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RISKS ASSOCIATED WITH DRILLING FLUIDS AT PETROLEUM DEVELOPMENT SITES IN THE OFFSHORE: EVALUATION OF THE POTENTIAL FOR AN ALIPHATIC HYDROCARBON BASED DRILLING FLUID TO PRODUCE SEDIMENTARY TOXICITY AND FOR BARITE TO BE ACUTELY TOXIC TO PLANKTON

by

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ABSTRACT

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An aliphatic hydrocarbon based drilling fluid, IPAR, is being used in the Newfoundland offshore. A number of studies were carried out over a three year period to assess its potential for producing sediment toxicity. Pilot studies were also carried out to assess the potential for barite and bentonite to produce false positives in the Microtox® assay as well as to assess the acute toxicity potential of barite for some representative marine organisms. Based on hydrocarbon concentrations found around the Hibernia and Terra Nova sites after extensive drilling, the results suggest that any significant sediment toxicity stemming from the use of IPAR type drilling fluids in the Grand Banks area of the Newfoundland offshore should be confined to a range of tens of meters from any cutting piles found in the immediate areas of rig sites. This viewpoint is based on the results of toxicity tests with Microtox®, amphipods and polychaetes, studies on the potential for IPAR to generate anaerobiosis in sediments and observations on IPAR weathering. Furthermore, results were obtained indicating that careful attention should be given to use of the Microtox® assay because of its potential for producing false positives in relation to grain size. Regarding the acute toxicity potential of barite, relatively high concentrations added to water were not toxic to capelin or snowcrab larvae or planktonic jellyfish after 24 hours of continuous exposure. No mortalities were also recorded for flounder force-fed relatively high concentrations of barite at weekly intervals over a period of one month.

RÉSUMÉ

Payne, J.F., Andrews, C., Guiney, J. and Whiteway, S. 2006. Risks associated with drilling fluids at petroleum development sites in the offshore: Evaluation of the potential for an aliphatic hydrocarbon based drilling fluid to produce sedimentary toxicity and for barite to be acutely toxic to plankton. Can. Tech. Rep. Fish. Aquat. Sci. 2679: 28 p.

Un fluide de forage basé sur l'hydrocarbure aliphatique, IPAR, est employé dàns Terre-Neuve, en mer. Plusieurs études ont été exécuté durant une période de trois ans pour évaluer son potential sur la toxicité des sédiments. Des études pilotes ont été aussi entreprises pour évaluer la toxicité aigue de la barytine et de la bentonite pour produire des faux positifs dans les analyses Microtox®, aussi bien que pour évaluer le potentiel de toxicité aigue de la barytine pour quelques organismes marins représentatifs. Basé sur les concentrations d'hydrocarbure trouvés autour des emplacements des sites de Terra Nova et d' Hibernia, les résultats suggérent que la toxicité due à l'utilisation d' IPAR dans la région des Grand Bank de Terre-Neuve en mer, devrait être confinée à une gamme des dizaines du métre de n' importe quelle coupe a eu des objections a trouvé dans le secteur immédiat de sites d'équipement. Ce point de vue est basé sur des résultats des éssais de toxicité avec des études de Microtox®, d'amphipodes et de polychétes sur le potentiel qu'IPAR produise de l'anaerobiose en sédiments ainsi que des observations sur la degradation d'IPAR. Il est a noté que les résultats obtenus ont aussi indiqué qu une attention particulière devrait être donne à l'utilisation de l'analyse de Microtox®, en raison du potentiel a produire des faux positifs associés à la taille de grains des sediments. Concernant le potentiel aigu de toxicité de la barytine, les concentrations relativement élevées ajoutées à l'eau n'étaient pas toxiques aux larves de capelan, de crabe de neige ou aux méduses planktonic après 24 heures d'exposition continue. Aucune morotalité n'a été également enregistrée chez les flétans exposé à des concentations relativement elevées de barytine par gavage et ce à intervalles hebdomadaires pendant un mois.

