



Mount Polley Mining Corporation

an Imperial Metals company

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Salmon Homing Behaviour, Fish Returns and the Potential for Olfactory Impacts from Copper

MPMC is aware of concerns that were expressed, shortly following the tailings breach, about the ability of wild salmon to find their natal (birth) streams. It is well known that in some circumstances, copper can impair the olfactory abilities of salmon to “smell” their way to their stream of origin. However, the form of copper and its concentration matter.

When these concerns were raised, MPMC asked Golder Associates to evaluate this concern. Golder found that based on the chemistry collected in August, the potential for olfactory impairment was low because the chemistry of Quesnel Lake showed dissolved copper concentrations below the widely cited values for those types of impacts.

Because much new data have been collected since that time, MPMC asked Golder to update the dataset used and to prepare a memorandum on the topic. Their conclusions remain the same and are provided in the memo attached. Specifically, they feel that the potential for impacts to the olfactory organs of fish is low because the concentrations of dissolved copper in the lake are below the thresholds for olfactory impairment that are reported in the scientific literature.

Recently, salmon have been returning to their spawning streams in very good numbers. These observations provide encouraging news and confirm our earlier expectations that homing behaviour would not be impacted.

The forecast returns into the Quesnel Lake and Quesnel River system were 1.5 million fish and those initial forecasts appear to have been considerably exceeded. Initial data estimates provided by the Department of Fisheries and Oceans indicate that catch + escapement numbers suggest that are strong and fish are showing up in spawning grounds.

Attachment: [Golder Associates Technical Memorandum on olfactory impacts dated October 2, 2014.](#)

DATE October 2, 2014**REFERENCE No.** 1411734-001-TM-Rev0**TO** Don Parsons, Dale Reimer, Steve Robertson
Mount Polley Mining Corporation**CC** Colleen Hughes, Lyn Anglin**FROM** Lee Nikl, Barbara Wernick**EMAIL** lnikl@golder.com**WILL DISSOLVED COPPER IN QUESNEL LAKE CAUSE SALMON TO LOSE THEIR SENSE OF “SMELL”
AND BE UNABLE TO FIND THEIR NATAL STREAM? A PRELIMINARY OVERVIEW****Introduction**

Concerns have been raised about the possibility that the spilled liquid and tailings from the Mount Polley Mine (MPM) Tailings Storage Facility (TSF) breach will impair the ability of salmon to find their natal stream because of damage to their olfactory organ (the organ that is responsible for sense of “smell”), which they use to find their natal streams (their “homing” ability). The legitimacy of this concern is supported by observations in the scientific literature that copper has long been reported to have the potential for damaging the olfactory organ of fish. However, as with other substance-induced impairment of biological function, there is a concentration at which such effects are observed and often only certain forms of substance induce such an effect.

Given the above considerations, it is appropriate for Mount Polley Mining Corporation (MPMC) to be able to provide an answer to this question. This memorandum was prepared to provide a brief evaluation of available¹ copper chemistry from Quesnel Lake near Hazeltine Creek, Quesnel Lake near Likely, and the Quesnel River and compare that to some of the levels at which homing abilities of salmon have been reported to have been impaired by copper. The objective in making this comparison is to evaluate whether or not this is an area of concern that requires detailed studies of fish behaviour in response to the tailings breach.

Copper in Quesnel Lake and Quesnel River Compared to Guidelines

The BC Water Quality Guidelines (BCWQG) provides threshold concentrations for chemicals for the protection of aquatic life. The initial application of freshwater aquatic life guidelines for copper are for the total metal concentration. However, the underlying data upon which the guidelines are derived are based on dissolved forms of copper. Dissolved copper concentration provides a better reflection of metal forms that could potentially lead to aquatic effects. Total metals, on the other hand, are likely to reflect the presence of particulate matter and do not necessarily represent harmful forms of copper because the copper is bound in the minerals that make up

¹ Note: The data reviewed was for the period of August 6 to September 16, 2014.



the particles. Table 1 below shows the average dissolved concentrations of copper measured at three locations: the head of Quesnel River near Likely, Quesnel Lake near Likely, and Quesnel Lake near Hazeltine Creek. The dissolved copper concentrations shown in Table 1 represent the average concentration of an aggregate of samples collected at various depths, during the period August 6 to September 16, 2014. At Quesnel River, data were only available for one sample location, but it had been sampled approximately 40 different times.

Table 1: Copper concentrations compared to BCWQG for freshwater aquatic life.

