Britannia Mine: contamination, remediation and monitoring

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What is happening?

In the early 1900s, the former Britannia Mine was considered to be amongst the biggest sources of metal contamination into waterways in North America.[1] The Ocean Watch Howe Sound Edition (OWHS) 2017 article on Britannia Mine Contamination summarized evidence of environmental impacts. Specifically, Sḵwx̱wú7mesh Úxwumixw/Squamish Nation people were heavily impacted because they typically consumed greater quantities of traditional seafood sources, such as bivalves, crustaceans and fish (e.g., Pacific salmon),

Britannia Mine Museum. (Credit: Bob Turner) which can be exposed to and retain these contaminants. Further, Sḵwx̱wú7mesh Úxwumixw/Squamish Nation have high value and spiritual/human connection for the integrity of the ecosystem (i.e., spiritual ecology). Salmon were, and still are, of particular importance as seafood and as a spiritual connection for the Sḵwx̱wú7mesh Úxwumixw/Squamish Nation (see Britannia Mine, OWHS 2017); metals can be lethal or impair important sensory function[i] in salmon (see Britannia Mine, OWHS 2017; additionally, see Salmon, OWHS 2020 for current population trends in Átl’ḵa7tsem/Txwnéwu7ts/Howe Sound).

In 2001, a remediation project was started by the provincial government that combined a number of mitigation actions; for example, a water treatment plant was built with a deep-water outfall (see Britannia Mine, OWHS 2017). An overall closure plan was developed, which stipulated remedial efforts and risk assessments were required to attain acceptable environmental conditions (e.g., acceptable human health risk), at which point site closure would be achieved.[2] For some measures, e.g., the groundwater management system, operation and maintenance will continue indefinitely.[2]

What is the current status?

Monitoring and reporting has continued around the Britannia Mine site.[3,4] Metal contaminants continue to be measured in porewater,[ii] including at three sites close to the groundwater management system (i.e., BB-2, BB-13 and BB-3), and two sites located further from the point of release of groundwater (i.e., BB-1 and BB-6, considered near-field reference sites) (Figure 1).

In 2017 and 2018, exceedances of B.C. water quality guidelines (WQG)[iii], a level set to protect marine species, were observed for boron, cadmium, chromium, copper, lead, manganese, nickel and zinc.[3,4] Additionally, an exceedance of the chronic[iv] and national safety levels[v] for mercury was observed, but only during a single sampling event in 2017. Other sampling events did not detect mercury.[3,4]

The main contaminants of concern at the Britannia Beach shoreline have been identified as copper and zinc.[4] Zinc concentrations at all sampling areas have decreased from 2017 to 2018. However, four of the five locations exceeded zinc WQG. Copper concentrations at all sampled areas appear to be generally the same as in previous years with a few locations showing slight decreases (i.e., BB-2, BB-3 and BB-13). However, all

i) Specifically, olfactory sensing, which is akin to smelling under water.

ii) Porewater – water contained in pores in soil or rock.

iii) B.C. water quality guidelines: boron (1.2 mg/L); cadmium (0.00012 mg/L); chromium (0.0015 mg/L); copper (maximum 0.003 mg/L; chronic 0.0002 mg/L); lead (maximum 0.14 mg/L; chronic 0.002 mg/L); manganese (chronic 0.1 mg/L); mercury (chronic 0.00002 mg/L); nickel (chronic 0.0083 mg/L); zinc (maximum 0.01 mg/L; chronic 0.055 mg/L).

iv) Chronic – long-term exposure.

v) B.C. water quality guidelines and Canadian Water Quality Interim recommendation for mercury (0.000016 mg/L) are to be revised as protection of predatory fish is not certain.[9]

Figure 1. Satellite map of the Britannia Mine area showing sampling areas (blue boxes), including near the groundwater management system (BB-2, BB-13 and BB-3) and near-field reference areas (BB-1 and BB-6). Blue arrows show the direction of groundwater flow; red and white dots indicate extraction wells that are part of the groundwater management system. Replicated from Golder report.[4]

locations remain in exceedance of WQG (Figure 2). Because the measured concentrations are higher than the guidelines, marine life may be negatively affected.