Introduction

From an economic or human standpoint, the major concern about oil development in the offshore is the potential for impacts on fish or the hindrance of fishing activities. However from a regulatory perspective under the habitat provisions of the Fisheries Act in Canada, attention is also given to the potential for impact or disturbance of the sea bed. Any small zones of sea-bed disturbance associated with oil development are obviously trivial compared with the disturbances caused by fishing, which on the basis of coverage of trawling and dragging activities (National Academy of Science 1983; GESAMP 1993; Veale et al. 2000; Watling et al. 2001; Wassenberg et al. 2002.) would be anticipated to be millions of fold greater over any general geographical area where oil exploration or development is taking place (Having said this, common sense is in order and it is difficult to see how fishing can be prosecuted without some disturbance to fish habitat). However, an argument can also be made that habitat disturbances caused by oil development (or other activities), however small, should come in for some attention due to a potential for the presence of contaminants.

Field studies in the North Sea and Gulf of Mexico indicate that effects on sedimentary benthic communities should be more or less localized around rig sites, with oil based cuttings (diesel or similar) probably being responsible for most of the effects. A study of 40 development and 300 single well sites in the North Sea where oil-based drilling muds were used to varying degrees, indicated major effects to be mostly confined to within 250-500 m of rig sites with subtle effects sometimes occurring out to 2000 m (GESAMP 1993). Subtle effects have also been reported at a distance of 4000-5000 m from a few development sites in the North Sea (Olsgard and Gray 1995). However, these development sites were notably quite large with diesel based drilling fluids being used to a considerable degree. In contrast to oil-based cuttings, more recent studies at sites where synthetic drilling muds were used indicate that effects are rarely seen outside 250-500 m (Frode Consulting 1999). Actually according to the data compiled in a number of reports (e.g. EPA 2000; Neff et al. 2000; Mathieu 2002; LGL 2003; Hurley and Ellis 2004) significant effects would rarely be expected to be seen beyond this range, except possibly in very shallow waters or waters with weak currents. Payne et al (1995) have also reported on the low chronic toxicity potential for fish of a synthetic alkane based drilling fluid used in the Arctic.

A synthetic based drilling fluid (IPAR) enriched in alkanes ($C_{10} - C_{21}$) is presently being used to some extent in the Newfoundland offshore. Toxicity studies carried out on scallops as well as selected studies with plankton and fish larvae, indicate a very low potential for acute toxicity (Cranford et al. 2000; Armsworthy et al. 2000; Payne et al. 2001a). This is supported by information on acute toxicity provided by industry (not reviewed here). Preliminary histopathological and biochemical studies carried out with snowcrab and lobster also indicate a similarly low potential for chronic toxicity (Andrews et al. 2004;

Hamoutene et al. 2004). Also, all three developers on the Grand Banks (Petro-Canada, Exxon-Mobil and Husky) have fairly extensive monitoring programs encompassing aspects related to fish health and tainting as well as sediment quality, and studies carried out to date around the Terra-Nova and Hibernia sites, where several wells have been drilled using IPAR, have not revealed any fish health, tainting, or habitat issues of concern (e.g. Jacques Whitford Environment Ltd. 2000; Jacques Whitford Environment Ltd. 2002; Deblois et al. 2005, Mathieu et al. 2005).

The present studies provide additional information for assessing risks associated with the use of isoalkane fluids such as IPAR and to a lesser extent, barite and bentonite in the Newfoundland offshore. General discussion of drilling muds and associated wastes can be found in Ray (1989) and Cranford et al (2001).

PURPOSE: EXPERIMENT 1

To assess dose-response relationships for levels of alkanes in medium to coarse sandy sediments and toxicity in three sediment bioassays – Microtox®, amphipods, polychaetes. Sediments were spiked with authentic drilling mud from Hibernia where IPAR was being used and weathered for 4 months before testing.

