FOREWORD

These guidelines are recommended by the Offshore Norge work group for guideline 046 on barite quality and the Offshore Norge Forum for climate and the environment. They have also been approved by the director general.

The responsible manager in Offshore Norge is the manager for the environment, who can be contacted via the switchboard at +47 51 84 65 00.

These guidelines have been developed with broad participation by interested parties in Norway's petroleum industry and are owned by Offshore Norge on behalf of the industry. Their administration is assigned to Offshore Norge.

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1 INTRODUCTION

Purpose

These guidelines specify the background for the work, its mandate and the composition of the work group, as well as requirements for sampling and the choice of analysis method for identifying heavy metal levels in barite to be used as a weight material when drilling on the Norwegian continental shelf (NCS).

2 BACKGROUND

These recommended guidelines are intended to establish a cost-effective common method which is as correct and uniform as possible for analysing and reporting the heavy metal content in barite.

They have been developed in response to the need for a procedure which meets government regulations and barite quality requirements set by the operators. Possible environmental effects of discharging weight materials are also described.

Barite is a mineral extracted by mining. Morocco is the dominant source for Norway's petroleum sector. The material is not 100 per cent pure and contains other substances and impurities, such as heavy metals. The main component in barite is barium sulphate – $BaSO_4$. This is virtually insoluble in water.

The guidelines also describe the discharge of barite to the marine environment and possible environmental effects.

Barite additionally contains a few percentage points of silica. The content of crystalline silica, the respirable fraction, when evaluating barite sources is below the qualification threshold of one per cent.

The suppliers report that barite quality can vary from mine to mine.

3 MANDATE

At the request of the forum for offshore chemicals, industry and government (SKIM) and a number of operators on the NCS, Offshore Norge appointed a work group to revise the existing recommended guideline 046 on barite quality. This work was initiated as early as 2014.

4 COMPOSITION

The group comprises operators, suppliers and Offshore Norge. A draft of the new guidelines has also been submitted to SKIM.

5 REQUIREMENTS FOR BARITE QUALITY

5.1 USE

Barite is used as a weight material in drilling fluids to achieve sufficient density, and is chosen because of its high density, virtual insolubility in water and low toxicity. When drilling has ceased, the bulk of spent water-based drilling fluids and drill cuttings contaminated with barite is discharged to the sea.

5.2 CHEMICAL COMPOSITION

Barite used as a weight material consists of about 90 per cent $BaSO_4$ plus other minerals. Novatech describes analyses of barite samples which have proved to contain various mineral components (Rønnekleiv et al, 2006):

- calcite ($CaCO_3$)
- siderite ($FeCO_3$)
- dolomite ($CaMg(CO_3)_2$
- quartz (SiO_2), celestite ($SrSO_4$)
- feldspar ($NaAlSi_3O_8$).

Small quantities of other compounds have also been identified, such as:

- PbO_2
- CdO
- Al_2O_3
- CrO_3
- CuO
- TiO_2
- $ZnSO_4$
- ZnS
- PbS.

The quantities of these compounds can vary between the various barite deposits (mines).

Barite may occur as both sedimentary and intrusive rocks. In its sedimentary form, the content of heavy metals is normally lower than in intrusive deposits. Chemical analyses have established substantial differences in heavy-metal content between the various mines used.

Barite contains heavy metals found in the Norwegian Environment Agency's (NEA) priority list.

5.3 Government requirements

Government requirements for barite quality were first presented in the 92:03 guidelines from the Norwegian Pollution Control Authority (SFT - now the NEA), which specified that barite to be used as a weight material during drilling must have a low content of heavy metals. The operator had to document routines for quality control in purchasing barite, with the emphasis on controlling heavy-metal content.

The current activities regulations do not set threshold limit values (TLV) for heavy-metal content or requirements for analysis methods, but note that the content of heavy metals must be as low as possible. The industry is responsible for setting TLVs and doing sampling and analysis in a uniform manner which provides accurate and comparable results.

