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Monitoring of runoff from quarry at Kaland, Mongstad

Risk assessment of deposited solids from TCC RotoMill process

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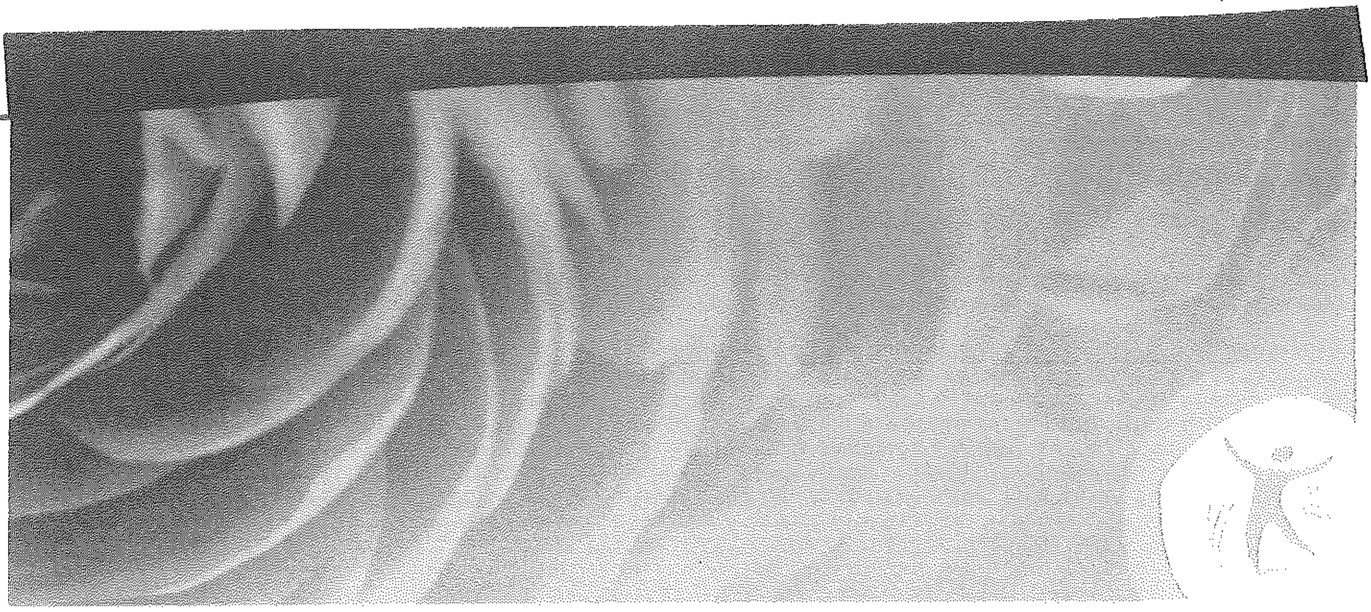

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Title:
Monitoring of runoff from quarry at Kaland, Mongstad. Risk assessment of deposited solids from TCC RotoMill-process.
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Summary:

During autumn 2011 runoff samples from quarry Kaland were sampled to give an indication on the influence of deposited solids from the TCC RotoMill process on runoff quality.

Samples were collected at 12. and 30.September, and 5.November 2011 from 3 (4) locations in a passing stream. pH, Conductivity, Dissolved organic carbon (DOC), Arsenic, Copper, Chromium, Nickel, Barium, Cadmium, Lead, Zinc, Molybdenum, Antimony, Chloride, Sulphate and Hydrocarbons (C10-C35) were determined in the water samples.

In this report the quality of the stream samples is summarized and an initial risk assessment is given.

Approved	Project leader
Roald Sørheim	Carl Einar Amundsen

Content

1. Summary

Leaching tests of solids from the TCC RotoMill process indicate that detrimental biological effects due to runoff may occur.

During autumn 2011 runoff samples from quarry Kaland were sampled to give an indication on the influence of deposited solids from the TCC RotoMill process on runoff quality.