METHODS
PREPARATION OF MESOCOSM

Drill mud cuttings from the borehole were obtained from Hibernia Management and Development Company and were stored in a 20L bucket at 4°C until used. Concentrations of drill mud cuttings were prepared by mixing 0, 36, 110, 330, 1000 and 4000mL of drill mud cuttings per 54L of dry sand. Homogeneous mixtures were ensured by gradual addition and thorough mixing of small quantities of medium to coarse sand into the drill cuttings. Each concentration (referred to as E-0, E-36, E-110, E-330, E-1000 and E-4000) was transferred to six 200L tanks supplied with aerated seawater in a flow through system at the Ocean Science Centre's aquarium, Logy Bay, NL. Each tank was held under ambient temperature conditions (~ 0-5°C) from March 5, 1999 to June 17-29, 1999. At the end of the exposure study, five 125mL jars of sediment were taken from each tank and stored at –30°C until used. Sediment from three of the five 125mL jars were pooled and stirred 20 times with a solvent cleaned spatula. A sub-sample (450g to 650g) was removed for alkane analysis. A second sub-sample (100g) was taken from each pool for use in the Microtox® Large Sample Procedure (LSP). A further sediment sample (125mL) from each tank was taken for assessment in the marine polychaete bioassay. All samples were kept frozen until analysis. A 1L sediment sample was also taken from each tank at the end of the exposure study and used in the amphipod survival bioassay.

HYDROCARBON ANALYSIS

Analysis of diesel range alkanes (C10 to C19) was carried out by gas chromatography–mass spectrometry. A procedural blank, duplicate, spiked matrix and surrogate standards were run along with the samples to ensure quality assurance and quality control. The detection limit was ~1mg/kg.

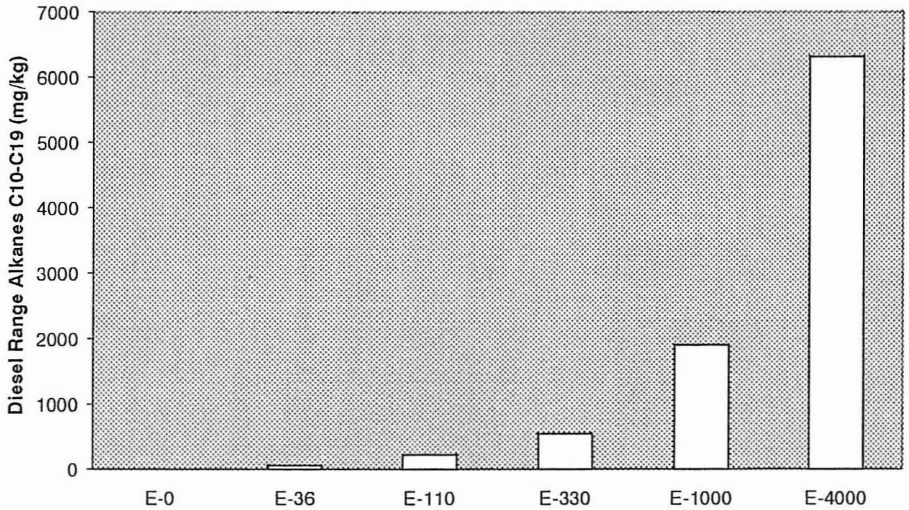


Figure 1. Diesel range alkanes (C10-C19) in Hibernia drilling mud sediment.

MICROTOX® BIOASSAY

The Microtox® Large Sample Procedure (Microbics 1992; Azur 1999) is based on suppression of the bioluminescence evolved by the marine bacterium *Vibrio fischeri* on exposure to toxicants. A sediment sample, 7.00 $\pm$ 0.004 g-wet-weight in 35.0mL of Solid Phase Test Diluent, was used to prepare a test concentration gradient up to 197000 mg-wet-weight/L. Two aliquots of the LSP primary dilution were tested simultaneously. Toxicity was expressed as the EC_{50} value, the effective concentration that induces 50% reduction of bioluminescence relative to test controls. The E-4000 descriptor which corresponds to an alkane concentration of 6300 mg/kg (Fig. 1), was the only sample that showed distinct toxicity (Fig. 2). EC50 values (>1000) are within the limits accepted by Environment Canada for the disposal of dredged sediment material (Tay et al. 1997).