5.4 Operator requirements

While the heavy-metal content must be as low as possible, cost/benefit assessments must be applied as well. That finds expression, too, in the Norwegian Pollution Control Act. Offshore Norge accordingly recommends that the TLVs applied are also based on available barite quality. This could mean in some cases that barite will exceed the TLVs.

The analysis method must be clearly defined.

Technical requirements for barite quality, API standard.

Density:	min 4.20 g/cm^3
Soluble metals, about:	max 250 ppm
Residual wet screened, 75 micrometres:	max 3.0%
Particles <6 micrometres:	max 30%

Old and new recommended TLVs from Offshore Norge for heavy-metal content in barite are presented below. The analysis methods are NS 4770 (partial digestion with nitric acid at 7M HNO_3 at 120°C for 30 minutes and inductively coupled plasma-atomic emission spectrometry (ICP-AES)).

Table 1. Old TLVs for heavy-metal content and proposed new values as an annual average.

Heavy metals – old TLVs	Heavy metals – proposed new TLVs
As: was not included	<100 mg/kg
Cd: <5 mg/kg	<3 mg/kg
Cr: <50 mg/kg	<50 mg/kg
Cu: <150 mg/kg	<150 mg/kg
Hg: <5 mg/kg	<4 mg/kg
Ni: <15 mg/kg	<15 mg/kg
Pb: <1 000 mg/kg	<200 mg/kg*
Zn: <1 000 mg/kg	<500 mg/kg

*up to 400 mg/kg for individual batches.

5.5 Operator quality control, sampling, methodology and analysis

When conducting internal quality control, operators should check that the quality of barite delivered accords with technical and heavy-metal content requirements. NS 4770 will be the analysis method for heavy metals. Barite used in Norway is imported from Morocco, and only from mines with a low heavy-metal content.

Reporting of discharges (annual reports by licences to the authorities through the Epim EnvironmentHub (EEH), for example) utilises an average value based on all consignments imported during the year. This value will be common to all the oil companies, based on an allocation of the imported barite to the various fields.

5.6 Quality control and sampling

MI-Swaco has reported on the quality control system for barite sampling and analysis operated by Norbars Minerals AS, which imports the mineral for crushing in Norway. This system is certified to ISO 9001 and ISO 14001.

MI-Swaco reports that samples are taken from all consignments dispatched from Morocco. These are collected during loading of the ship in port and dispatched via Fedex to an accredited laboratory in Norway for testing of their heavy metal content. The results are reported to the operator/client, who can enter them in *EnvironmentHub* for use in statistics and environmental reporting.

When the ore is discharged with the shovel loader at Karmøy, the operator takes half a shovel from the cargo every 30 minutes as a sample. The sample is placed in a dedicated area of the warehouse. Pure ore is initially discharged for about half-an-hour from the cargo to be sampled. Samples amount to about one per cent of the consignment (in the order of 50-80 tonnes). They are tested solely for specific gravity. The whole sample consignment is then run.

Batches with varying specific gravities are stored in dedicated warehouse areas, so that the desired specific gravity can be achieved by mixing extracts from different batches.

Samples are crushed and taken for analysis. Sampling must be conducted at fairly frequent intervals during preliminary crushing – every 10 minutes, for example, corresponding to one-two buckets. Samples after preliminary crushing are used for technical analyses.

Halliburton has a supplier certified to ISO 9001 and recently also to ISO 14001 and OHSAS. A third-party company takes a representative and homogenous sample during discharge of the product and under the supervision of the supplier. Analyses are carried out to NS 4770 by an accredited lab.

- The raw mineral is registered and crushed to powder.
- The water content is measured from the raw mineral.
- Specific gravity is measured from the crushed mineral.

- The final barite product is sent to an external lab for analysis to NS 4770 with a nitric acid solution (five per cent) and a heavy-metal analysis to ICP-AES.