Samples were collected at 12. and 30.Sepetember, and 5.November 2011 from 3 (4) locations. pH, Conductivity, Dissolved organic carbon (DOC), Arsenic, Copper, Chromium, Nickel, Barium, Cadmium, Lead, Zinc, Molybdenum, Antimony, Chloride, Sulphate and Hydrocarbons (C10-C35) were determined in the water samples.

The results from analyses of water samples at the quarry at Kaland in autumn 2011 show that deposited solids from the TCC RotoMill-process increase the concentration of barium, suspended matter and chloride in the stream. The concentrations of these compounds in the passing stream are considered to have no significant detrimental effect on aquatic biota.

In autumn 2011 recovered solids from the TCC RotoMill process have not been deposited at the quarry, which was stopped in summer 2011. The monitoring of runoff performed in autumn 2011 does not therefore give information on leaching from the quarry during the restoration process. Continued deposition therefore must be accompanied by regular and frequent monitoring of water quality in the stream running north from the quarry towards the sea.

Monitoring of water quality should include samples from the reference site and runoff out from the restoration area.

2. Introduction

2.1 Background

The Solids from the TCC RotoMill process are characterised by high pH (10-12), high levels of chloride, sulphate, barium and hydrocarbons with chain-length C16-C35 (Amundsen and Sørheim 2011). All these parameters are much higher in the Solids than in Norwegian soils. The mean and maximum concentrations of cadmium, lead, mercury, copper, nickel, chromium and zinc, arsenic, polycyclic aromatic hydrocarbons (PAH), are comparable with the content in Norwegian soils and overbank sediment.

The leaching tests show that the content of dissolved organic carbon (DOC), chloride and fluorine in the eluate may exceed the limit value set for landfills for non-hazardous and hazardous waste.

Comparison of eluate concentrations from the batch extraction test (LS10) with biological effect concentrations (PNEC-values), indicate that detrimental biological effects due to runoff may occur. Local considerations (dilution, water quality, ecological vulnerability) and monitoring have to be performed when Solids from the TCC RotoMill process are being applied. Monitoring of water bodies should involve the parameters pH, Conductivity, Dissolved organic carbon (DOC), Arsenic, Copper, Chromium, Nickel, Barium, Chloride, Sulphate, Fluoride, Hydrocarbons (C10-C35) and Phenols (Phenol Index).

2.2 Site specific assessment

The total and leachable concentrations of a compound is used to decide on what type of landfill the waste should be deposited (landfill for inert, ordinary or hazardous waste), and are not directly applicable for site specific risk assessments. In these cases detailed information about the local conditions is required i.e. information on the hydrology at the site (annual runoff), quality of runoff, background concentrations of contaminants in runoff, the ecological value and vulnerability of receiving waters etc.

The summary of results given above (Amundsen and Sørheim 2011) can however be used as an indication on what parameters should be monitored in a site specific assessment.

2.3 Objective of report

This report summarises results from analyses of runoff from the quarry where solids from the TCC RotoMill-process has been deposited. The risk for negative effects on water living organisms in the adjacent stream is discussed and recommendations for future disposal of solids from the TCC RotoMill-process are given.

3. Description of site

3.1 Location

The current site of reuse is to the North of a minor quarry situated at the junction of route 57 and route 565 at Kaland (Figure 3-1).

The site is currently utilised as a rock quarry and is being backfilled and extended utilising a number of different materials including forestry, construction and demolition wastes as well as the recovered solids from the TWMA facility.

The quarry sits on a small rise and falls away to the North with a small stream flowing approximately 2km through principally rough grazing land prior to discharging into Leirvågsundet.

3.2 History of quarry restoration

Solids from the TCC RotoMill-process have been deposited at the quarry at Kaland in the period 2006-2011 (for five years). Approximately 15000tons have been deposited annually. Assuming a density of 2tons/m^3, this amounts to 37500 m^3 in the period. The filling height has been approximately 10metres, which means that the restoration area used for solids from the TCC RotoMill-process is 3700m^2. This is about 13% of the total area of the quarry.

Before deposited the recovered solids were mixed with local topsoil rich in organic matter. The mixing was performed using heavy machinery, resulting in a quite inhomogeneous mixing.