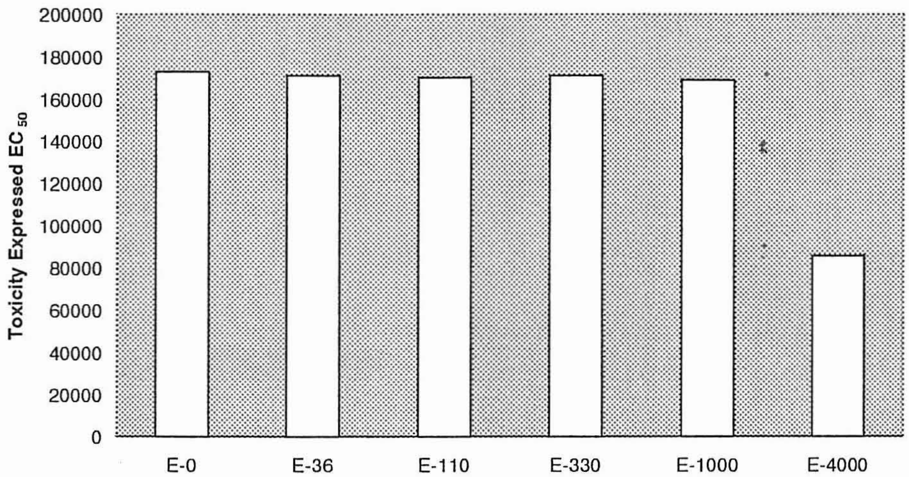


Figure 2. Microtox bioassay with Hibernia drilling mud.

AMPHIPOD BIOASSAY

Test conditions for the 10-day marine amphipod bioassay were followed according to the Biological Test Method: Reference Method for Determining Acute Lethality of Sediment to Marine or Estuarine Amphipods (Report EPS 1/RM/35 December 1998). All test parameters were maintained within the recommended level outlined in the protocol.

Amphipod, *Rhepoxynius abronius*, was obtained from Environmental Resolution Services – Whitby Island, Seattle Oregon, US. The bioassay was set-up using 175mL of sediment under static test conditions, in a temperature controlled water bath (15°C) aerated with 2-3 bubbles/s (90–100% saturation) for 10 days. Five trials were conducted for each concentration using 20 amphipods per trial. The endpoints were recorded as mean survival. As for Microtox®, the E-4000 exposure which corresponds to an alkane concentration of 6300 mg/kg was the only one that displayed distinct toxicity (Fig. 3) in relation to guidelines used by Environment Canada for ocean disposal, which is a decrease in amphipod survival of 20% or more (Porebski et al 1998).

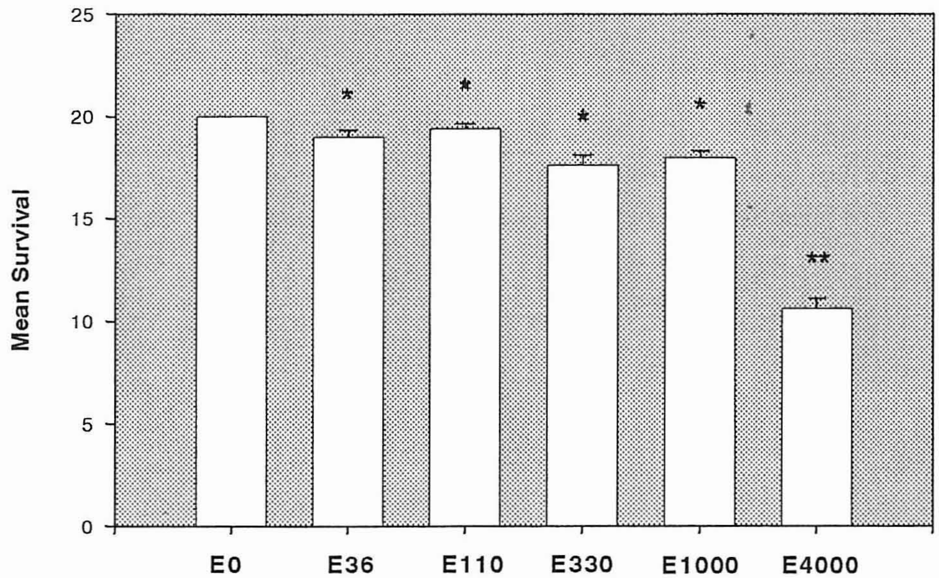


Figure 3. Amphipod survival with Hibernia drilling mud. Five trials using 20 amphipods per trial; Data reported as mean ± SE;
* Significantly different, P< 0.05 with the students T-test;
** Toxic in relation to guidelines used by Environment Canada.

