

# Classification and treatment of LSA-sludge from the Brent Spar

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## Abstract

Assessments of the levels of radioactivity in sludge from the Brent Spar storage tanks have been performed. Based on field and laboratory measurements, only 44 drums (of a total of 2268 drums) were identified as drums with <sup>226</sup>Ra-concentrations above the exemption level of 10 Bq/g given by the Authorities. Field measurements showed satisfactory agreement with laboratory measurements. The drums containing radioactivity concentrations below the exemption level were classified as non-radioactive and shipped to Sløvåg Industriservice AS for incineration. Only small amounts of radioactivity were found in the ashes after incineration. The concentrations in the offgas and the outlet water were below or close to the detection limit for gamma spectrometry. Incineration of sludge with activity concentrations below the exemption level was found to be a well-suited method for disposal.

## Introduction

On request from Wood-GMC AS in 1999, Institute for Energy Technology (IFE) assessed the levels of radioactivity in sludge from the oil storage tanks on Brent Spar. The sludge was contained in 2268 standard-size steel drums at Raunes Quay at Vats, Rogaland, Norway.

The assessment was carried out in two stages:

- I) Survey of the distribution and levels of radioactivity throughout the storage facility, including estimation of the within-drum variation in activity concentration (homogeneity test) [1,2].
- II) Final assessment including identification of the drums containing sludge with radioactivity concentrations above the exemption level given by the Norwegian Radiation Protection Authority [2,3].

IFE was also asked to carry out verification measurements during incineration of the sludge that had been classified as non-radioactive [2,4].

## Legislation

A preliminary exemption level of 10 Bq/g for  $^{226}\text{Ra}$ ,  $^{228}\text{Ra}$  or  $^{210}\text{Pb}$  was given by the Norwegian Radiation Protection Authority (NRPA) in 1995 [5]. Waste from the petroleum industry with activity concentrations exceeding this level for one of the radionuclides mentioned shall be regarded as radioactive waste and handled as such. This exemption level is in accordance with international recommendations [6,7].

## Stage I

### Sampling and measurements

The sludge was contained in numbered standard-size steel drums stored in containers. Based on knowledge of the origin of the sludge, it was assumed that the activity concentration in drum number  $x$  would be similar to the activity concentration in drum number  $x+1$ . For the purpose of establishing regions of drum numbers with expected high, intermediate or low activity concentrations, one sample was collected in one drum in each storage container. All samples were taken below the "water table" inside the drums to avoid sampling of oxidised and semi-dry material. Four additional samples were collected in selected drums for test of the variation in activity concentration with the drums.

A total of 127 samples were collected from 107 of the drums. All samples were packed in plastic containers and analysed with high-resolution gamma spectrometry. Based on earlier measurements of the Brent Spar sludge,  $^{210}\text{Pb}$  could be excluded from the assessment, as its presence was only as a daughter of  $^{226}\text{Ra}$ .  $^{226}\text{Ra}$  was analysed directly by its 186 keV gamma line and the results were corrected for self-absorption, which was 12% for the counting conditions in question.  $^{228}\text{Ra}$  was analysed through its daughter  $^{228}\text{Ac}$ .

### Results and recommendations for Stage II

The results from Stage I revealed no drums with an activity concentration exceeding the exemption level of 10 Bq/g. The mean activity was found to be  $5.9 \pm 1.5$  Bq/g and  $1.6 \pm 0.5$  Bq/g for  $^{226}\text{Ra}$  and  $^{228}\text{Ra}$  respectively. The  $^{226}\text{Ra}:^{228}\text{Ra}$  ratio was found to be  $3.8 \pm 0.5$  with three outliers all high in  $^{226}\text{Ra}$ . The mean within drum variation in activity concentration for  $^{226}\text{Ra}$  was found to be 6.7% with the highest variation being 13.0%. It was therefore concluded that the homogeneity of the material was sufficient for conclusive determinations with respect to the exemption level based on one sample per drum for measured activity levels below 8 Bq/g. Additional sampling might be necessary for activity levels exceeding 8 Bq/g.