Today the mixture of recovered solids and topsoil that are deposited at the quarry is not covered by other materials. It makes a compact surface with no odour. The runoff from this area has no colour.

3.3 Natural runoff in the area

The annual discharge from this area using data from NVE-atlas (45 litres/sec/km^2 or 1372mm/year), results in an average discharge of 0.17 litres/sec/year. The discharge in the stream passing by the restoration area is far higher than this (estimated discharge at 12.September about 10 l/sec), resulting in a quite significant dilution of the leaching from the deposited recovered solids.

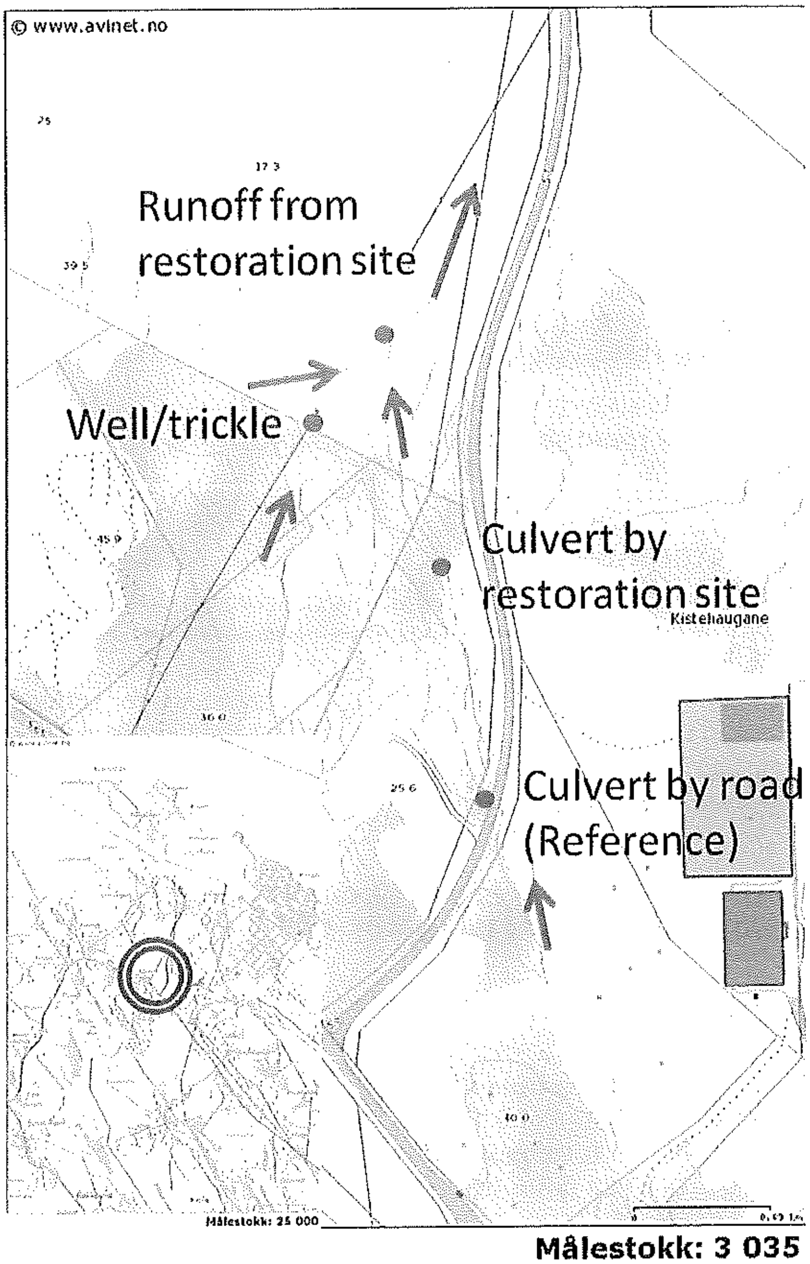

Figure 3-1: Overview of area at restoration site (gray) and runoff sampling points established 12.September 2011.

