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DUNDAS TITANIUM

Discharge of silt – Analysis of metals

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INTRODUCTION

The Dundas Titanium project will discharge silt from the mining process to the sea. The discharges will take place at four location along the coast. The salt water used in the wet plant to melt and wash the mined material will be mixed with excess silt material and disposed of in the sea via pipeline. No chemical additives will be used in the process circuit.

To determine if the seawater after being used to wash the excavated material could be enriched in metals and have obtained concentrations that could pose a risk to marine life a series of simulations were carried out (shake flask tests). In these tests, material from different drill holes were mixed with saltwater and subsequently analysed.

The results from the Shake flask tests are included at the end of this report.

1.1 Water quality aspects related to effluent of soluble metals

It has been assessed if the discharge of water from the project could have water quality impact in the fjord. Data from the shale flask laboratory tests of the content of water-soluble metals are used to assess the impact on the environment.

The shake flask tests mimic the washing process at the mine facility. The sediment to water ratio in the shake flask test 1:3 w/w, and the ratio in the actual production 2/1.8 w/w. Assuming that the release of substances is related to the amount of sediment, the concentration found in water phase are multiplied by 3.33 to mimic the actual production conditions.

The limit values are ambient concentration whereas the shake flask concentrations mimic effluent discharges. The effluent concentration is exceeding the ambient limit for barium, cadmium, cobalt, copper, manganese, nickel, strontium, uranium and zinc – see Table 1.

Table 1 Water quality limits and measured values. Column three: GG is Greenlandic Guidelines for mining operation, DK is Danish requirements for good ecological status (Bek. 1625, 2017). GG values are anticipated to be maximum values. column "SF – corrected" contains shake – flask test results that are corrected to mimic production conditions. Red markings show where limit are exceeded.

		Limit			SF - corrected	
Name of substance	Unit	Origin	Average	Maximum	Average	Maximum
Aluminum Dissolved	[µg/l]				1000	5967
Antimony Dissolved	[µg/l]	DK	11.3	177	n/a	n/a
Arsenic Dissolved	[µg/l]	GG	5	5	n/a	n/a
Barium Dissolved	[µg/l]	DK	5.8	145	4362	13000
Beryllium Dissolved	[µg/l]				n/a	n/a
Bismuth Dissolved	[µg/l]				n/a	n/a
Boron Dissolved	[µg/l]	DK	94	2080	n/a	2000
Cadmium Dissolved	[µg/l]	GG	0.20	0.20	1.26	6.33
Calcium Dissolved	[µg/l]				444571	836667
Chromium Dissolved	[µg/l]	GG	3	3	n/a	n/a
Cobalt Dissolved	[µg/l]	DK	0.28	34	31	153
Copper Dissolved	[µg/l]	GG	2	2	164	743
Iron Dissolved	[µg/l]	GG	30	30	n/a	n/a
Lead Dissolved	[µg/l]	GG	2	2	n/a	n/a
Lithium Dissolved	[µg/l]				90	327
Magnesium Dissolved	[µg/l]				92831	230667
Manganese Dissolved	[µg/l]	DK	150	420	628	5200
Mercury Dissolved	[µg/l]	GG	0.05	0.05	n/a	n/a
Molybdenum Dissolved	[µg/l]	DK	6.7	587	5	13
Nickel Dissolved	[µg/l]	GG	5	5	55	230
Phosphorus Dissolved	[µg/l]				4524	16667
Potassium Dissolved	[µg/l]				148024	426667
Selenium Dissolved	[µg/l]	DK	0.08	31	n/a	n/a
Silicon Dissolved	[µg/l]				2643	4333
Silver Dissolved	[µg/l]	DK	0.2	1.2	n/a	n/a
Sodium Dissolved	[µg/l]					
Strontium Dissolved	[µg/l]	DK	2100	5530	3386	4933
Sulphur Dissolved	[µg/l]				67619	140000
Tellurium Dissolved	[µg/l]				n/a	n/a
Thallium Dissolved	[µg/l]	DK	0.48	1.2	n/a	n/a
Thorium Dissolved	[µg/l]				n/a	17
Tin Dissolved	[µg/l]	DK	0.2	20	n/a	n/a
Titanium Dissolved	[µg/l]				19	43
Tungsten Dissolved	[µg/l]				43	220
Uranium Dissolved	[µg/l]	DK	0.15	2.3	4	17
Vanadium Dissolved	[µg/l]	DK	4.1	57.8	n/a	n/a

Zinc Dissolved	[µg/l]	GG	10	10	205	1267
Zirconium Dissolved	[µg/l]				n/a	n/a

When effluent concentrations exceed the ambient limits in EU and Denmark operates with the identification of mixing zones where the Ecological Quality Standard (EQS) is exceeded. Calculation following "Technical guidelines on identification of mixing zones, CIS – WFD, 2010" are made:

An initial jet mixing zone can be calculated to 132 m (x_{max}^{jet}) with a corresponding dilution factor (M_x^{3D-jet}) of 64, assuming a water depth = 10 m, and ambient velocity of 0,02 m, diffusor diameter = 0,315 m, discharge = 0.21 m³/s.

The limit where jet mixing is dominating is calculated:

$$x_{\max}^{jet} = \frac{7 \cdot \ell_Q \cdot w_0}{2 \cdot u}$$

x_{max}^{jet} = maximum distance for jet calculation
l_q = characteristic length scale = $D * \sqrt{\pi/4}\ (round\ jet)$
w_0 = maximum velocity in the effluent stream
u = ambient water velocity

$$M_x^{3D-jet} = \frac{x}{5{,}6 * l_Q} = \frac{x}{5{,}6 * D * \sqrt{\pi/4}}$$

M_x^{3D-jet} = dilution faktor
D diameter of diffusor
X distance from diffusor

Table 2 - Comparison of ambient limit and concentration after initial mixing.

