal)	-	-	-	B.C. MOE 2013
CCME	Annual Average CAAQS	8.8-10	Premature mortality	Human	Various	CCME 2012; 2000
CARB	Annual Average	12	Population mortality /morbidity	Human	Various	CARB 2009
METRO VANCOUVER	Annual Average AAQO	8 (objective) 6 (goal)	-	-	-	MV 2011
RIVM	-	-	-	-	-	RIVM, 2001
TCEQ	-	-	-	-	-	TCEQ 2014

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
US EPA	Annual Average NAAQS	12	Population mortality/ morbidity	Human	Various	US EPA 2012; 2009
WHO	Annual Average	10	Population mortality/ morbidity	Human	Pope et al., 2002, others	WHO 2006; 2000

Table 6: Chronic Inhalation Exposure Limits for PM10

Agency	Exposure Limit Type	Exposure Limit Value (µg/m^3)	Critical Organ or Effect	Species	Study	Source
ATSDR	-	-	-	-	-	ATSDR 2013
B.C. MOE	Annual Average AAQO		-	-	-	B.C. MOE 2013
CCME	-	-	-	-	-	CCME 2012; 2000
CARB	Annual Average	20	Population mortality /morbidity	Human	Various	CARB 2009
METRO VANCOUVER	Annual Average AAQO	20	-	-	-	MV 2011
RIVM	-	-	-	-	-	RIVM, 2001
TCEQ	-	-	-	-	-	TCEQ 2014
US EPA	-	-	-	-	-	US EPA 2012; 2009
WHO	Annual Average	20	Based on PM2.5		Based on PM2.5	WHO 2006; 2000

Annual average CAAQS for $PM_{2.5}$ were published in the Canada Gazette in May 2013. The annual average standard to be achieved by 2015 will be 10 µg/m^3 with a slightly more stringent standard of 8.8 µg/m^3 recommended for 2020. The CAAQS is based on the 3-year average of the annual average concentrations (CCME 2012).

The CARB (2009) established annual ambient air quality standards of 12 and 20 µg/m^3 (arithmetic means) for $PM_{2.5}$ and PM_{10}, respectively. These standards are intended to protect against increased risk of hospitalization for lung and heart-related illness, premature death of the elderly and individuals with compromised pulmonary function, and reduced lung function or increased respiratory symptoms/illness in children.

The US EPA (2012) has implemented a primary annual standard (NAAQS) of 12 µg/m^3 for $PM_{2.5}$ based on the 3-year average of 98th percentile concentrations. The annual standard is intended to continue protection against adverse health effects associated with chronic exposure to respirable particles, including cardiovascular effects, respiratory effects, and premature mortality (US EPA 2009).

The WHO (2006) established an annual mean guideline of 10 µg/m^3 for $PM_{2.5}$. This guideline represents the lower end of the air concentration range in the American Cancer Society (ACS) epidemiological study at which robust associations were reported between mortality and long- term exposure to $PM_{2.5}$ (Pope et al., 2002). Although threshold levels were not identified, the long-term epidemiological studies reported robust associations between $PM_{2.5}$ exposure and mortality and annual average target concentrations for $PM_{2.5}$ should take precedence over 24- hour average concentrations (WHO 2006). An annual mean guideline of 20 µg/m^3 is recommended for PM_{10} assuming a $PM_{2.5}/PM_{10}$ ratio of 0.5 and using $PM_{2.5}$ as an indicator of potential health effects.

Three interim target levels were developed for the annual mean guidelines for PM as a stepped approach for countries as they develop successive and sustained abatement measures to move towards eventual compliance with the recommended air quality guidelines (WHO 2006). The highest interim targets (35 and 70 µg/m^3 for $PM_{2.5}$ and PM_{10}, respectively) are associated with a 15% higher long-term mortality risk relative to the mortality risk at the lowest recommended air quality guideline. Attainment of intermediate interim targets (25 and 50 µg/m^3 for $PM_{2.5}$ and PM_{10}, respectively) is expected to lower the mortality risks by 6% when compared to the highest interim targets. The lowest interim targets (15 and 30 µg/m^3 for $PM_{2.5}$ and $PM_{10,}$ respectively) would reduce by the mortality risks by a further 6%, compared to the intermediate targets (WHO 2006).

The B.C. MOE (2009, 2013) have established an annual air quality objective of 8 µg/m^3 and, in the absence of a safe threshold for human health effects, a planning goal of 6 µg/m^3 for $PM_{2.5}$. The intent of the planning goal being *to guide airshed planning efforts and encourage communities to maintain good air quality in the face of economic growth and development* (B.C. MOE 2009). The annual objectives recommended for $PM_{2.5}$ by B.C. MOE (2013) have been adopted by Metro Vancouver (2011).

In the absence of an identified threshold for mortality risks associated with long-term exposure to $PM_{2.5}$ (WHO 2006), the lowest recommended guideline of 6 µg/m^3 (B.C. MOE 2013) was adopted for the current assessment of risks associated with chronic inhalation exposure to $PM_{2.5}$. The chronic guideline of 20 µg/m^3, supported by WHO (2006), CARB (2009); B.C. MOE (2013) and Metro Vancouver (MV 2011), was selected for the assessment of long-term exposure to PM_{10}.

$PM_{2.5}$ and PM_{10} were included in the population mortality/morbidity group for chronic inhalation exposures.

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