4. Sampling of runoff

4.1 Location of sampling points

The quarry and the runoff situation in the area was examined 12.September 2011 by personnel from Bioforsk. It was heavy rain and significant amounts of surface runoff during this day.

A stream is running into the quarry from the south (Figure 3-1). Prior to running into the quarry area it is influenced by other sources (roads, dense surfaces, industry etc). After passing through a culvert in the road (57), the stream runs north parallel to the quarry. A sampling point at the culvert was established (1-Culvert by road-Reference). The stream runs through a second culvert further north (3-Culvert by restoration site), before it runs north towards the sea (4-Runoff from quarry).

Surface runoff from the restoration site (trickle) and groundwater northwest of the front of the restoration site were also sampled (2-Trickle/well).

4.1.1 Culvert by road- Reference (1)

A sampling point was established in the stream after passing through a culvert by the road (57) (Figure 4-1). Prior to running into the quarry area it is probably influenced by other sources (roads, dense surfaces, industry etc). Water quality in the stream at this site will be important for evaluating the influence of the restoration site on water quality flowing out from the area.

4.1.2 Trickle/well northwest of restoration site (2)

Surface runoff (trickle) northwest of the restoration site (Figure 4-2) was sampled at 12.September. Measurements of conductivity in the surface runoff showed that the runoff at points was quite concentrated with salts. Runoff from a marsh west of the site rapidly dilutes the salty runoff before it runs into the main stream north of the quarry.

12.September a groundwater well was installed. A PE-pipe (54mm inner diameter) was knocked through the bog and about 1m into the clay underground. After installation the pipe was emptied several times to remove clay particles. The well was sampled 30.Ssepember and 5.November.

4.1.3 Culvert by restoration site (3)

The stream running parallel to the quarry (east) runs through a culvert in the northern part (Figure 4-3). At this point the stream is influenced by runoff from a large part of the restoration site, but to a smaller extent of deposited solids from the TCC RotoMill process. Sampling at this point was only performed 12.Sepetmber.

4.1.4 Runoff from quarry

The stream runs north after the last culvert (3). About 50meters north of the restoration site a sampling point was established (Figure 4-4). At this point surface runoff and groundwater are mixed with the stream running north from the quarry.

Table 4-1: Description of sampling locations at quarry Kaland used for monitoring of

	Sampling location	UTM E-W	UTM N-S	Description of location
1	Culvert by road (Reference)	282687	6747441	Stream running from the south through a culvert by the road. Sampling point after the stream has passed the road (Figure 4-1)
2	Trickle/well	282577	6747746	A well was established 12.September to sample runoff from groundwater in front of the site. Surface runoff (trickle) was sampled 12.September (Figure 4-2)
3	Culvert by restoration site			Stream running through the northern part of quarry in culvert (Figure 4-3)
4	Runoff from quarry	282644	6747771	Stream after passing restoration site. Sampling south of the fence (Figure 4-4)

Figure 4-1: Stream from south passing the road in culvert (Reference). Road can be seen above.

Figure 4-2: Well (white stick) and trickle west of the front of the restoration site (front of restoration area to the right).

Figure 4-3: Stream going through culvert by the quarry. Sampling at this site was done only 12.September.

Figure 4-4: Stream from the restoration site going north towards the sea. Sampling of runoff was done at the fence.

4.2 Sampling of runoff autumn 2011

During sampling a 0.5l and 0.1l PE-bottle were filled (inorganic parameters, DOC), and a 1l Glass bottle (Hydrocarbons). The bottles were rinsed twice prior to sampling (bottles completely filled) and transported to the laboratory as fast as possible.

Measurements of pH, conductivity, temperature and turbidity were performed at each sampling point prior to sampling.

The chemical analyses were performed at ALS Laboratory Group.

4.2.1 12. September

It was heavy rain, wet conditions and heavy runoff (Table 5-1) at the quarry 12.September. During the last 14days prior to sampling there had been quite heavy rainfall (170mm). Water samples were collected from all four sampling points.

4.2.2 30. September

There was no rain during sampling and less wet than 12.September (only 110mm the last 14days before sampling!) and thereby less runoff.