The emphasis when sampling is on obtaining an analysis material which is statistically accurate for the cargo. Barite will normally be tested every other hour in the mill. If the ore is bagged, each bag will be tested. Bulk consignments (sea or road) are tested before loading. These are the values reported in the monthly certificates of analysis.

The various consignments are stored on site until optimal. Should barite qualities differ, they can be mixed during crushing in predetermined proportions to achieve the desired outcome (in terms of heavy metals, for example). After crushing, the barite is stored in silos in the quay area. Different qualities can also be blended after crushing. Mean values for the year can be calculated from the quantity of barite imported and chemical analysis of the heavy-metal content in each consignment.

5.7 Barium in the environment

The heavy-metal content in barite delivered to the operator as weight material for drilling can vary somewhat. However, heavy metals in spent drilling fluids where barite is mixed with undrilled rock spoil will be very diluted, and will spread over a large area after discharge to dilute it even further.

Values for barite in sediments on the Ekofisk field provide an example. These have been acquired from environmental monitoring of seabed sediments on a triennial basis. Activity and discharges have been under way on Ekofisk since the 1960s, although with varying use of barite as a weight material. Levels of barium in the sediments at the field stations close to discharge points have lain around 1 000-2 000 milligrams per kilogram, while levels at the reference stations have been 30-50 mg/kg. Barite is easy to trace in the sediments, but heavy-metal levels nevertheless show no rise.

On Oseberg in region III, average values for barium in sediments near the field have ranged from 800 mg/kg in 1998 to 477 mg/kg in 2004, compared with 50 and 63 mg/kg respectively for the reference stations.

Sediment monitoring on Ekofisk has, for example, identified the following levels of various heavy metals at the stations in the immediate vicinity of the field in accordance with the classification of sediments (Bakke et al, 2007).

Table 2. Heavy-metal content in stations close to Ekofisk (Renaud et al, 2008)

Heavy metal	mg/kg	Condition class, Bakke et al, 2007
Cd	0.01-0.03	I – Background
Cu	1.2-3.8	I – Background
Hg	0.01- 0.04	I – Background
Pb	9.8-13.3	I – Background
Zn	7.8-17.8	I – Background

The observed values for heavy metals in the seabed sediments fall within the background class, as reported in 10-year offshore environmental monitoring of the sediments (Renaud et al, 2008). A corresponding position exists on Oseberg and a number of other NCS fields. The barite content in the sediments at the regional stations (previously reference stations) for the different NCS regions varies from four to 102 mg/kg in Region I to 229-462 mg/kg in the deepwater (274-354 metres) part of Region III. The heavy-metal levels deriving from the use and discharge of barite are overwhelmingly low and unlikely to represent any post-discharge environmental hazard. However, several experiments with water-based drill cuttings show effects resulting from burial and, to some extent, oxygen consumption from organic compounds contained in the drilling fluids close to the discharge point. Environmental monitoring of the sediments around offshore fields has revealed some increase in levels of trace metals at stations close to the field, but no indication exists that the heavy-metal level in fish and mussels caught at these positions is significantly higher than the natural background figures for the area (Bakke et al, 2013). Nor have effects been detected in sediment macrofauna *in situ* from discharges of water-based drilling fluids (and barite).

Barite has been identified at many locations elsewhere in the North Sea and in the deep areas of the Norwegian Trench, far from drilling activity and discharges. This demonstrates that fine barite particles can be carried very considerable distances by ocean currents before being deposited.

Novatech produced a report in 2006 (*Vektmaterialer – beste praksis, problemstilling)* for Offshore Norge (OLF – former name of Offshore Norge) which concluded in part that the effect of heavy metals in barite is consistent with the criteria specified for including barite on the Plonor list.