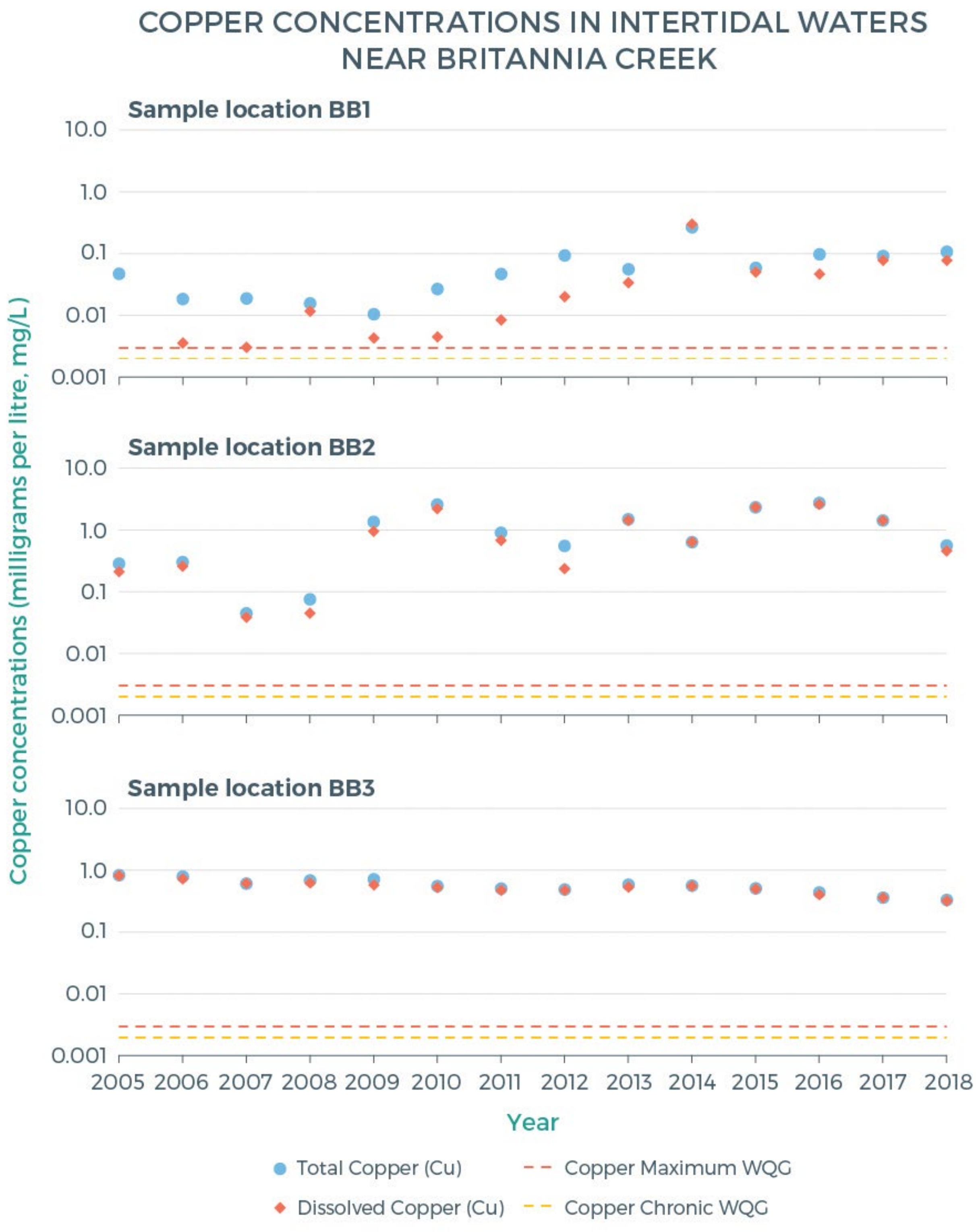
Surveys of intertidal animals[vi] were also conducted at the three sites located near the groundwater management system to monitor for effects from the above metals (Figure 1). Based on data from 2003 to 2018, the sampling location with the highest metal concentrations (i.e., BB-13) generally had the lowest number of motile[vii] invertebrates (e.g., crustaceans), a smaller coverage of aquatic plants and fewer indicator invertebrates (e.g., crab species [*Hemigrapsus* sp.]).

Additionally, the most common species at this location was green algae (*Cladophora* sp.), whereas the other locations were dominated by a brown algae seaweed species (i.e., *Fucus gardneri*). Another notable difference was the lower coverage of barnacles (*Balanus glandula*) at locations near the groundwater management system, excluding BB-13, compared to the near-field reference locations. In the case of site BB-13, the location with the highest metal concentrations, the coverage of barnacles and green algae had increased compared to recent years (i.e., since approximately 2012/2013).[4]

Trends observed in motile invertebrates suggest a natural variability in the presence of these species, as well as some evidence of recovery. For example, since 2013, an increase in decapods (e.g., crab species) has been observed at reference sites and locations near the

vi) Intertidal animals – animals living in the zone that is periodically covered/uncovered by water due to tidal movement.

vii) Motile – capable of movement.


