



January 21, 2013

Fraser Surrey Docks
11060 Elevator Road
Surrey, BC, V3V 2R7

Attention: Jurgen Franke, P.Eng, Fraser Surrey Docks

Sent via email: jurgenf@fsd.bc.ca

Re: Overview discussion of the potential toxicity of unburned coal

1.0 Introduction

This document has been prepared for Fraser Surrey Docks (FSD) in response to questions on the potential toxicity of coal. FSD is proposing a temporary offloading facility at 11060 Elevator Road for Powder River Basin (PRB) coal from the Signal Peak and Cloud Peak operations in Wyoming and Montana. The coal will arrive at FSD by train and be loaded into barges for transit down the Lower Fraser River and out to the west coast of Texada Island, which is located about 8 km southwest of Powell River. *Coal burning will not be undertaken onsite.* Only unburned coal treated with water and / or non-toxic dust suppressants will be barged offsite. To help answer related questions this document provides information on the following:

- How coal is formed
- How coal is classified
- How coal may enter the Fraser River from the FSD site
- Chemicals of potential concern in coal
- How these chemicals may behave in the environment

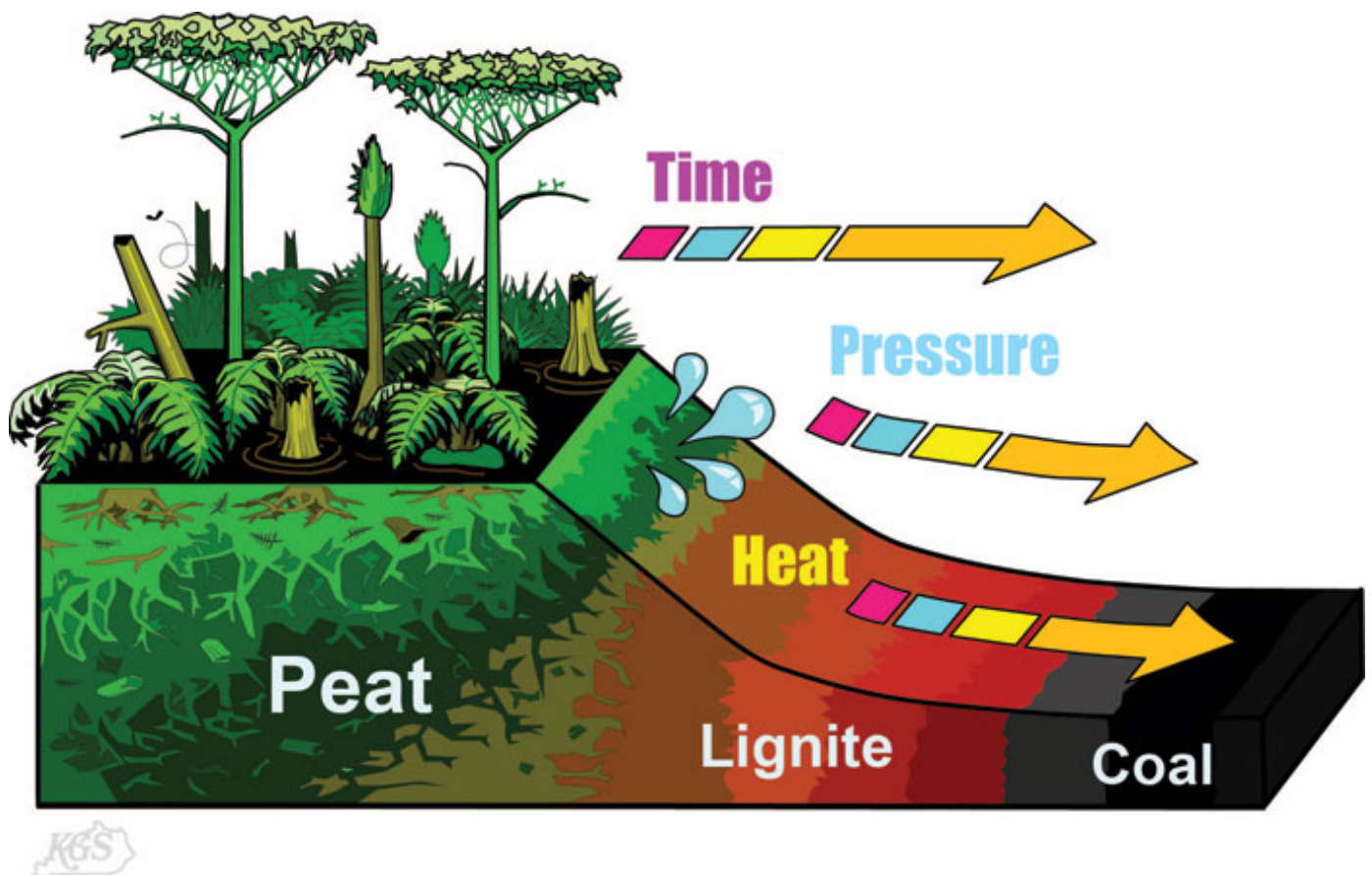
2.0 Coal formation

Coal is formed from peat, which is a mix of decayed and partly decayed plant material that builds up over time in very wet, oxygen poor environments (Figure 1). The change from peat into coal is a natural process called “coalification” and takes millions of years to complete.

Peat changes into coal through breakdown by bacteria, compaction (which exerts pressure on the peat), heat and time. The pressure on the peat squeezes out the water and pushes out methane and other gasses making the deposit rich in carbon over time. The longer the peat is exposed to heat and pressure the more carbon rich the deposit becomes.