MARINE POLYCHAETE BIOASSAY

The marine juvenile polychaete sediment bioassay was conducted using test organism *Neanthes arenaceodentata*, obtained from California State University, Long Beach, Ca. The bioassay was set-up using 175mL of sediment under static conditions, in a temperature controlled room (20°C), aerated for 20 days. Five trials were conducted for each concentration of Hibernia drill mud cuttings in sediment using 5 polychaetes per trial. Percent survival was not less than 96% in all concentrations tested. The endpoint was recorded as individual growth weight (mg/worm/day). There were no statistically significant differences between the control and the groups exposed to the cuttings (Fig. 4).

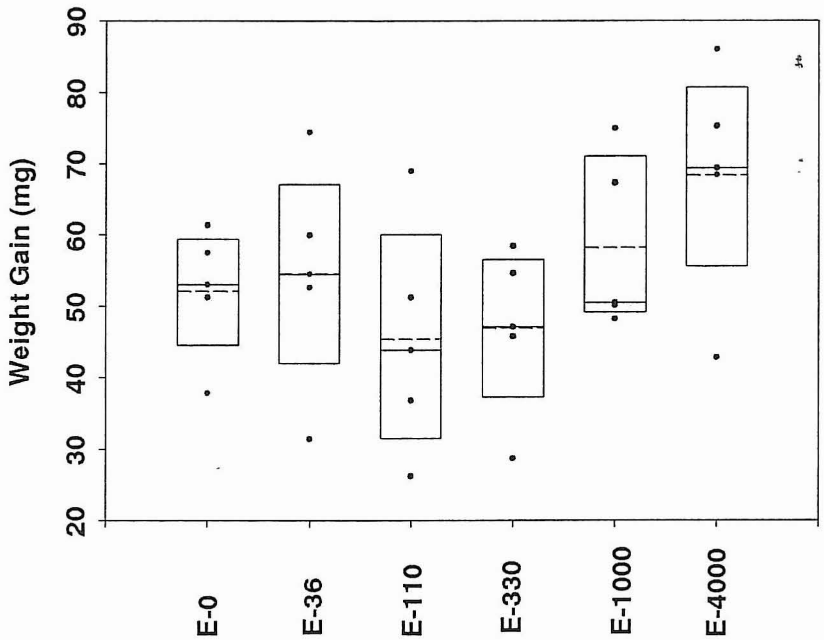


Figure 4. Polycheate weight gain bioassay with Hibernia drilling mud. Whisker Caps: 10th and 90th percentiles; Box: 25th – 75th percentiles; Short Dash Line: Mean; Solid Line: Median

CONCLUSION: EXPERIMENT 1

Microtox®, amphipod and polychaete bioassays are commonly used in sediment monitoring programs and are presently being used at some petroleum development sites off the east coast of Canada. Dose response relationships were derived for these monitoring surrogates in studies with Hibernia source cuttings containing an aliphatic hydrocarbon based synthetic fluid. The sediments were weathered for several months so as to "include" toxicity stemming from any degradation byproducts and possibly anaerobiosis. The toxicological studies indicate that IPAR based aliphatic hydrocarbons in sediment at a concentration around 6000mg/kg were toxic in the Microtox® and amphipod assays while even those relatively high concentrations did not adversely reduce polychaete growth. In the meantime hydrocarbon concentrations found in sediments around the Hibernia site after drilling around one-third of their projected number of wells, were indicated to be around 100mg/kg or less at 1000m (Jacques Whitford Environment Ltd. 2000; Payne et al. 2001b.) Thus any significant sediment toxicity directly linked to hydrocarbons from the use of IPAR type drilling fluid in the Newfoundland offshore, should be confined to a range of tens of meters from any cutting piles found in the immediate area of rig sites. This is also supported by monitoring studies at the Terra Nova site where concentrations of alkanes within 500-1000 meters of drill sites (Jacques Whitford Environment Ltd. 2002) were less than one-hundreth of the concentration required to effect toxicity in the Microtox® and amphipod bioassays, as noted here.

PURPOSE: EXPERIMENT 2

To assess the potential for toxicity generation in medium to coarse sandy sediments containing IPAR in relation to hydrocarbon concentration and sediment depth. The sediments were spiked with authentic drilling mud from Hibernia and weathered for a period of one year.

