

K2

Environmental Ltd

Specialists in Air Quality Measurement

Proposal for Assessment Toxic Material from Fire Residue

Pike River Recovery *Pike River*

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1 BACKGROUND INFORMATION

1.1 What has happened?

The Pike River re-entry team has been working its way up the mine drift.

The Pike River re-entry team has come across an area of black substance on the walls and ceilings of the mine. This material has been analysed and contains varying amounts of Polycyclic Aromatic Hydrocarbons (PAH).

1.2 Scope of Work

The scope of work required to ensure Pike River Recovery Agency (PRRA) staff are not at risk to toxins from the material found in the mine on the walls, floor and ceiling.

This involves the following steps:-

1. Identify
2. Evaluate
3. Control
4. Review

1.3 Site Overview

The following is a brief overview of the site:

- Pike River Recovery Agency was established to conduct a manned recovery of the mine drift
- The purpose of re-entry is to gather evidence to assist with the investigation of the 2010 disaster and, if possible, recover any human remains
- No mining of coal or any other kind of material products will take place
- The re-entry is carried out in fresh air, via the current portal, with suitable safety controls in place
- Key milestones of the project as of mid-March 2020:
 - Foam plug installed successfully on the 4th November 2019
 - The drift has been purged with fresh air
 - 170 m seal broken on the 17th December 2019
 - By the 23rd March 2020, the recovery has progressed to 870 m
 - From the beginning of July 2020 the operation is carried out in two 10-hour shifts per day. Prior to the end of June 2020, the operation was carried in two 8-hour shifts per day
- The underground activities include, but are not limited to:
 - Bolting
 - Extending services
 - Forensics collection
- On average, the recovery advances 20 metres per work shift, but varies greatly depending on the conditions of the tunnel
- Two vehicles are used in the drift:
 - Drift runner for workers transportation
 - Loader to power the bolting rig (hydraulic transmission)

1.4 Ventilation

A detailed ventilation plan can be obtained at this location.
<https://www.pikeriverrecovery.govt.nz/documents/document/?ID=625>

It has been reported that:-

- the ventilation rate inside the mine is 15m³ per second in the drift
- the air flow is even
- any pockets and cavities are tested for noxious and flammable gases and to date, have not found any such accumulations of gas
- Pike River maintains sufficient air flow velocity to prevent layering of gases or having unventilated areas or cavities in the recovered parts of the drift

There are rules around where the workers are allowed to be in relation to the ventilation and the vehicles. This is to make sure that the workers are always in the stream of fresh air, "they are not allowed to be any more than 20m in front of the end of the ducting, delivering fresh air".

The fresh air is supplied directly into the work zone

1. The most of it is returned down the drift and exhausted through the portal
2. A small portion of it is pulled deeper into the mine towards the plug and sucked out by the venturi

2 REVIEW OF WORKPLACE FACTORS

2.1 Mine staff - Worker Shifts

The mine operates 5 days per week Mon-Fri

- Two 10 hr shifts per day
 - Day shift is Mon-Fri start 7am finish 5pm they have Saturday and Sunday off
 - Afternoon shift work Mon-Thurs start 4:30pm finish 2:30am they have Friday, Saturday and Sunday off
 - The shifts rotate week about
- Maximum of 6 people underground at any one time
 - Whenever anyone is underground, there is always 4 response people on the surface, plus a control room operator
- Total workforce up at the site about 30 Agency staff plus Police
 - The Police do not go underground
- This is a short term project, all underground work will be completed by December 2020 or at the latest January 2021

Who else is at Risk?

- Ventilation Officer, monitors and records ventilation status
- Geotech Engineer monitors the ground and strata
- H & S Advisor conducts audits
- Other statutory mining officials
- Worksafe inspectors

2.2 Daily Activity Summary – PRRA staff

We are recovering a tunnel which is 2.3km long, we are currently at 1632m, our main objectives are

- Gather evidence to better understand what happened in 2010, with an eye to preventing future mining tragedies, and promoting accountability for this mining tragedy
- Give the Pike River families and victims overdue closure and peace of mind, and
- Recover human remains where possible

2.2.1 Activity on a typical day – PRRA staff

Common Entry Tasks

Each phase of the entry will include the following tasks carried out in a staged advance and recovery process:

- Geotechnical and safety assessment of the drift to be entered.
 - The distance of advance is determined by ground and atmospheric conditions Max 20m.
 - Assessment is in accordance with the Ground and Strata Instability PHMP and the Pike River Mine Drift Re-Entry Geotechnical Assessment Report PRRA4966 (18th March 2019).
 - This stage includes:
 - Initial health and safety assessment of the area roadway to be advanced into by PRRA staff
 - geotechnical hazard mapping by a geotechnical engineer
 - Forensic scan by PRRA staff
- Identify re-support required or mark out sections where no personnel or machinery can go
- Set monitoring systems as required, in accordance with Ground and Strata Instability PHMP and the Pike River Mine Drift Re-Entry Geotechnical Assessment Report PRRA4966 (18th March 2019). Including:
 - Ground support monitoring
 - Installing ground support designed for gneiss rock and coal measures
 - geotechnical risk monitoring
 - TARPs
- Install required ground support, using machinery and other equipment as identified and, in accordance with the Ground and Strata Instability PHMP and TARPs
- Carry out forensic work as required and defined in the NZ Police Forensics Planning Report (October 2018). This includes:
 - Initial search for items of interest
 - photograph and survey items insitu
 - if approved by police, recover items and remove from the mine, in accordance with police forensic processes and controls
 - if required by police, leave items untouched until police have decided what action to be taken
 - Continue with re-entry tasks, once area has been cleared by police
- Advance mine services such as machinery, air duct, water pipe, compressed air and ensure roadway is in a trafficable condition
- Advance emergency equipment including:
 - Navigational Aids
 - emergency pack and first aid
 - refuge chamber
 - CABA sets,

2.2.2 What other tasks do they do apart from the main ones? Unexpected and other tasks?

- Roof support, this involves wet drilling into the roof and walls
- Mechanical and electrical repairs, as required
- Advancing services air and water pipes
- Advancing communication line phones and intercoms
- Advancing gas monitoring lines both wireless real time and tube bundle system
- Conducting combustible dust sampling and applying stone dust (limestone) if required

2.2.3 Worker Behaviour¹

Most activities stir up dust

- erecting vent bag
- dismantling structure
- rolling belt
- moving the refuge chamber - because of re-routing hoses/cables, bolting etc

Conditions at the site²

It's quite noticeable that the tunnel is drying out due to the effect of the ventilation current.

2.3 Police Activity at Mine Site

- To date, Police have not deployed underground at Pike River Mine.
- Agency personnel photograph
- document and
- recover items of interest from underground

These items are handed-over to Police on the surface.

- Small exhibits and items of interest are placed by Agency personnel into sealed plastic bins
- Larger items, such as robots, are recovered in accordance with risk assessed processes using heavy machinery where required

¹ From Robin Hughs in an email

² From Robin Hughs in an email

2.3.1 Processing of Items.

Police receive the item and exhibit bins from the underground teams, these bins contain objects which were recovered from a particular grid (20m) section within the drift. The items are things such as:-

- cable ties
- rags
- pieces of wood
- broken conduit etc

Exhibits are things such as:-

- electric items
- robots
- self-rescuer
- clothing etc

Police process (examine, document and record) the contents of the item boxes and exhibits. The processing of the items includes washing these items on the deck outside the Police base using a sieve. Gloves are worn for the washing process

2.3.2 Drying of Items

Police dry and re packaging the items (handling generally without gloves during the listing and repackaging process, unless it is an exhibit may require DNA testing)

The drying rooms for small items and exhibits are situated within Police Base on site at Pike River Mine

2.3.3 Storage of Items and Exhibits

Once the items are dry they are repackaged and stored in a secure exhibit container on site, in plastic bags, unsealed to avoid moisture build up

Once the exhibits are dry they are repackaged and smaller exhibits stored in a secure room in the Pike River Mine Police base

Police also have two other exhibit store containers, where the robots are kept and other larger exhibits

3 IDENTIFIED RISKS

Previously identified risks are:-

- Combustion fumes from vehicles
- Crystalline silica
- Particulate - Elemental Carbon, diesel particulate, respirable, total and ultrafine
- Organics – PAH, volatile organics, aldehydes
- Oil mist
- Biological – mould and bacteria
- Noise and Vibration

3.1 Previous Monitoring

Before December 2019, Pike River ventilation officer Borys Poborowski carried out quarterly monitoring. The measurements included sampling for respirable dust, silica dust and diesel particulate matter in:

- April, May and December 2018
- April, June and September 2019

In December 2019, March 2020 and June 2020, K2 Environmental carried out quarterly monitoring. The range of monitoring parameters include personal exposure measurements to