The first type of coal to form from peat is lignite, followed by sub-bituminous coal, bituminous coal and anthracite coal. Each of these types of coal has different chemical and physical properties that set them apart from each other. Lignite and sub-bituminous coals are generally used for electrical power generation. Bituminous coal and anthracite are used for generating electricity and in metal processing.

Figure 1. Diagram showing how coal is formed from peat (Source: Kentucky Geological Survey)



3.0 Coal classification

As mentioned above coal falls into four main groups based on age and a variety of chemical and physical features (Table 1)¹:

- Lignite
- Bituminous
- Sub-bituminous
- Anthracite

There are different classification systems for coal around the world and Canada follows the system used by the American Society for Testing and Materials (ASTM) (Ting and Laman, n.d.). Lignite is the youngest and lowest ranking coal, with heating values of <6,300 British Thermal Units per pound² (BTU/lb) to 8,300 BTU/lb. Sub-bituminous coal generally has a volatile³ content of >31% and heating values between 8,300 and 11,500 BTU/lb. Sub-bituminous coal contains less sulphur (generally <1%) and as a result is cleaner burning than other coals, which is important to air quality. Bituminous coal has an approximate carbon content of 14% to >31% and heating values of 10,500 to ≥14,000 BTU/lb. Finally, anthracite has the lowest volatile content, ranging from <2% to 8% with heating values of >14,000 BTU/lb (Miller, 2005; EPA updated 2011, Ting and Laman, n.d.).

Table 1. ASTM coal classification system data

Coal type	Volatile matter %	Fixed carbon	BTU / pound
Anthracite group			
<i>Meta-anthracite</i>	<2%	≥98%	-
<i>Anthracite</i>	2 to 8%	≥92% <98%	-
<i>Semi anthracite - Lean coal</i>	8 to 14%	≥86% <92%	-

¹ Including but not limited to the amount of volatile matter, fixed carbon, % moisture and oxygen

² British Thermal Units (BTU) is a unit of energy and is roughly the amount of energy needed to heat one pound of water by one degree Fahrenheit (°F)

³ Volatile content – volatile content in coal refers to material that will burn off with heating