4.2.3 *5. November*

There was only slight rain in the area the 5. November, and only 60-70mm rain 14days prior to sampling. Due to heavy rain (120% of normal) in September and October, the water flow in the stream was quite high, possibly higher than 12.Sepember.

Samples were collected from points 1, 2 and 4.

5. Results and discussion

5.1 Field measurements and observations at site

The pH in the stream is about the same at the reference site and in runoff from the quarry, i.e. the quarry does not seem to influence pH. The conductivity and turbidity in the stream increase, however, after passing the quarry (Table 5-1). Solids from the TCC RotoMill process most likely contribute to this increase. Other parts of the quarry which has been filled with other materials, also contribute to this increase.

Water flow at the various sampling points was roughly estimated at the time of sampling (Table 5-1).

Table 5-1: Field measurements of pH, conductivity, temperature and turbidity in runoff from quarry at Kaland.

		Culvert by road (Reference)			Trickle/well			Runoff from quarry		
		12.09	14.10	05.11	12.09	14.10	05.11	12.09	14.10	05.11
pH		6.99	6.7	8.4	5.58	5.1	8.4	7.14	6.7	8.2
Conductivity	µS/m	158	181	115	130	170	90	375	389	270
Temperature	°C	11.8	13.1	10.1	12.3	12.1	10.9	12	13.3	10.2
Turbidity	NTU	3.28	5.4	1.5		189	30.2	32.1	9.3	15.3
Waterflow*	l/sec	10-15	5	20	0.2	0.1	1	20	10	25

*Estimated values - used only for relative comparisons.

5.2 Inorganic components in runoff

The concentration of chloride, sulphate, DOC, copper and nickel in the water running into the quarry was quite high and showed that this water (Reference sample, Table 5-2) was already contaminated before running parallel to the quarry. As mentioned, the quarry is located in an area with several other pollutant sources: roads, parking lots, agriculture, industry, domestic areas etc. All these sources will contribute to elevated concentrations of chloride, sulphate, DOC, copper and nickel (and other heavy metals) in surface runoff in the area. The concentrations of copper and nickel (also zinc) in the stream at the reference site are far higher than the PNEC-values for these metals.

The concentrations of chloride, suspended matter, barium and to some extent lead has increased in the stream after passing through the quarry (Table 5-2).Out of these components, chloride and barium can be directly related to solids from the TCC RotoMill process. Results from the leaching tests of the solids (Amundsen and Sørheim 2011) give no indication that lead leaches from the solids and the increased concentration of lead in the stream after passing through the quarry most likely is due to other sources.

5.2.1 Suspended matter

The concentration of suspended matter in the runoff from the quarry characterise the stream water as highly contaminated as it exceeds the limit of 10 mg/l (SFT 97:04). The concentration of suspended matter in the stream by the restoration site is, however, also high (Table 5-2). This shows that other parts of the site contribute considerably to the amount of suspended matter in the stream water. The runoff from the quarry is influenced by all the materials deposited. Permeability, quantity, depth, and chemical composition of the deposited materials are all decisive factors for the quantity of various compounds leaching to the stream. The solids from the TCC RotoMill-process constitute a minor fraction of total deposited materials.

Water quality guidelines for levels of suspended solids in surface waters vary considerably. In the European Union the concentrations of suspended solids should not exceed 25mg/l in waters suitable for both salmonid and cyprinid fish populations (guideline values), while in Australia guideline values range from 1-50 NTU in lowland rivers. In Canada, at low flow, the concentrations should not increase by more than 25 mg/l from background level at any short-term exposure (e.g. 24-h period).

Based upon these guideline values, the field measurements of turbidity and concentrations of suspended materials in runoff (Table 5-1 and 5-3), it does not seem that suspended materials will cause detrimental effects in the stream in the present situation (no active deposition of solids).

5.2.2 *Barium*

Barium was the metal that increased most in the stream after passing through the quarry. This is most likely due to barium sulphate ($BaSO_4$) in the solids. Barium sulphate is used as a weight material in drilling fluids.