The permission for activity (discharge permit) issued by the NEA states: “Discharges of drill cuttings including weight materials are regulated in the activities regulations. The NEA does not normally set specific conditions for the discharge of cuttings drilled out with water-based fluid. Water-based drilling fluid systems usually have a high salt content and contain easily degradable organic components. These chemicals have little effect on the marine environment. Discharges of cuttings lead to physical smothering of the seabed close to the discharge point, and expose organisms to rock particles in the water column and on the seabed. Mineral-based weight materials in the drilling fluid system also contribute to this smothering effect.”

Where seabed deposition of bentonite and barite and its possible environmental effects are concerned, the operators have applied the same TLVs as for corals: 1-3mm for little effect, 3-10mm for moderate effect and >10mm for high effect. These are smothering effects which can occur in the immediate vicinity of the discharge point.

The NEA does not set discharge ceilings for substances in its green category, but assumes that consumption and discharges are minimised. Acute toxicity in water-based drilling fluids is generally low.

Environmental monitoring on the NCS has failed to identify *in situ* effects from discharges of water-based drilling fluids containing barite on the macrofauna in the sediment, other than possible smothering effects at the stations closest to the discharge point. The conclusion drawn is accordingly that water-based drill cuttings only have local effects of brief duration on sediment fauna.

Professor John S Gray prepared a report for the OLF in 2006 on the availability of lead in barite after discharge to the sea. He concluded: "There are three main exposure routes of metals to marine organisms 1) from water (the water column or from pore water), 2) from ingested sediment, and 3) from ingesting animals that themselves have accumulated metals. The biota accumulate lead primarily through the body surface and respiratory organs and to a lesser extent from ingested sediment and food items. The bioavailability of lead from cutting piles is most strongly related to the pore water content rather than the sediment load. Yet lead is rapidly excreted and so does not in general bioccumulate up the food web."

6 WORKING ENVIRONMENT CONSIDERATIONS

The content of respirable crystalline silica can have consequences for the working environment. The Norwegian Labour Inspection Authority recommends that mixtures of substances containing more than one but less than 10 per cent of respirable crystalline silica should be labelled as hazardous to health in the R48/20 risk phase (danger of serious damage to health by prolonged exposure through inhalation). This is translated in the classification, labelling and packaging (CLP) regulation to specific target organ toxicity, repeated exposure 2 (STOT RE 2) with hazard statement H373, "may cause damage to organs through prolonged or repeated exposure".

7 CONCLUSIONS AND RECOMMENDATIONS

The work group has concluded that the procedures for sampling and analysing heavy metals in barite in the revised 046 guidelines are suitable for the purpose. The work has been presented to the committee on the environment.

- Operators choose barite with the lowest possible heavy-metal content.
- Quality control for barite is adequate and provides representative values.
- Information from the suppliers shows that heavy-metal values are generally low. Following barite's use as a weight material and discharge together with drill cuttings, environmental monitoring of cuttings shows that heavy-metal values lie within or close to the background level pursuant to the classification of environmental condition (Bakke et al, 2007).
- Taking cost/benefit assessments (financial considerations) into account could also be necessary when choosing barite in the future, pursuant to the Pollution Control Act.
- Heavy-metal levels in barite have not demonstrated toxic effects on benthic fauna through discharge to the sea.

- Effects from discharging barite with water-based drilling fluids relate to physical consequences, such as smothering and burial.

8 REFERENCES

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APPENDIX A SPECIFICATION OF AMENDMENTS TO THE GUIDELINES

Guideline 046 on barite quality was first issued in September 1995. At the request of the operators, it has been revised to update requirements on the content of heavy metals in barite. The work has been carried out by the administration with the support of the work group. The Norwegian Environment Agency (NEA) has been kept informed of the work.

The guideline has included arsenic, As among the parametres to be analysed and proposed a threshold limit value, TLV.
The changes cover new threshold limit values (TLVs) for heavy metals in barite, as specified in table 1. In addition, a section (5.7) has been added on the discharge of drill cuttings contaminated with barite and its possible environmental impact.