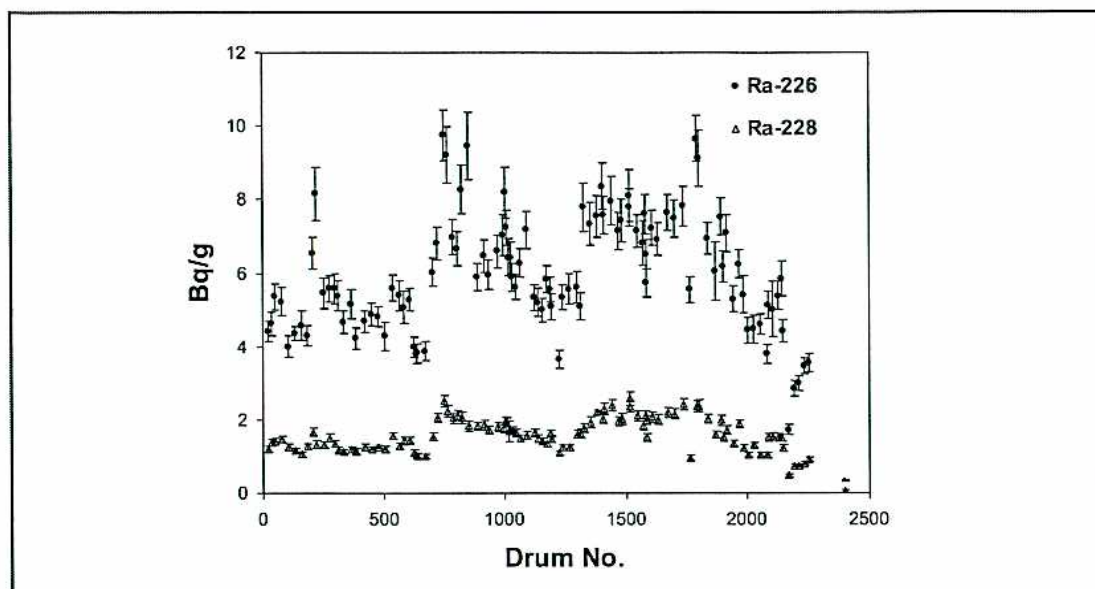


Figure 1. Specific activity of  $^{226}\text{Ra}$  and  $^{228}\text{Ra}$  vs. drum number. Results from Stage I.

Viewing the results as a function of drum number (Fig.1), there appeared to be three drum number intervals with activity concentrations that might exceed the exemption level. All drums in this region should therefore be sampled during Stage II. In all other regions it was not deemed necessary to sample and measure the activity concentration in each and every drum.

An action level of 8 Bq/g were proposed for the field measurements in Stage II. All samples exceeding this limit should be brought back to IFE for further measurements using high-resolution gamma spectrometry. Measurements above this action level from drums in expected low activity regions should lead to sampling of ten drums above and below.

## Stage II

### Sampling and measurements

The work in Stage II was performed according to recommendations given in Stage I. Samples were collected after the same procedure as in Stage I and packed in standard size plastic containers. Screening measurements of the sludge were carried out at site using a hand held monitor (NE Electra with a beta sensitive BP4-probe, Fig. 2). The measurements were made with a fixed geometry between the probe and the samples to ensure proper analytical quality. The instrumental set-up was calibrated using the results and the ratio between the two radium isotopes obtained in Stage I.

Each sample was measured for one minute and the background count rate automatically subtracted. The background count rate was measured

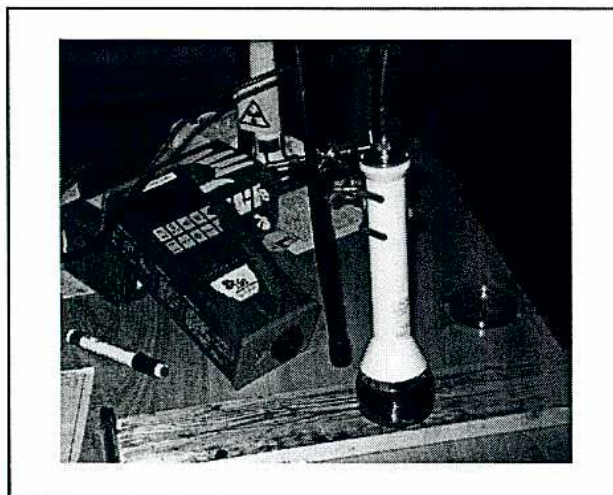


Figure 2. Experimental set-up at Vats.

regularly, and if it had changed significantly, a new background count rate was determined. All samples measured to have activity concentrations above 8 Bq/g were sent to IFE for possible re-measurement using high-resolution gamma spectrometry.