Table 1. ASTM coal classification system data

Coal type	Volatile matter %	Fixed carbon	BTU / pound
Bituminous group			
Low volatile bituminous	14 to 22%	≥78% <86%	
Medium volatile bituminous	22 to 31%	≥69% <78%	
High volatile bituminous A	>31%	<69%	≥14,000
High volatile bituminous B	>31%		13,000 to 14,000
High volatile bituminous C	>31%	-	10,500 to 13,000
Sub-bituminous group			
	>31%		
Sub-bituminous A	-	-	10,500 to 13,000
Sub-bituminous B	-	-	9,500 to 10,500
Sub-bituminous C	-	-	8,300 to 9,500
Lignite			
Lignite A	-	-	6,300 to 8,300
Lignite B	-	-	<6,300

Note: The PRB coal proposed for the FSD facility is a cleaner burning sub-bituminous coal, with 'as received' samples from the supplier containing 0.29% sulphur, 32.82% volatile matter and providing 9,125 BTU/lb.

4.0 Coal entry into the Fraser River

Coal has some potential to enter the Fraser at the FSD site as dust fall, from equipment or system failures and through vessel accidents resulting in spills. Detailed mitigation planning and the implementation of best management practices to limit dust and the potential for spills include but are not necessarily limited to:

- Daily site cleaning
- Use of water in the unloading shed, along the conveyor and other areas as needed to suppress dust
- Avoiding coal stockpiling onsite

- Monitoring weather conditions that may affect operations
- Planning activities around forecasted windy weather
- Spill preparedness and response

Daily inspections and monitoring along with routine maintenance of all supporting systems (e.g. conveyors, sprinklers, run off collection and water treatment infrastructure) will be undertaken to identify potential issues and avoid system failures. Barges will be double-walled, which will make them less vulnerable to damage that could result in spills. Prior to barge loading FSD personnel will confirm the barges are free of debris, in good condition, and are properly closed. As part of the barging contract, FSD will also require contractors to submit maintenance and training records. All of these measures will help minimize the potential for coal to enter the Fraser River at FSD.

5.0 Chemicals of potential concern in coal

From an ecological stand point the chemicals of possible concern in coal are metals, metalloids⁴ and organic compounds – in particular polycyclic aromatic hydrocarbons (PAH). Metals occur naturally in the plant material that makes up peat, and these metals remain in the peat as it changes into coal. PAHs occur naturally in coal and form through the combustion or burning of organic matter at low heat (100°C -150 °C) over long periods of time (Ministry of Environment, Lands and Parks, 1993).

5.1 Metals and metalloids

Metals and metalloids can be of concern if they dissolve or leach out of the coal matrix. This can happen, for example, in coals with higher sulphur content (3%) (Ahrens and Morrisey, 2005) that are exposed to rainfall. The combination of higher sulphur and rainfall can result in the creation of acidic runoff (e.g. pH ~2.0) which can cause different metals and elements to dissolve out of the coal⁵. Similarly, acidic and / or low oxygen conditions in sediments can result in the release of dissolved metals (Biggs *et al* 1984). Some metals, like selenium have a different chemistry and can become available in dissolved form under more alkaline pH conditions (e.g. ≥9.0) (Al-Abed *et al.*, 2006).

⁴ Metalloid: is an element with metallic and non-metallic properties (e.g. antimony, arsenic, boron, silicon, tellurium)

⁵ Coals with lower levels of sulphur (1-25) typically generate more neutral pH (Davis & Beogly 1981b, Tiwary, 2001, Cook & Fritz 2002 in Ahrens and Morrisey, 2005)

5.1.1 Dissolved metals in the water column

Metals in dissolved form are of potential concern because they can be available to aquatic life for uptake depending on a wide variety of environmental conditions (e.g. the pH and dissolved organic matter of water) and sediment chemistry (pH, cations, oxides, sulfides, % carbon). A chemical is bioavailable, if it is in a form that can be taken up by aquatic life from the environment. In fish for example, dissolved metals in water are bioavailable if they successfully attach to, and pass through the gill surface, which allows the metals to move into their blood stream.