METHODS

PREPARATION OF SEDIMENT

Medium to coarse sand was collected from a beach in Placentia Bay and left to airdry. The concentration of alkanes in a sample of sand contaminated with a given amount of Hibernia drill cuttings was determined. Cuttings were then added to sand to give neat concentrations of diesel range alkanes as follows:

100ppm = 1.17mL/L	or	3.5mL/3L
300ppm = 3.53mL/L	or	10.5mL/3L
1000ppm = 11.75mL/L	or	35mL/3L
3000ppm = 35.24mL/L	or	105mL/3L

Small amounts of sand (approx. 50mL) were mixed with drill mud cuttings, gradually increasing to 3L of sand. Sand and cuttings were mixed in a 10L plastic bucket using a stainless steel spoon. The drill cuttings were measured using a plastic syringe (5mL for the 3.5mL/3L; 10mL + 5mL for the 10.5mL/3L; 3X10mL + 5mL for the 35mL/3L; and a graduated cylinder for the 105mL/3L.
The sand/drill cuttings were stored in 5L buckets at 4°C until used (1 day).

PREPARATION OF STEP MESOCOSM

Thirty tall Pyrex beakers were cut at 6 heights to accommodate 6 different sediment depths. Each was cut to be 2 cm higher than the surface of the sediment. The surface depths were: 1 cm, 2 cm, 4 cm, 8 cm, 12 cm, and 16 cm. Each jar was marked to indicate appropriate depth.

Each beaker was filled with 5 concentrations (0, 100, 300, 1000, 3000 ppm) of the drill mud sediment. For each of the 5 concentrations there were 6 different depths (1 cm, 2 cm, 4 cm, 8 cm, 12 cm and 16 cm.) Thirty beakers were used. The jars were secured in a rack and placed in an aquarium at ambient seawater temperature. The seawater inlet into the tank was split so that water ran on both sides of the bottom of the mesocosm.

The configuration of the set-up was as follows:

Depths in beakers, Orientation in tank						Concentrations
1	2	4	8	12	16 cm	0ppm
16	12	8	4	2	1 cm	100ppm
1	2	4	8	12	16 cm	300ppm
16	12	8	4	2	1 cm	1000ppm
1	2	4	8	12	16 cm	3000ppm
DRAIN				SEAWATER INLET		

A thermograph set to record temperatures every 6 hrs was placed in the mesocosm. Upon weathering for one year, sediments were assessed for hydrocarbon loss as well as toxicity in the Microtox® assay. A profile of ambient water temperature over the 1 year period is provided in the Appendix.

RESULTS

Results of measurements on hydrocarbon loss, sediment toxicity and porewater toxicity are given in Figs. 5, 6 and 7 respectively.