COPPER CONCENTRATIONS IN INTERTIDAL WATERS NEAR BRITANNIA CREEK
Sample location BB1
Sample location BB2
Sample location BB3
10.0
1.0
0.1
0.01
0.001
Copper concentrations (milligrams per litre, mg/L)
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
Year
Total Copper (Cu)
Dissolved Copper (Cu)
Copper Maximum WQG
Copper Chronic WQG

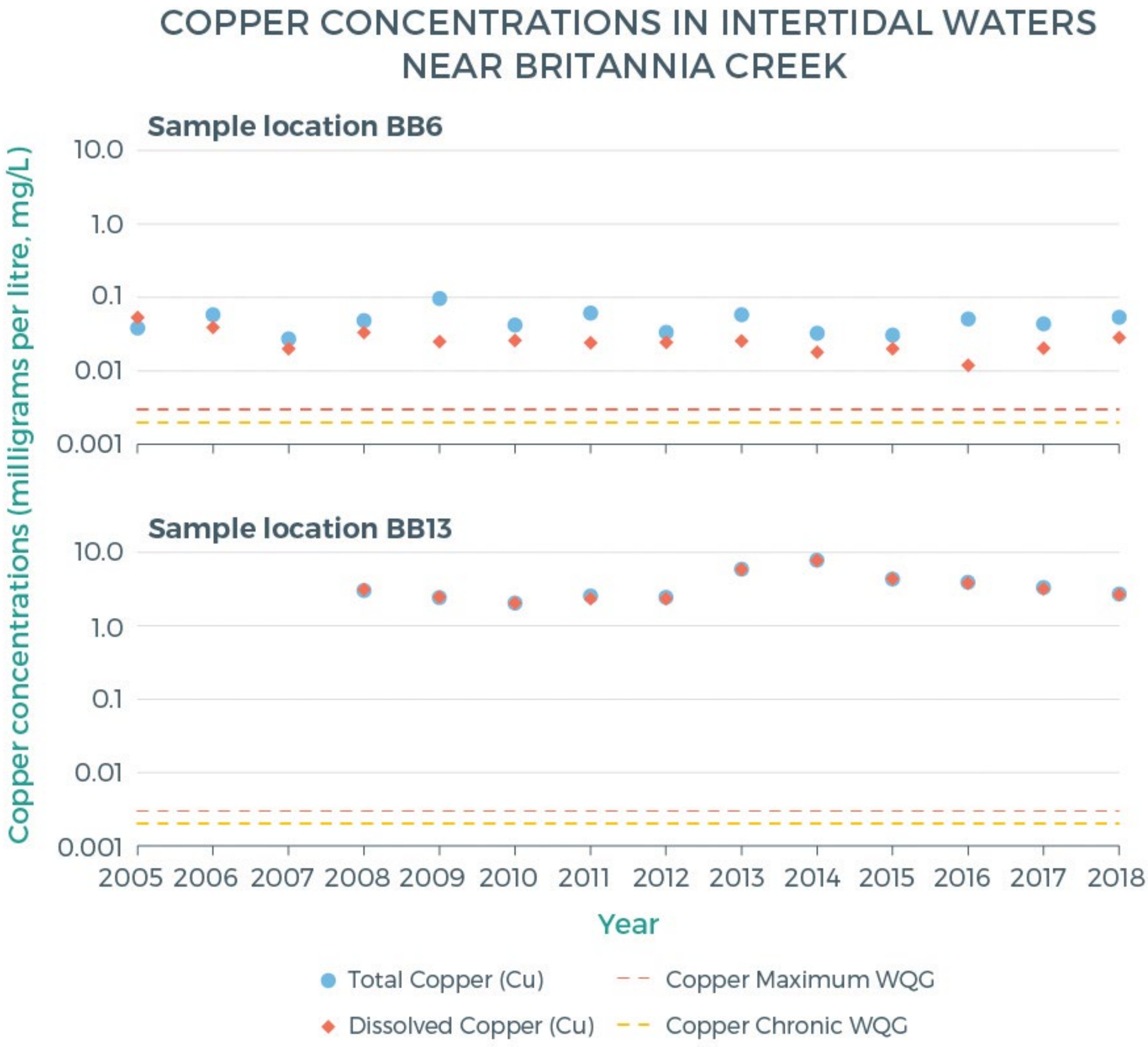
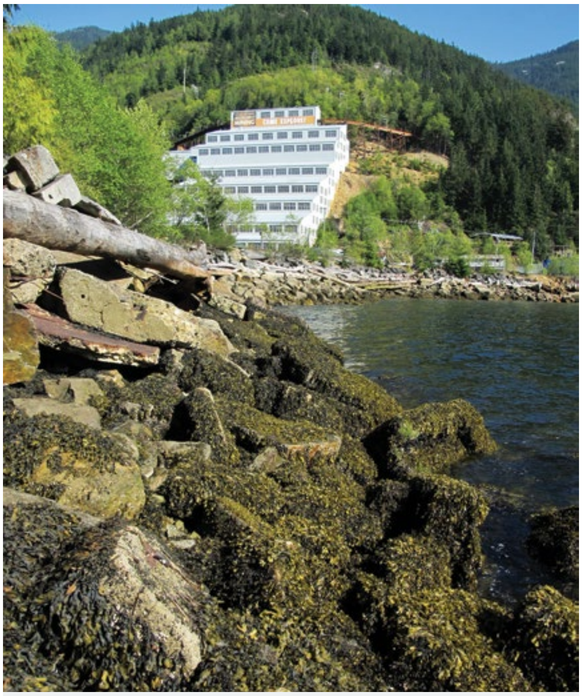