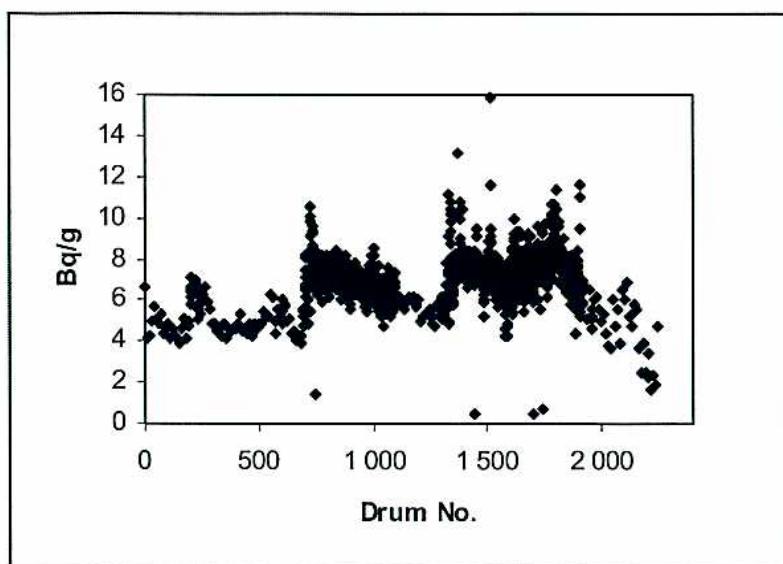
Assuming a reasonable correlation between the field measurements and the “true” values it was decided to analyse the samples brought back to IFE in batches with decreasing order of activity until no more samples within one batch were found to have activity concentrations exceeding the exemption level. The rest of the samples were then assumed to contain less than 10 Bq/g of  $^{226}\text{Ra}$ .  $^{226}\text{Ra}$  was analysed directly by its 186 keV gamma line and the results were corrected for self-absorption.

## Results and conclusions

A total of 1266 measurements were made at Vats (the results are shown in Fig. 3). Based on the screening measurements samples from 203 drums were found to have a  $^{226}\text{Ra}$  concentration above 8 Bq/g and consequently brought back to IFE. At IFE 164 samples, divided into six batches, were measured with high-resolution gamma spectrometry.

The criterion for selection of the drums with concentrations above the exemption level was defined to be: “Analytical value + total analytical uncertainty  $\geq 10$  Bq/g”.

Based on this criterion, a total of 44 drums were identified and classified as “above exemption level”-drums. These drums were shipped back to the UK. The mean  $^{226}\text{Ra}$ -activity concentration of all the sludge material was found to be  $6.0 \pm 0.6$  Bq/g.



**Figure 3.** Specific activity of  $^{226}\text{Ra}$  vs. drum number. Results based on fieldwork and measurements at Vats – Stage II

On average, each drum contained 230 kg of sludge (data from Wood-GMC AS). Total activity of  $^{226}\text{Ra}$  was then estimated as:

- Total  $^{226}\text{Ra}$  activity in all Brent Spar sludge:  $3.1 \pm 0.3$  GBq in 2268 drums
- $^{226}\text{Ra}$  activity in “above exemption level”-drums:  $0.10 \pm 0.01$  GBq in 44 drums
- $^{226}\text{Ra}$  activity in “below exemption level”-drums:  $3.0 \pm 0.3$  GBq in 2224 drums

There was good agreement between the results obtained in Stage I and the results from the screening measurements in Stage II. All “above exemption level”-drums identified in Stage II were found in the high activity regions identified in Stage I. Also the correlation between the field measurements and the “true” values were fairly good. The average discrepancy was about 8 %, with a maximum of 27.9%. Considering the simplicity of the method used in field, this must be regarded as a satisfactory result.