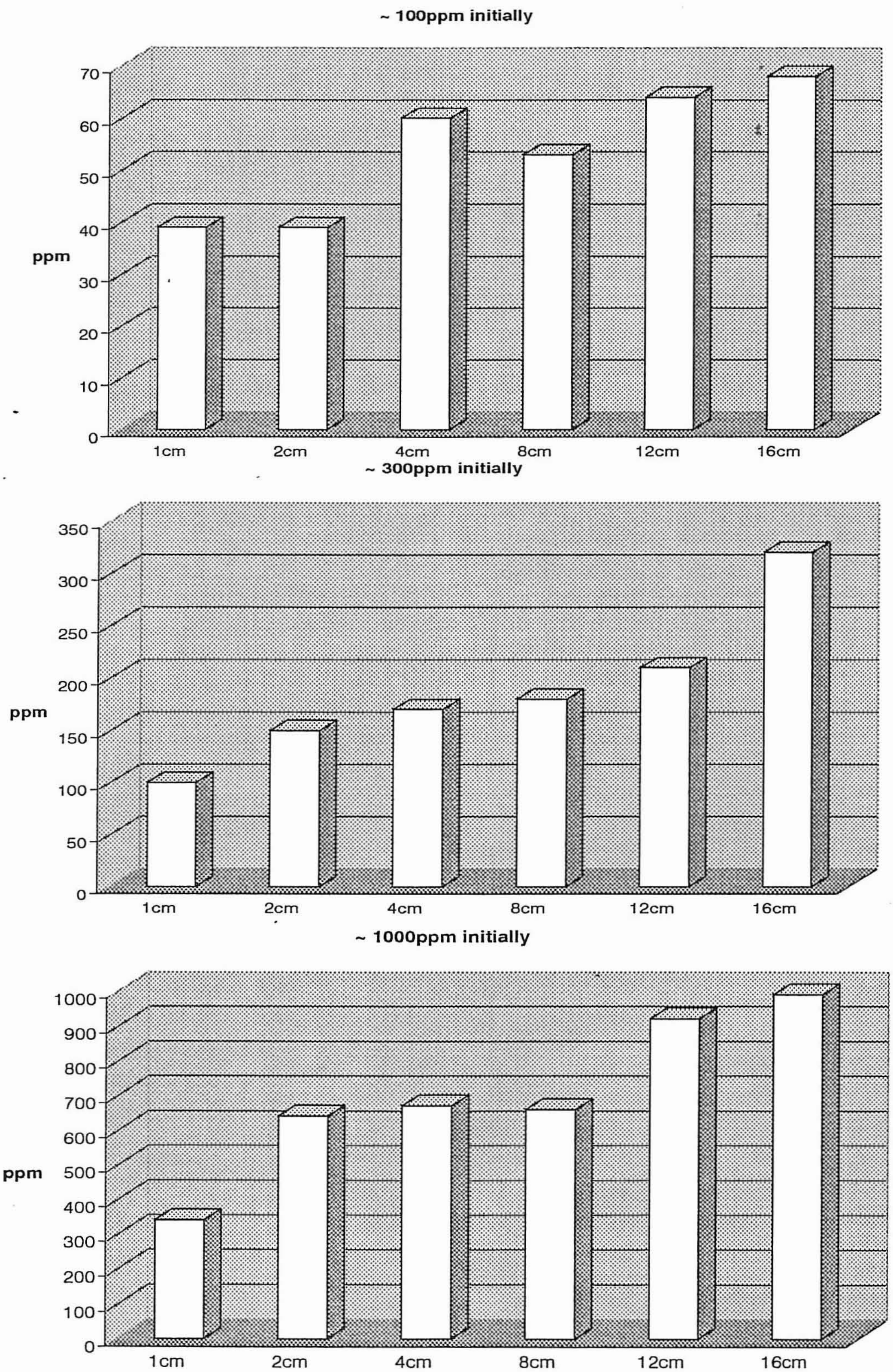


Figure 5. Loss of fuel range alkanes from sediments contaminated with Hibernia drilling mud containing IPAR in relation to sediment depth and hydrocarbon concentrations after a weathering period of one year.

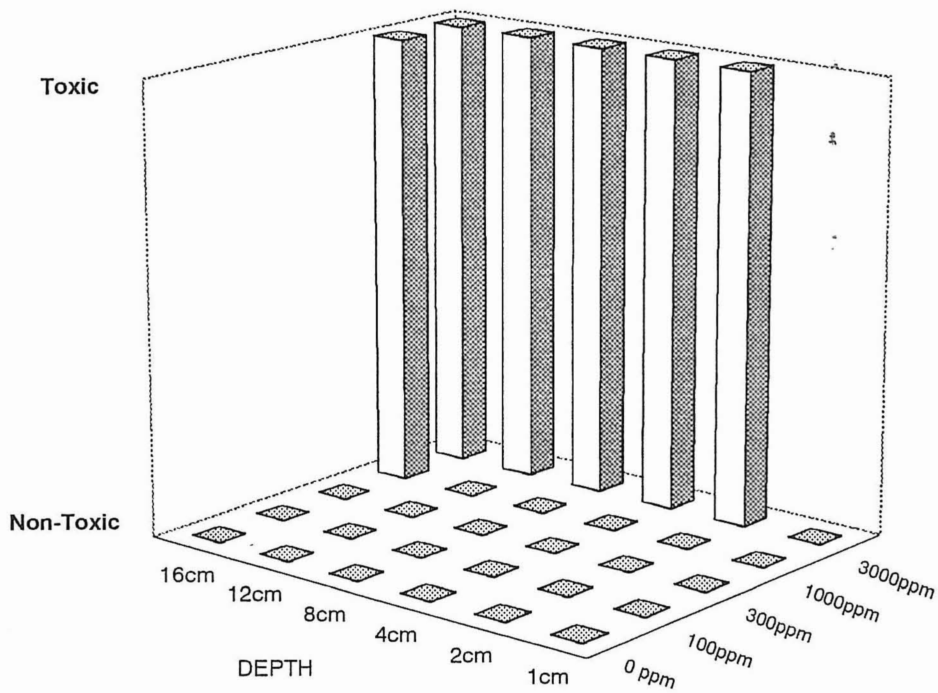


Figure 6. Microtox test on weathered sediments contaminated with Hibernia drilling mud containing IPAR. Study considered sediment depth as well as hydrocarbon concentration.