Figure 2. Porewater concentrations of total and dissolved copper in milligrams per liter (mg/L) for sampling locations BB-1, BB-2, BB-3, BB-6 and BB-13, top to bottom, respectively. WQG – water quality guideline. mg/L = milligrams per litre. There are 1000 milligrams per litre.

groundwater management system, except the location with the highest metals concentrations (BB-13).[4]

Overall, metal concentrations measured in 2017 and 2018 were comparable to previous years. Results from the location with the highest metal concentrations provide evidence of marine effects, but there were also signs of recovery. To support the understanding and recovery of the site, monitoring and remediation are ongoing.



The foreshore near Britannia Mine. (Credit: Bob Turner)

What are the potential impacts of climate change on contamination from Britannia Mine?

Pollutants from Britannia Mine have resulted in contaminated sediment.[5] These sediments now act as a sink and storage for contaminants and can potentially be released back into the environment (e.g., bioturbation by benthic macroinvertebrates, sediment resuspension by human activities, and due to disturbance during storm events). Additionally, there is evidence that the routes of exposure, accumulation and toxic effects from metals (e.g., mercury) can increase with warmer sea temperatures and under more acidic conditions (i.e., climate change-induced pollutant sensitivity in marine species).[6–8] The metal concentrations at Britannia Mine sites are already higher than the B.C. WQG for the protection of aquatic life. Increased temperatures coupled with exposure to metals stored in sediments has the potential to slow or even reverse ecosystem recovery.

What has been done since 2017?

The table below reports on progress made on recommended actions from the previous 2017 article, where identified. Many of these require ongoing action.

2017 ACTION	ACTION TAKEN
INDIVIDUAL AND ORGANIZATION ACTIONS	
Reach out to the community with updates on remediation in the Britannia Mine area. The community needs information about observed metal concentrations and any risk of harm they pose to human and marine life.	Publication of a previous Ocean Watch report supports this action. All finalized reports for the Britannia Mine Remediation Project are submitted to the Ministry of Environment and Climate Change Strategies for review and approval. These reports are publicly available through the B.C. Ministry of Environment's Land Remediation Website: www2.gov.bc.ca/gov/content/environment/air-land-water/site-remediation/contaminated-sites/information-about-sites
Recycle all batteries.	The B.C.-wide provincial program supports this action, with drop-off areas in Squamish/Sḵwx̱wú7mesh, West Vancouver and Gibsons. Link below. www.call2recycle.ca/british-columbia/
GOVERNMENT ACTIONS AND POLICY	
Track the state of the ecosystem health using a consistent ocean pollution indicator. Identify a consistently occurring, abundant biological indicator or bioindicator (i.e., an organism that can be used to monitor the state of pollution levels in the long term) to track metal contamination.	The Golder reports include surveys of intertidal animals.
Increase public education campaigns designed to educate citizens about the impact of phosphates, chlorine and pesticides, and how to minimize their impact.	Federal government sites support individual actions and access to additional resources. Links below. www.canada.ca/en/environment-climate-change/services/pollution-prevention/home.html https://pollution-waste.canada.ca/pollution-prevention-resources/Home/SearchIndividuals?lang=en
Support local recycling and zero waste initiatives.	The District of Squamish has developed a zero-waste strategy. Additionally, guidance for recycling items in B.C. is available from the Recycling Council of B.C. Links below. https://squamish.ca/our-services/garbage-and-waste-diversion/zerowaste/ www.rcbc.ca/recyclepedia/search

What can you do?