- Combustion gases NO₂, SO₂
- Aldehydes and ketones
- Oil mist
- Particulate inhalable, respirable, crystalline silica

Static monitoring for a variety of

- volatile organic compounds including
- polycyclic aromatic hydrocarbon
- Mould monitoring

Other monitoring includes

- Noise monitoring
- Whole body vibration assessment

3.1.1 Previous Reports

The K2 results were presented in the reports labelled U0533 and V0123. The results of this report indicate that:

- Personal exposure to all measured chemical agents was below the NZ WES
- Oil mist was demonstrated not to be a hazard when the hydraulic-powered bolting rig is used instead of pneumatic
- Three areas on the surface contained excessive noise
 - Helicopter pad
 - Main ventilation fan at the portal
 - Compressor cabinet of the gas monitoring system
- All underground workers are exposed to excessive noise

4 PREDICTED COMPOSITION OF BLACK MATERIAL

The fume of a fire can contain high concentrations of organic material. This can be comprised of unburnt coal. As the fume moves through the mine and comes in contact with a cooler surface the fume can condense out this unburnt fuel. This is similar to Creosote formation in domestic fires.

The fire temperatures can potentially be up to 2500° C. As the fumes and smoke from the fire progress up the mine tunnel, they can come into contact with cooler surfaces. The cooler surfaces could be in the hundreds of degrees and this process of condensation of fume can occur.

4.1 Creosote Formation

Creosote forms in chimney fires. It forms in three stages:-

- Stage one – mostly soot, easily removed
- Stage two – combustion black flakes. Combustion by-products are in the form of shiny black flakes (like hardened tar cornflakes)
- Stage three – concentrated fuel, hardened, can be sticky

4.2 Feedback from Miners

The miners who were at the site of the black material had the following feedback:-

- The material was soot like and was baked on
- It was on the roof and walls of the mine
- It seemed to increase, the further you progress into the mine
- There was a little noticeable odour when you first arrive but, with time in the mine, it is not as noticeable
- The samples gathered have an odour consistent with creosote

4.3 Bulk Material Sample Analysis – for PAH

Solid Samples sampling procedure

- When a change in the roof material was noticed they tried to collect some dust by brushing it off into a bag.
 - The ventilation in the area meant that most of it blew away.
 - 6-7 rocks that fit through the mesh were gathered. These were put them into a bag
- Once they were in the bag and safe from being blown away they brushed the dirt off with a wire brush.
- The samples came from an area less than 1 square metre.

4.3.1 Sample Results

Samples of the material were sent to an external laboratory for analysis of PAH composition. The sample was taken Tuesday 11th August between 185m and 1613m

Table 1 Bulk Material Analysis Results

	Quantity found mg/kg	Melting point C	Molecular weight	IARC ³ Carcinogen Classification
Di benzo (a, h) anthracene	0.22	170	278	2a
Benzo (k) fluoroanthene	0.6	257	252	2b
Benzo(a) Pyrene	0.68	177	252	1
Benzo (g, h) perylene	0.81	178	278	3
Benzo (a) anthracene	0.94	167	228	2b
Acenaphthene	0.99	93.4	152	3
Indeno(1,2,3-c,d)pyrene	1.06	164	276	2b
Chrysene	1.6	258	228	2b
Benzo (b) fluoroanthene	2.27	168	168	2b
Pyrene	2.35	151	202	3
Fluoranthene	2.37	108	202	3
Anthracene	2.64	215	178	3
Fluorene	3.05	115	166	3
Acenaphthylene	4.97	92.5	152	
Phenanthrene	10.84	99.2	178	3
1 methyl naphthalene ⁴	12.1	-30.4	142	
2 methyl naphthalene	19.57	34.6	142	
Naphthalene	20.76	80.2	128	2b

³ IARC International Agency for research on cancer.

⁴ Flash point 82° C

4.3.2 IARC Carcinogen Classifications⁵

Group 1	Carcinogen to humans
Group 2a	Probable Carcinogens
Group 2b	Reasonably Anticipated to be human carcinogen
Group 3	Not classifiable as its carcinogenicity

4.4 Bag Sample

4.4.1 Bag Sample Procedure

- The bag sample was taken the same way as the other bag samples, using an aspirator pump.
- This system has been improved to using an odour sampling system. A barrel which the bag is attached to. A pump to draw air out of the barrel to create a vacuum.
- The air into the bag only is in contact with the bag no other sampling system.