### Incineration process

The remaining 2224 drums were shipped to Sløvåg Industriservice AS for incineration. To obtain optimal conditions for combustion, the sludge was mixed with drill cuttings at a ratio of 1:9. An evaluation of the expected activity levels in exhaust gases, water and ashes had been made before the verification work began [8]. The radioactivity in the sludge was assumed to follow the solid fraction, and mixed with the drill cuttings the activity concentration in the ashes was expected to be in the range 2-6 Bq/g. The activity concentration in discharges to water and air were expected to be insignificant.

IFE was requested to carry out verification measurements during the incineration to ensure that the radioactivity levels were well within current regulations and within calculated levels for exhaust gases and water [8].

A sampling programme was set up covering the following sampling points: Coarse ash under incinerator, ash below the cooler outlet, ash from skimmer (auger), ash from main filter (auger), water from scrubber and offgas from stack. The external dose rate in the vicinity of the sampling points were measured using a Geiger counter of the type Automess AD5. In addition, contamination control, using an Electra contamination monitor, was performed along the transport route for the sludge. Two sampling rounds were performed the day before the incineration process began. The first day of incineration four sampling rounds were performed. A total of five visits were made during the incineration period, and two sampling rounds were performed at each visit. A final visit was made three weeks after the incineration period.

All samples were analysed using the same experimental set-up as described earlier. A selection of samples were analysed with high-resolution gamma spectrometry to establish a calibration factor for the measurements. At very low count rates, the uncertainty in the measurements would be substantial and a discrepancy between field and laboratory measurements was expected.

Analyses of the ash from the incineration showed activity concentrations well below the estimates given in [8], the highest concentration of  $^{226}\text{Ra}$  being approximately 2.5 Bq/g. Samples of water and offgas showed activity concentrations below or close to the detection limit for gamma spectrometry. Dose rate measurements in working areas in the vicinity of the sampling points did not reveal any increase from the background level measured before the incineration began.

It was concluded that incineration of sludge with activity concentrations below the exemption level is a well-suited method for disposal. The dose to personnel at the incineration facility will under normal circumstances be very low. Risk for intake, especially inhalation of dust having elevated activity levels, should however be observed.

## References

- [1] Varskog, P., Strålberg E. and Ramsøy, T., 1999. *Activity concentrations in drums containing sludge from Brent Spar. Results and assessments from Stage I*. Report: IFE/KR/F-99/138. Kjeller, Norway. 18 pp.

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- [2] Ramsøy, T., Strålberg E. and Varskog, P., 2001. *Classification, treatment and storage of low specific activity radioactive waste from the petroleum industry*. ICEM'01. The 8<sup>th</sup> international conference on radioactive waste management and environmental remediation, Bruges October 2001
- [3] Varskog, P., Strålberg E. and Juvik, B., 2000. *Activity concentrations in drums containing sludge from Brent Spar - Results and final assessment*. Report: IFE/KR/F-99/178. Kjeller, Norway. 48pp.
- [4] Ramsøy, T. and Strålberg, E., 2000. *Verification of incineration of low specific activity sludge from the Brent Spar*. Report: IFE/KR/F-2000/141. Kjeller, Norway. 25pp.
- [5] Norwegian Radiation Protection Authority, 1997. *Avleiringer av naturlig radioaktive stoffer i olje- og gassproduksjon*. Strålevernhefte 12. 25pp. (In Norwegian)
- [6] EU, 1996. *Council Directive 96/29/Euratom of 13 May 1996 laying down basic safety standards for the protection of the health of workers and the general public against the dangers arising from ionizing radiation*.
- [7] IAEA, 1994. *International Basic Safety Standards for Protection against Ionizing Radiation and for the safety of Radiation Sources*. Safety series No. 115-I
- [8] Østland, P. W. *Anleggbeskrivelse, Sløvåg Industriservice AS. Brenselvurdering, radioaktivitet, Sludge fra Brent Spar*. Industrimiljø, 2000-01-18 (In Norwegian)