Dissolved metals may, under certain circumstances, have negative effects on aquatic life. However, it is important to remember negative effects do not occur just because dissolved metals are present. Many complex factors determine whether or not dissolved metals can be taken up by aquatic life and have a demonstrated toxic effect.

The potential toxicity of metals like copper, cadmium, silver and zinc, for example, can be affected by the presence of minerals like calcium and magnesium and organic matter in the water. Calcium and magnesium are the main components of water hardness, which is important to determining the potential toxicity of some metals. Increased water hardness is associated with decreased toxicity for some metals.

In water, dissolved calcium and magnesium are present as positively charged particles (cations) that float freely in the water column. Other metals like copper, cadmium, silver and zinc are also present as charged particles. Using the example of the fish gill again, calcium and magnesium in water will compete with copper, cadmium, silver and zinc in water for attachment sites at the gill surface. When calcium and magnesium are in the water at higher concentrations, they can actually prevent other metals from attaching to the gill – making these metals *unavailable* for uptake. Generally speaking, the higher the calcium and magnesium concentrations the less available other metals are for uptake. This means that even though metals like copper, cadmium, silver and zinc may be present in a dissolved form that could have a toxic effect; they may not be able to reach the location on the fish gill to exert a toxic effect.

A similar situation can result when organic matter (carbon) is present in the water. Certain metals, again copper, cadmium, silver and zinc will join with organic matter in the water and when they come together, they form metal complexes that cannot cross the gill surface. Like calcium and magnesium, the more organic matter is present in the water, the more potential for metal complexes to form and the less potential for some metals to attach to the gill and have a toxic effect.

5.1.2 Potential for dissolved metals effects

Because of the low sulphur content of the PRB coal, and because of the mitigation measures described in Section 3.0 (dust control, limited stockpiling, daily site cleaning, routine maintenance, storm water runoff treatment) exposure to potentially toxic levels of dissolved metals levels from site runoff or dust fall into the Fraser is not anticipated.

In the event of a spill from a barge accident or barge overflowing, the combination of large, flowing water volumes and slightly alkaline pH of the lower Fraser River would generally limit the potential for metals and elements to be released from the coal in concentrations that would be of concern. For example, the Ministry of Environment (2004) reported pH levels in the lower Fraser ranging from 7.2 to 7.8 at the Patullo Bridge and 7.4 to 7.7 at Annacis Island. An average pH of 7.64 (n=76) was observed at Fraser River Water Quality Buoy, 12 km u/s of the mouth. These levels indicate the Fraser River is near neutral and slightly alkaline and given these observations any metal or element leaching that might occur is not expected to result in levels of concern in the Fraser River.

Calcium and magnesium levels in the lower Fraser change with the tides, with salt water on the incoming tides increasing calcium and magnesium levels in the river. Swain *et al* (1998) reported an average calcium concentration of 30.0 mg/L and an average magnesium concentration of 39.96 mg/L in the lower Fraser downstream of the Patullo Bridge. This corresponded to a calculated hardness of 238.76 mg/L. BWP Consulting (2001) reported calcium, magnesium and / or hardness levels at selected locations in the Lower Fraser as follows:

- Calcium (15.6 mg/L) and magnesium (4.9 mg/L) at Annacis Island
- 698 mg/L (54.6 mg/L calcium and 137 mg/L magnesium) at Ewen Slough in the South Arm of the Fraser, downstream of Ladner

Both magnesium and calcium provide some protection against the toxicity of dissolved metals to aquatic organisms. It has been stated above the potential for leaching to occur to levels of concern for metals and other elements is unlikely and the levels of calcium and magnesium the Fraser River will help protect aquatic organisms. In the marine environment the levels of calcium and magnesium are much higher than in freshwater systems like the Fraser River and the potential for problems arising from metals or elements from spilled coal is not likely.