A detailed overview of recommended actions relating to climate change is included in *The path to zero carbon municipalities* (OWHS 2020). In some cases, no progress was identified on previous recommended actions; these remain listed below. Additional actions marked as **NEW** also follow.

Individual and Organization Actions:

- Sources of metals in wastewater are not all industrial. Be aware that what goes down your household drain or into the street gutter almost always ends up the ocean. Water treatment facilities can remove many contaminants, but plenty of dangerous chemicals that go down your drain will still end up in rivers, lakes, and oceans. Phosphates from detergents, chlorine from bleach, and the toxins in pesticides will all wreak havoc on fragile ecosystems once they leave your local sewage treatment plant.
- Do not put paint, solvents, pesticides or other chemicals down your drain.
- Help reduce the environmental impacts of mining by:
- Reducing your consumption of minerals; reducing consumption of consumer goods in general.
- Taking transit rather than buying a new car.
- Using recycled materials instead of mined materials and recycling all your metals (e.g., tin cans).

Government Actions and Policy:

- Increase support of research focuses to assess levels of metal contamination in waterways.
- Protect salmon stocks against the negative health effects of copper to the salmon’s olfactory system similar to that established in Washington State (http://www.seadocsociety.org/scientists-who-showed-how-copper-damages-salmons-sense-of-smell-receive-prestigious-award/), which will benefit salmon recovery by reducing the amount of toxic metals entering the Salish Sea by hundreds of thousands of pounds each year.
- Legislate against the use of phosphates in household products.
- **NEW** Fund studies examining relationships between contaminant concentrations and temperature.
- **NEW** Potential for increased sensitivity of species to contaminants at higher temperatures will need to be considered in water quality guidelines.

Methods

Data was summarized from the Golder reports.[3,4] Briefly, data from these reports were collected from the intertidal zone using sampling and survey methods. Porewater samples to measure metal concentrations were collected and submitted to an accredited laboratory for analysis. Data for intertidal species surveys were collected using visual observations during low tide at water sampling locations. Species were identified and coverage recorded, or presence noted.

Metal data from Golder[4] along with data from previous reports, dating back as far as 2005, were compiled to determine trends. As the most recent reports have reported on metal concentrations from porewater samples, only these data were analyzed. Comparisons with graphs from the previous Britannia Mine article are not possible because surface and bottom water concentrations were reported.

References

1 BC Government. Britannia Mine [Internet]. 2019 [cited 2019 Aug 21]. Available from: https://www2.gov.bc.ca/gov/content/environment/air-land-water/site-remediation/remediation-project-profiles/britannia-mine

2 Golder Associates. Overall Closure Plan Framework Document. Britannia Mine Remediation Project. Submitted to: Ministry of Agriculture and Lands. 15 June 2010. Report Number 012-1830/32120.; 2010.

3 Golder Associates. Britannia Mine Environmental Monitoring, 2017 Data Report. Submitted to Ministry of Forests, Lands and Natural Resource Operations. 23 February 2018. Report Number: 1786668-001-R-Rev0-2000; 2017.

4 Golder Associates. Britannia Mine Environmental Monitoring, 2018 Data Report. Submitted to Ministry of Forests, Lands and Natural Resource Operations. 27 February 2019. Report Number: 1786668-002-R-Rev0-2000; 2018.

5 BC government. Britannia Mine – Post Mining Conditions [Internet]. 2019 [cited 2019 Oct 21]. Available from: https://www2.gov.bc.ca/assets/gov/environment/air-land-water/site-remediation/imgs/acid_mine_fig3.jpg

6 Sokolova IM, Lannig G. Interactive effects of metal pollution and temperature on metabolism in aquatic ectotherms: Implications of global climate change. Clim Res. 2008;37:181–201.

7 Alava JJ, Cheung WWL, Ross PS, Sumaila UR. Climate change–contaminant interactions in marine food webs: Toward a conceptual framework. Glob Chang Biol. 2017;23:3984–4001.

8 Alava JJ. Ocean pollution and warming oceans: toward ocean solutions and natural marine bioremediation. In: Predicting Future Oceans. 2019. p. 495–518.

9 Canadian Council of Ministers of the Environment. Canadian Water Quality Guidelines for the Protection of Aquatic Life: Guidance on water quality guidelines in Canada: Procedures for deriving numerical water quality objectives. Can Environ Qual Guidel. 2003;146.