4.4.2 Results

- The bag sample was analysed for benzene compounds and simple alkanes using selected ion flow tube mass spectrometry (SIFT-MS) in selected ion mode
- The bag sample was then analysed in mass scan mode, in order to detect any other compounds present. Formaldehyde was the only chemical detected in this mode
- The sample was taken Tuesday 11th August in the operational zone 1620m

Table 2 Bag Sample Results

Analyte	Concentration	
	ppbv	µg/m ³
Trimethylbenzene and ethyl toluenes	<5	<24.6
Methyl naphthalenes	<5	<29.1
Tetramethylbenzenes	<5	<27.4
Benzene	<5	<16.0
Naphthalene (PAH)	<5	<26.2
Xylene and ethyl benzene	<5	<21.7
Styrene	<5	<21.3
Toluene	<5	<18.8
Hexanes	128	451
Pentanes	123	363
Formaldehyde	149	183

⁵ IARC International Agency for research on cancer.

4.5 Black Material – Other Toxins Expected

The deposited material is expected to off-gas volatile organic compounds. However as it is sometime since the fire, the off gassing will be considerably reduced as is suggested by the results in Table 2. Typically, compounds with lower molecular weights and lower melting points, will be the first to off-gas.

4.5.1 Trace Metals

Consideration needs to be given to metals in particulate - this is in the airborne black dust, as well as any ash particles that are in the mine.

These are expected to be low and not significant. The cost of checking for 31 elements is not high and can verify the absence of metals that may be a risk to health.

5 WHAT WE KNOW SO FAR

1. The team discovered soot deposits on the ribs and the roof of the drift as they got closer to the historic fire epicentre
 - a. This was expected and has been considered in previous risk assessment exercises
 - b. Upon the discovery, procedures of the risk management have been triggered, bulk samples taken and analysed for PAH
2. The results indicated the presence of carcinogenic compounds and triggered suspension of the operation
3. Nonetheless, presence of PAH in soot comes as no surprise and was expected. To date naphthalene is the only PAH that has been identified in air samples.
 - a. The air sampling results previously have detected Naphthalene in the following concentrations. June 2020 0.11 µg/m³, March 2020 1 µg/m³, December 0.02 µg/m³
4. The results of the bulk samples are useful in identifying the make-up of the deposit and can be used to identify a hazard, however these results cannot be used directly in an exposure risk assessment as
 - i. Undisturbed soot does not pose an immediate risk for people
 - ii. Routes of exposure have not been taken into account
 - iii. Personal exposure has not been assessed
 - iv. Reference limits (toxicological criteria) for the analysed media do not exist
5. A potential hazard has been identified , but further bulk sampling of soot, soil or any other solid matter is of little value
 - a. Bulk samples will always contain toxins
 - b. The toxins are bound to the matrix
 - c. There's no way to translate this into humans exposure

5.1 What are the risks for the workers?

1. Health effects are only expected if the workers receive a harmful dose
2. A dose may be assessed through
 - a. personal exposure measurements
 - b. biological sampling
3. There are two main possible routes of exposure
 - a. By inhalation
 - b. Dermal contact, with consequent
 - i. Hand-to-mouth transmission
 - ii. Take home on skin and clothes

5.2 Are there immediate risks?

1. Based on the quarterly monitoring results, the airborne levels of VOC's were relatively low and exposure through inhalation is not expected to be harmful
 - a. The black substance has always been present in the drift and was shown not to off-gas intensely at least until June
2. The risks cannot be ruled out because:
 - a. Static samples do not represent personal exposure
 - b. Working conditions may have changed as the project advances

5.3 What needs to be done

1. Even when hazardous substances are present at the workplace, they do not necessarily affect the workers
2. Presence or absence of harmful exposure can be demonstrated by exposure monitoring
3. Exposure monitoring must take into account variability, worst case scenarios and factor in a degree of uncertainty
 - a. This can be assessed through probability assessments using statistical tools

6 SAMPLING PLAN - WHAT NEEDS TO BE MEASURED

1. Combustion products include many individual organic compounds
 - a. Sampling all of them is unrealistic
 - b. A number of indicators must be selected
2. Based on the K2 experience with fire surveys and, available peer-reviewed literature, the proposed list of indicators should include:
 - a. Aldehydes – formaldehyde and acrolein
 - b. PAHs including, Benzo(a)pyrene which is considered the most toxic and naphthalene which has been identified in previous quarterly samples at the site.
 - c. Volatile organic compounds

6.1 How to obtain valid exposure measurement

1. Personal samples should be taken on the workers for the length of their shift
2. Aim for sufficient sampling population
 - a. It is suggested that a minimum of six samples per day are collected. Ten samples per day would be ideal
 - b. Sampling should take place over a minimum of three days
 - c. Further samples may be necessary if the variability of the data is significant.
3. Static sampling for the purpose of risk evaluation is discouraged

6.1.1 Monitoring Detail

There is one SEG that has been identified.