5.1.3 Metals in sediments

In order to evaluate the potential for negative effects of coal on sediment quality, we reviewed chemical data from the source coal and compared them with the BC provincial and federal sediment quality guidelines for the protection of aquatic life. Our review showed no concentrations of metals in the source coal above the Interim Sediment Quality Guidelines (ISQG), lowest effect levels (LEL) or the effects range low (ERL) levels (Table 2). Levels below the ISQG are considered protective of aquatic life. This means that spilled coal settling out in bottom sediments would not be expected to result in metals concentrations above the Interim Sediment Quality Guidelines.

Table 2 Comparison of trace element analyses to available provincial and federal sediment quality guidelines

	Arsenic	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Selenium	Silver	Zinc
	1.9	0.09	3	9	0.7	16	0.034	2	0.6	0.03	5
	1	0.05	3	9	1.2	15	0.049	2	0.6	0.02	6
	1.5	0.06	2	9	1.2	21	0.053	2	0.6	0.04	6
	1.6	0.05	2	9	1.2	21	0.068	2	0.5	0.03	5
	2.1	0.05	2	9	1.1	27	0.095	2	0.6	0.05	3
	1.1	0.07	2	9	1.3	15	0.058	2	0.5	0.03	5
	1.3	0.04	2	7	0.7	16	0.059	1	0.4	0.02	3
	1.3	0.04	3	10	1.1	16	0.038	2	0.5	0.02	4
	1.6	0.07	3	9	1.3	68	0.0413	2	0.4	0.02	5
Average of source coal samples	1.5	0.06	2	9	1.1	24	0.055	2	0.5	0.029	5
BC Working sediment quality guidelines - freshwater	5.9 (ISQG)	0.6 (ISQG)	37.3 (ISQG)	35.7 (ISQG)	35 ISQG	460 (LEL)	0.170 ISQG	16 (LEL)	2	0.5	123 ISQG
BC Working sediment quality guidelines - marine	7.24 (ISQG)	0.7 (ISQG)	52.3 (ISQG)	18.7 ISQG	30 ISQG	-	0.130 ISQG	30 (ERL)	-	1.0 (ERL)	124 ISQG
CCME Sediment quality guidelines - freshwater	5.9 (ISQG)	0.6 (ISQG)	37.3 (ISQG)	35.7 (ISQG)	35	-	0.170 ISQG	-	-	-	123 ISQG
CCME Sediment quality guidelines - marine	7.24 (ISQG)	0.7 (ISQG)	52.3 (ISQG)	18.7 ISQG	30.2	-	0.130 ISQG	-	-	-	124 ISQG

ISQG - Interim sediment quality guideline

LEL – lowest effect level ; concentration that 95% of the benthic biota can tolerate (Ontario Ministry of Environment and Energy - freshwater biota)

ERL - effects range low ; concentration below which effects are rarely observed or predicted among sensitive life stages and (or) species

5.2 Polycyclic Aromatic Hydrocarbons (PAHs)

PAHs are organic compounds from a variety of sources but can occur as a result of incomplete combustion from forest fires, combustion engines, wood stoves, coke production⁶, etc. (CCME, 1999). PAHs occur naturally in bituminous fuels like coal and crude oil. Examples of PAHs that occur naturally in coal include: benz [a] anthracene, benzo [a] pyrene, benzo [e] pyrene, dibenzo [c,d,m] pyrene, perylene and phenanthrene (Woo *et al.*, 1978 in MELP, 1993).

PAHs do not easily dissolve in water and they tend to adsorb or strongly attach themselves to particulate matter - especially organic matter such as coal (Bucheli and Gustafsson, 2000 in Ahrens and Morrisey, 2005). As a result, PAHs released into the aquatic environment often have limited potential to occur in dissolved form, or if they are present in water, it is only for a short time. PAHs released into the environment are more likely to remain bound to particulates eventually settling out into bottom sediments⁷. Studies conducted by BC Research (BC Research, 1996) indicated that when coal dust entered water, it did not dissolve but formed a suspension in which the PAHs remained attached to the particles⁸.