		Average [µg/l]		Maximum [µg/l]	
Name of substance	Unit	Initial diluted	LimIt	Initial diluted	Limit
Barium Dissolved	[µg/l]	68	5.8	203	145
Cadmium Dissolved	[µg/l]	0.02	0.2	0.1	0.2
Cobalt Dissolved	[µg/l]	0.48	0.28	2.4	34
Copper Dissolved	[µg/l]	2.6	2	12	2
Manganese Dissolved	[µg/l]	10	150	81	420
Nickel Dissolved	[µg/l]	0.85	5	3.6	5
Strontium Dissolved	[µg/l]	53	2100	77	5530
Uranium Dissolved	[µg/l]	0.06	0.15	0.3	2.3
Zinc Dissolved	[µg/l]	3.20	10	20	10

- On average the concentration of zinc is below the Greenland water quality guideline value outside the initial mixing zone. However, two of the 14 sample have concentrations that exceeds the guideline limit.

- Both maximum and average concentration for copper are high which is caused by two of 14 samples having high values. The average concentration of copper is below the Greenland water quality guideline values outside the initial mixing zone. Two of 14 samples have concentrations that exceed the limit. The concentration for copper in the Danish ecological standard is 4.9 [µg/l].

- The concentration of barium is generally high with the concentration in several samples exceeds the Danish limit values.

Outside the 132m zone barium, copper and zinc will have concentrations that are significantly higher than the guideline limit.

In Canada effluent discharge limits are given for the metal mining sector. For TDS, Copper, Nickel and Zinc values are listed in Table 3.

Table 3: Process effluent limits (Ontario 2017, compared to measured average and maximum concentrations.

			Average	Monthly average limit	Maximum	Daily limit
TDS	Enhed	GG	34800	15000	35400	30000
Copper Dissolved	[µg/l]	GG	164	300	743	600
Nickel Dissolved	[µg/l]	GG	55	500	230	1000
Zinc Dissolved	[µg/l]	DK	208	500	1267	1000

Table 4: Daily load for dissolved substances

	Daily load
Name of substance	kg/day
Aluminum Dissolved	18
Barium Dissolved	79
Cadmium Dissolved	0.02
Calcium Dissolved	8091
Cobalt Dissolved	0.56
Copper Dissolved	3.0
Lithium Dissolved	1.63

Magnesium Dissolved	1690
Manganese Dissolved	11
Molybdenum Dissolved	0.1
Nickel Dissolved	1.0
Phosphorus Dissolved	82
Potassium Dissolved	2694
Silicon Dissolved	48
Strontium Dissolved	62
Sulphur Dissolved	1231
Titanium Dissolved	0.3
Tungsten Dissolved	0.8
Uranium Dissolved	0.1
Zinc Dissolved	3.7

Calculation of the daily load (Table 4) is based on mean concentration in base flask test corrected to mimic production conditions. The concentration in is set the half the detection limit for test result below the detection limit.

1.2 Background levels for soluble metals

To describe the background levels of metals in the project areas four samples were taken in August 2019. The samples were collected near the approximate four discharge points. Data are presented in Table 5:

Table 5 Comparison of concentrations of; background sea water concentration, shake flask tests results of production water, limit values and concentration after initial mixing.

		Natural background		Shake Flask-test		Guideline Limits		After initial mixing	
Name of substance	Unit	Average	Max	Average	Max	Average	Max	Average	Max
Barium Dissolved	[µg/l]	17	24	4362	13000	6	145	68	203
Cadmium Dissolved	[µg/l]	< 0,2	< 0,2	1.26	6.33	0.20	1.50	0	0
Cobalt Dissolved	[µg/l]	< 0,5	< 0,5	31	153	0	34	0	2
Copper Dissolved	[µg/l]	< 3	< 3	164	743	2	2	2.6	11.6
Manganese Dissolved	[µg/l]	32	41	628	5200	150	420	10	81
Nickel Dissolved	[µg/l]	2.8	4.7	54.5	230.0	5.0	5.0	1	4
Strontium Dissolved	[µg/l]	6200	6500	3386	4933	2100	5530	53	77
Uranium Dissolved	[µg/l]	2.65	2.8	4	17	0	2	0	0
Zinc Dissolved	[µg/l]	< 2	< 2	205	1267	10	10	3	19.8

- The concentration of barium is generally high in the area. The natural background concentration exceeds the Danish limit values by a factor 3 and the concentration after initial mixing exceeds the Danish average limit values by a factor 11.

- The concentration of zinc is on average below Greenlandic water quality guideline values outside the initial mixing zone. Two of 14 sample have concentrations that exceeds the limit.

- Both maximum and average concentration for copper are high which is caused by two of 14 samples having high values.

- The concentration of zinc is on average below Greenlandic water quality guideline values outside the initial mixing zone.

1.3 References

- CIS – WFD, 2010, Technical Background Document on Identification of Mixing Zones
- ONTARIO REGULATION 560/94, EFFLUENT MONITORING AND EFFLUENT LIMITS — METAL MINING SECTOR, July 28, 2017
- BEK nr 1625 af 19/12/2017 Bekendtgørelse om fastlæggelse af miljømål for vandløb, søer, overgangsvande, kystvande og grundvand.