Although soluble salts of barium are moderately toxic to humans, barium sulphate is nontoxic due to its insolubility (solubility product pKsp=9.96). A guideline value of 0.7mg/litre has been derived for barium in drinking-water (WHO/SDE/WSH/03.04/76).

Ecotoxicological studies of barium show that EC50/LC50/NOEC-values for plants, crustaceans and fish are in the range 26-500 mg/l (http://www.pesticideinfo.org/List_AquireAll.jsp?Rec_Id=PC41174). This indicates that it is unlikely that the concentrations of barium in the stream (<1 mg/l total barium) will cause any toxicological effects on aquatic biota.

Another aspect concerning the barium concentrations in the stream was that more than 70% were bound to particles, most likely barium sulphate. After filtering of the runoff (0.45 µm), more than 70% of the barium was removed (Table 5-2). When transported to the sea where the concentration of sulphate is high, the solubility of barium sulphate will be lower than in the stream.

Table 5-2: Concentrations of barium in runoff from quarry. Total (unfiltered) and filtered (0.45µm) samples. Unit: µg/l.

Date	12.09.2011		14.10.2011		05.11.2011	
	Total	Filtered	Total	Filtered	Total	Filtered
Reference	29.1		25.6	24.5	24.1	21.7
Well/trickle	609		5250	440	1660	464
Runoff from restoration area	927		430	195	444	169

5.3 Hydrocarbons

Hydrocarbons were not detected in any of the runoff samples at quarry Kaland (Table 5-3). This is somewhat surprising since hydrocarbons (C_{10}-C_{40}) were found in all solid samples from the TCC RotoMill process (Amundsen and Sørheim 2011).

The mixing of recovered solids with organic rich topsoil probably will reduce leachability of hydrocarbons from the recovered solids. Humus is known to adsorb hydrocarbons effectively and the low concentrations of hydrocarbons in the runoff may be explained by such sorption processes.

5.4 Contaminant index

The ratio between the concentrations in the outlet from the quarry and reference samples, give an indication on what parameters are influenced most by runoff from deposited materials at the quarry (i.e. Contaminant Index) (Table 5-4).

The CI show that barium, suspended matter, chloride and conductivity increase mostly in the stream after passing of the quarry. Except from the CI of barium and suspended matter, CI considered small.

In the trickle/well-samples also lead, zinc, cadmium and arsenic are elevated relative to the reference sample (Table 5-4). Due to dilution, however, the concentrations in the stream out from the quarry for these metals have not increased relative to the reference.

Table 5-3: Composition of runoff samples (autumn 2011) at quarry Kaland. PNEC-Predicted No Effect Concentration.