Like dissolved metals, the presence of PAHs in sediments does not necessarily mean adverse effects on aquatic life will occur. In studies of the possible effects of PAH exposure on crustaceans (*Rhepoxynius abronius*), *Neanthes arenaceodentata* (worms) and *Mytilus edulis* (blue mussel); Chapman (1996) concluded PAHs associated with coal particles were not bioavailable as toxic responses to PAH were not observed. Paine *et al.* (1996) and Allard *et al* (1997) studied the fate of PAHs in sediments offshore from the Alcan Smelter in Kitimat Arm. The authors found elevated levels of PAHs in some samples (up to 10,000 ppm total PAHs) but observed limited effects on aquatic life (benthic infauna, crab and bottom fish). Toxicity testing in the study showed no effects related to PAHs (Chapman (1996) in Triton, 2003). The authors concluded PAHs were not bioavailable because of the source of PAH in the sediments was from pitch globules and coal particles to which the PAHs were tightly bound.

⁶ Coke: solid residue of impure carbon from bituminous coal and other carbonaceous materials after volatiles removal by destructive distillation. Coke is used as a fuel and in making steel

⁷ In their review of the potential effects of PAH (and other chemicals) from unburned coal in marine environments, Ahrens and Morrisey (2005) reported PAH concentrations in filtered leachates of <0.05 mg/L (ppm), with levels of 0.005 mg/L occurring more frequently

⁸

Johnson and Bustin (2005) reported coal particles in sediments at the Westshore facility at Robert's Bank, with mean coal concentrations of 1.80% in 1977 of 3.60% in 1999

This tendency to strongly bind or attach to organic matter was also demonstrated by Gosh *et al.* (2000) who reported PAH concentrations associated with coal and wood particles in sediment were many times higher than PAH concentrations associated with silica (inorganic) particles. The coal and wood particles made up only 5% of the sediment by weight, but contained 62% of the total PAH. The remaining 38% occurred in the clay and silt fractions of the sediment. These authors also studied the PAH desorption (or release) rate from the coal, wood, clays and silts and found low bioavailability of PAHs from coal and wood components the bioavailability of PAHs clays and silts was higher because these fractions had less organic matter (as cited in Triton, 2003). In addition, Jeffrey *et al.* (2002) studied the binding and bioavailability of PAHs in coal and in silt / clay from Milwaukee Harbour sediments and found PAHs were generally associated with coal particles limiting their bioavailability and confirming PAHs will preferentially remain bound to coal particles under normal water quality. These PAH were strongly bound to the coal particles, with only 8% of the PAH releasing from the coal after 100 days, as compared with 80% of the PAH releasing from the clay / silt fraction in roughly 60 days (as cited in Triton, 2003). The same study included toxicity testing (acute toxicity and bioaccumulation trials) on earthworms and the results indicated only the PAH associated with the silt / clay fraction were readily bioavailable. Ultimately, coal particles can bind PAH by incorporating them into the coal matrix or through adsorption (attachment), making them unavailable and / or resulting in limited availability for uptake by aquatic life.

6.0 Summary

Based on our review and analysis of information provided by the coal supplier we note the following:

- Coal is formed naturally from peat through the application of heat and pressure over millions of years
- The main chemicals of concern in coal are metals, metalloids and PAHs
- Peat and coal both contain metals and metalloids, because these are naturally present in the decaying / decayed plant material from which the peat developed
- Coal contains PAHs as a result of the naturally occurring combustion of organic matter
- Given the mitigation measures proposed at the FSD facility there will be tight controls on surface runoff and on transiting barges and this will limit or avoid the potential for unburned coal to enter the environment

- Metals, metalloids and PAHs are present in unburned coal, but they are often not considered harmful to aquatic life because they are generally not bioavailable under normal conditions
- Given the tendency of PAHs to adsorb or attach strongly to coal, we do not anticipate PAHs will be bioavailable or result in potentially toxic levels of PAHs being released

7.0 Closing

If you have any questions, comments or concerns about this letter please feel free to contact the undersigned at 604-279-2093, twatson@triton-en.com or kgraf@triton-env.com

Sincerely

Dr Tom Watson, RPBio, PBIol
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