- Six of these workers go into the drift in the day shift and six in the afternoon shift.
- There are VOC, Aldehydes, Acrolien, Particulate and PAH sampling
- Each is a separate sampling train.
- We have allowed for each person working in the drift to wear one pump
- We need multiple days to do all of the recommended sampling.
- We did not consider one person wearing multiple pumps on a shift as a viable option.

There are a maximum of six underground at any time. There can be less than six. These are all considered one similar exposure group. There are no stationary workplaces and working conditions vary greatly as the work progresses deep into the drift. Refer to the sampling plan in section 6.3

6.2 How to conduct monitoring safely

Anyone entering the drift is required to wear the following or equivalent.

1. PPE to be worn and must include
 - a. Face fitted respirators with organic filters and particulate pre-filters⁶
 - i. 3m 7501, 7502, 7503 (small medium large) silicon half face masks
 - ii. 3m 6075 Organic and formaldehyde cartridges
 - iii. 3m 5925 P2 pre-filters for particulate
 - iv. 3m 501 filter retainers.
 - b. Disposable coveralls
 - c. Impermeable gloves under working gloves
2. Ventilation rate – as usual. It is believed to be sufficient

6.3 METHODS

Only methods validated by reputable agencies such as OSHA, NIOSH, USEPA or similar should be considered. Non-agency methods are not recommended.

Sample type	Flow rate	Sample time	Sample Volume	Notes
NIOSH 2016 Aldehydes	200ml/min	½ shift	48L	Exceeds method maximum sample volume of 15L Flow rate is as long as pump can handle. Pumps do not have timers to be able to turn off automatically
NIOSH 5515 PAH's	2L/min	Full shift	480L	Method sample volume is 200-1000L
OSHA 52 Acrolein	200ml/min	½ shift	48L	Exceeds method maximum sample volume of 24L Flow rate is as long as pump can handle. Pumps do not have timers to be able to turn off automatically
TO-17 VOC's	200ml/min	Variable	48L	Some samples will be run for half a shift and others for a full shift. Longer samples are taken to ensure that low level compounds can be detected. Shorter samples are taken to ensure that higher level compounds are not overloading the tubes
Inhalable Particulate	2L/min	Full shift	480L	It is possible that the filter may become overloaded after a full shift. If this occurs then further sampling will be done for half shifts

⁶ Consideration to using either half face or full face masks.

Sample type	Thursday Night Shift	Friday Day Shift	Monday Day Shift	Monday Night Shift	Tuesday Day Shift	Tuesday Night Shift
NIOSH 2016 Aldehydes	1 ½ shift	2 ½ shift	2 ½ shift	1 ½ shift	2 ½ shift	1 ½ shift
NIOSH 5515 PAH's	1 Full Shift	1 Full Shift	1 Full Shift	1 Full Shift	1 Full Shift	2 Full Shift
OSHA 52 Acrolein	1 ½ shift	2 ½ shift	2 ½ shift	1 ½ shift	2 ½ shift	1 ½ shift
TO-17 VOC's	1 Full Shift	1 Full Shift	2 ½ shift	1 Full Shift	2 ½ shift	1 Full Shift
Inhalable Particulate	1 Full Shift	1 Full Shift	1 Full Shift	1 Full Shift	1 Full Shift	

6.4 Periodicity of assessment

1. Initial semi volatile and volatile organic compound personal exposure assessment ASAP (over a minimum of 3 days)
2. A second round once the operations have moved 100 m into the drift.
3. Further monitoring quarterly. This may change depending on the variability and results obtained.
 - a. A second round once the operations have moved 100 m into the drift to identify any linear changes along the drift
 - b. The requirement for further testing outside of the normal quarterly assessment, will be based on the monitoring results of these two tranches of monitoring and the exposure risks identified.
 - c. This will be carried out by the PPRA risk assessment group
4. Canister sampling (full scan/library search) fortnightly to assist with hazard identification
 - a. 100-metres into the drift (takes 20 minutes, with necessary precautions) and
 - b. in the tunnel branches (PBIS)
5. Periodicity can be reassessed at any point, should new information become available