	Location	Culvert by road (Reference)			Trickle/well			Runoff from quarry			Culvert by restoration area	PNEC
Parameter	Unit	12.09	14.10	05.11	12.09	14.10	05.11	12.09	14.10	05.11	12.09	
pH		7.06	7.17	7.07	6.94	5.6	5.52	7.16	7.18	7.07	7.36	
Conductivity	mS/m	16.7	19	14.4	117	6.37	6.82	39.5	36.4	28	20.1	
Chloride (Cl-)	mg/l	19.9	23.9	23.4	312	11.8	13.8	63.9	60.3	50.1	17.4	150
Sulphate (SO4)	mg/l	18.6	23.3	16.7	33.5	<5.00	<5.00	27.7	28.4	15.7	30	100
DOC	mg/l	14.8	15.4	10.6	43.9	9.69	12.8	18.5	13	11.7	15.8	
Suspended matter	mg/l	<5.0	<5.0	<5.0	14.1	51.3	77.2	26.6	15.5	10	26.4	
Hydrocarbon >C10-C12	µg/l	<5.0	<5.0		<5.0		<5.0	<5.0	<5.0	<5.0	<5.0	
Hydrocarbon >C12-C16	µg/l	<5.0	<5.0		<5.0		<5.0	<5.0	<5.0	<5.0	<5.0	
Hydrocarbon >C16-C35	µg/l	<30	<30		<30		<30	<30	<30	<30	<30	
Hydrocarbon >C12-C35	µg/l	<35	<35		<35		<35	<35	<35	<35	<35	
Hydrocarbon >C35-C40	µg/l	<10	<10		<10		<10	<10	<10	<10	<10	
Sum Hydrocarbon>C10-C40	µg/l	n.d	n.d.		n.d		n.d	n.d	n.d.	n.d	n.d	10
Arsenic	µg/l	<0.5	<0.5	<0.5	1.02	1.12	<0.5	<0.5	<1	<0.5	<0.5	5
Barium	µg/l	29.1	25.6	24.1	609	5250	1660	927	430	444	113	
Cadmium	µg/l	<0.05	<0.05	<0.05	0.0595	0.143	<0.05	<0.05	<0.05	<0.05	<0.05	0.24
Chromium	µg/l	1.19	1.22	<0.9	<0.9	5.44	1.12	1.52	1.15	1.5	2.05	5
Copper	µg/l	40.1	37.3	26.4	1.52	13.6	2.96	24	23.4	13.4	31.5	0.64
Nickel	µg/l	20	17	13.4	19.8	6.76	1.45	13.7	13.5	10.2	14	2.2
Lead	µg/l	0.561	0.574	0.523	0.938	10.5	2.14	0.965	0.806	0.907	0.88	2.2
Zinc	µg/l	8.96	11.3	<4	7.54	30.7	5.45	10.4	5.53	5.45	10.1	2.9
Molybdenium	µg/l	0.893	1.02	0.844	2.95	0.694	<0.5	1.29	0.84	0.791	0.999	
Antimony	µg/l	0.326	0.134	0.379	0.147	0.519	0.469	0.236	0.126	0.239	0.214	113

Table 5-4: Ratio between concentration in runoff from the quarry and reference, and between well-trickle and Reference (Contaminant Index).

Parameter	Runoff from quarry /Reference	Well-trickle/Reference
pH	1.0	0.8
Conductivity	2.1	2.6
Chloride (Cl-)	2.6	5.0
Sulphate (SO4)	1.2	0.7
DOC	1.1	1.6
Suspended matter	6.9	19
Hydrocarbon >C10-C12	1.0	1.0
Hydrocarbon >C12-C16	1.0	1.0
Hydrocarbon >C16-C35	1.0	1.0
Hydrocarbon >C12-C35	1.0	1.0
Hydrocarbon >C35-C40	1.0	1.0
Sum Hydrocarbon>C10-C40		
Arsenic	1.3	3.2
Barium	23	9.0
Cadmium	1.0	3.0
Chromium	1.2	1.9
Copper	0.6	0.2
Nickel	0.7	0.6
Lead	1.6	8.2
Zinc	1.0	2.0
Molybdenum	1.1	1.4
Antimony	0.7	1.4

6. Conclusions and recommendations

The results from analyses of water samples at the quarry at Kaland in autumn 2011 show that deposited solids from the TCC RotoMill-process increase the concentration of barium, suspended matter and chloride in the stream. The concentrations of these compounds in the stream running to the sea are considered to have no significant detrimental effect on biota in the stream.

Former analyses of water extracts of water based drill cuttings (Amundsen et al. 2006a,b) have shown that there are a lot of water soluble organic compounds in untreated drill cutting. At present it is unclear what fraction of these organic compounds is removed in the TCC RotoMill process. Experimental data from development of analytical procedures for hydrocarbon analyses in water indicate that several organic compounds are still present.

Uncertainty related to the composition of runoff from the quarry, urge for ecotoxicological analyses of the runoff. Both freshwater and marine organisms should be included. Ecotoxicological analyses of runoff should be made prior to continued restoration of the area.

In autumn 2011 recovered solids from the TCC RotoMill process have not been deposited at the quarry, which was stopped in summer 2011. The monitoring of runoff performed in autumn 2011 does not therefore give information on leaching from the quarry during the deposition process of solids. If the ecotoxicological analyses permit continued deposition of solids at the quarry at Kaland, the deposition therefore must be accompanied by regular and frequent monitoring of water quality in the stream running north from the quarry and from the reference site.

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