Location	Dissolved Cu (µg/L)			pH	Hardness (mg/L CaCO ₃)	DOC (mg/L)	Guideline 30-day*	Guideline Max*
	Mean	Min	Max					
Quesnel Lake near Hazeltine Creek	1.35	<0.25	6.6	7.7 – 8.1	47 - 73	1.5 - 3.2	2 µg/L	6 µg/L
Quesnel Lake near Likely	0.76	<0.25	4.2	7.8 – 8.0	45 - 69	1.7 - 2.5		
Quesnel River	0.71	<0.5	1.53	7.7 – 8.1	45 - 54	1.7 - 2.5		

*Note: BCWQG for copper is hardness dependent. The guidelines shown are based on the lower end of the hardness range, representing the most conservative guideline concentration.
 DOC = dissolved organic carbon

Overview of Olfactory Impacts of Copper

The following provides a brief (but not exhaustive) summary of the literature on olfactory impacts:

- The primary research on the effects of metals on olfactory function has been on juvenile salmonids as it is understood that imprinting occurs prior to out-migration (first studied >40 years ago).
- Olfactory cues are not the only means by which salmon find their natal streams.
- Field observations indicate that copper, in sufficient concentration, can influence migration of adult salmon to spawning areas.
- Dissolved copper (Cu²⁺) is the more toxic form. In natural waters, copper is known to be complexed with a variety of organic and inorganic ligands and thus free copper (Cu²⁺) is typically present in minor amounts (Allen and Hansen, 1996; Bazzi, 2002). It is this Cu²⁺ form that also has greater effect on olfactory organs.
- Dissolved organic carbon reduces copper effects on olfactory sensory organs, as it does with copper toxicity.
- DeForest et al. (2011) indicate that USEPA's (2007) Biotic Ligand Model (BLM)-based water quality criteria for dissolved copper would be protective against olfactory effects in juvenile salmon. This was based on an evaluation of water chemistry data from some 113 watercourses. As an example, DeForest et al. (2011) estimated a BLM-based 20% olfactory effect level concentration (EC20) of 13.1 µg/L for a creek with water chemistry that has similarities to the chemistry of Quesnel Lake (i.e., the creek had the following characteristics: pH = 8.2, hardness = 80 mg/L, dissolved organic carbon = 1.1 mg/L). This estimated concentration is higher than both the acute (8.1 µg/L) and chronic (5.0 µg/L) BLM-based USEPA water quality criteria, suggesting that the BLM-based criteria protect against olfactory impacts.

Table 2 below provides a concentration based summary of some of the literature findings on olfactory impacts of copper on adult salmonids.

Table 2: Studies on copper and olfactory impacts that are most commonly cited

Copper Conc. (µg/L)	Hardness (mg/L)	Exposure Duration	Effect	Source
20	20	Indefinite	Atlantic salmon spawning migrations in the wild interrupted	Sprague et al. (1965) cited in Hecht et al. (2007)
10-25	40	Indefinite	Chinook salmon spawning migrations in the wild apparently disrupted	Mebane (2000)
44	n/a	n/a	90% reduction in selection of home stream by Atlantic salmon	Sutterlin and Gray (1973), cited in Mebane (1994)

Note: n/a - not available

Copper in Quesnel Lake and Potential for Olfactory Impacts

Extensive water quality sampling has been carried out and more is in progress in Quesnel Lake and elsewhere in the area of the TSF breach. Pertinent data collected by MPMC are as shown in Table 1, above. Dissolved and not total copper is shown because the literature supports the use of dissolved copper².

The highest concentration of dissolved copper measured in MPMC’s monitoring program³ was 6.6 µg/L, from a sample location near Hazeltine Creek. This is a conservative characterization of the concentration that salmon would be exposed to because the average concentrations, representing the majority of the water chemistry, are lower. The average concentrations measured in the three assessed areas were 1.35 µg/L in Quesnel Lake near Hazeltine Creek, 0.76 µg/L in Quesnel Lake near Likely, and 0.71 µg/L in the Quesnel River.

When compared to the literature thresholds for olfactory impairment, these concentrations are below the thresholds at which we would expect to see olfactory problems in salmon. This is also true for the maximum measured concentration of dissolved copper (6.6 µg/L) which is below the reported olfactory thresholds. Therefore, based on the current water chemistry data from Quesnel Lake and Quesnel River, impacts on fish migration through olfactory impairment and lost “homing” ability are unlikely.

Salmon Returns to the Quesnel System

To identify whether or not field observations support our expectations that homing abilities are unimpaired, forecast estimates and preliminary in-season returns of salmon were sourced to see if salmon were finding spawning areas.

A pre-season forecast for the 2014 Fraser River sockeye run size and timing was obtained from the Department of Fisheries and Oceans Area Director in an email dated September 30, 2014. The pre-season forecast of summer run sockeye was for a total of approximately 1.5 million fish expected to be returning to the Quesnel system in 2014. Preliminary data of catch and escapement from lower down in the Fraser River system (i.e., the Mission passage) are used to provide an updated in-season run size, which currently predicts a larger than forecast run of approximately 2.3 million fish for the Quesnel system⁴.

² “Dissolved” metals are operationally defined as passing through a 0.45 µm filter. Some form of undissolved (i.e., not bioavailable) copper could pass through this filter. The dissolved metals results do not account for speciation or binding to organic and inorganic ligands.

³ Note: The data reviewed was for the period of August 6 to September 16, 2014.

⁴ Run sizes are usually not adopted until after the peak of the run has passed through marine test fishery areas in Juan de Fuca and Johnstone Straits.

Actual numbers of returning sockeye to the Quesnel system will not be available until later this year; however, it is clear that salmon are showing up in considerable numbers at their spawning areas in the Quesnel system, indicating that homing abilities have not been impaired by the tailings breach. Monitoring and specific studies are underway to identify whether this situation might change in the future.

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