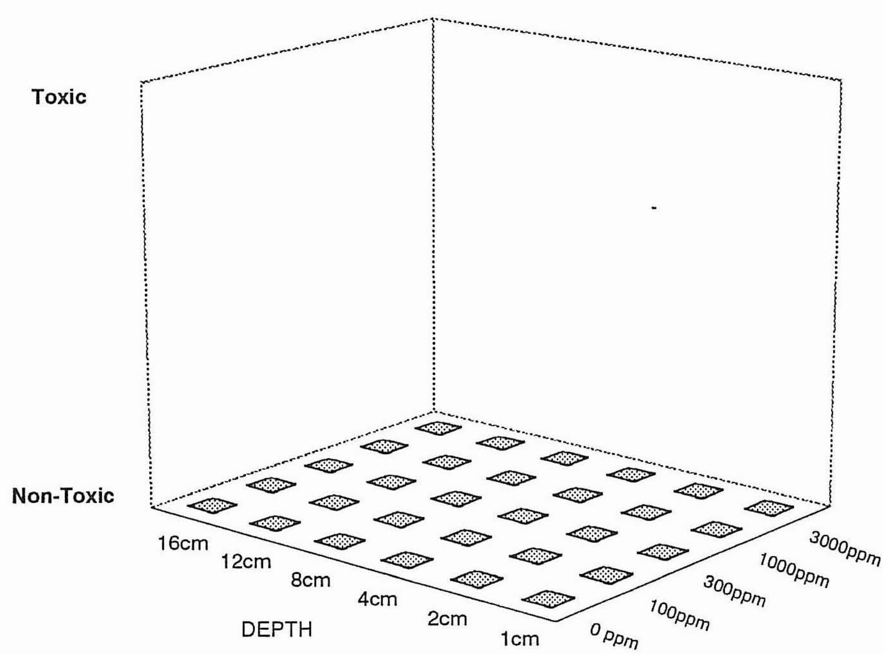


Figure 7. Microtox tests on pore water from weathered sediments contaminated with Hibernia drilling mud containing IPAR. Study considered sediment depth as well as hydrocarbon concentration.

CONCLUSION: EXPERIMENT 2

Pore water was non-toxic in the Microtox® test at any sediment depth or hydrocarbon concentration after a year of weathering. Distinct toxicity was observed in the solid phase test at concentrations of diesel range hydrocarbons (IPAR) in the 3000ppm range and sediment depths of 2, 4, 8, 12 and 16 cm. This further supports the hypothesis that any significant sediment toxicity stemming from use of IPAR type fluids should be confined to a range of tens of meters from any cutting piles found in the immediate are of rig sites in the Newfoundland offshore.

PURPOSE: EXPERIMENT 3

To assess the potential of IPAR to generate anaerobic conditions in medium to coarse sediments over a 12 month period in relation to hydrocarbon concentration.

METHODS

Cuttings were added to seven liter portions of sandt to give neat hydrocarbon concentrations as follows: 0ppm, 100ppm, 300ppm, 1000ppm, 3000ppm. Five ten-liter aquaria were filled with sediment and immersed into a flow-through aquarium for 12 months. Redox potentials were assessed after varying periods of sediment weathering. Measurements of "naturally occurring" redox potentials were also taken from intertidal sediments at sites in Manuels, Carbonear and Harbour Grace.

RESULTS

Redox potentials found in sediments after weathering for 12 months are noted in Fig. 8 while the generation of anaerobic conditions as expressed through darkening from sulfides is presented pictorially in Fig. 9. The common occurrence of sedimentary anaerobic conditions in the natural environment is also noted for perspective in Fig. 10.

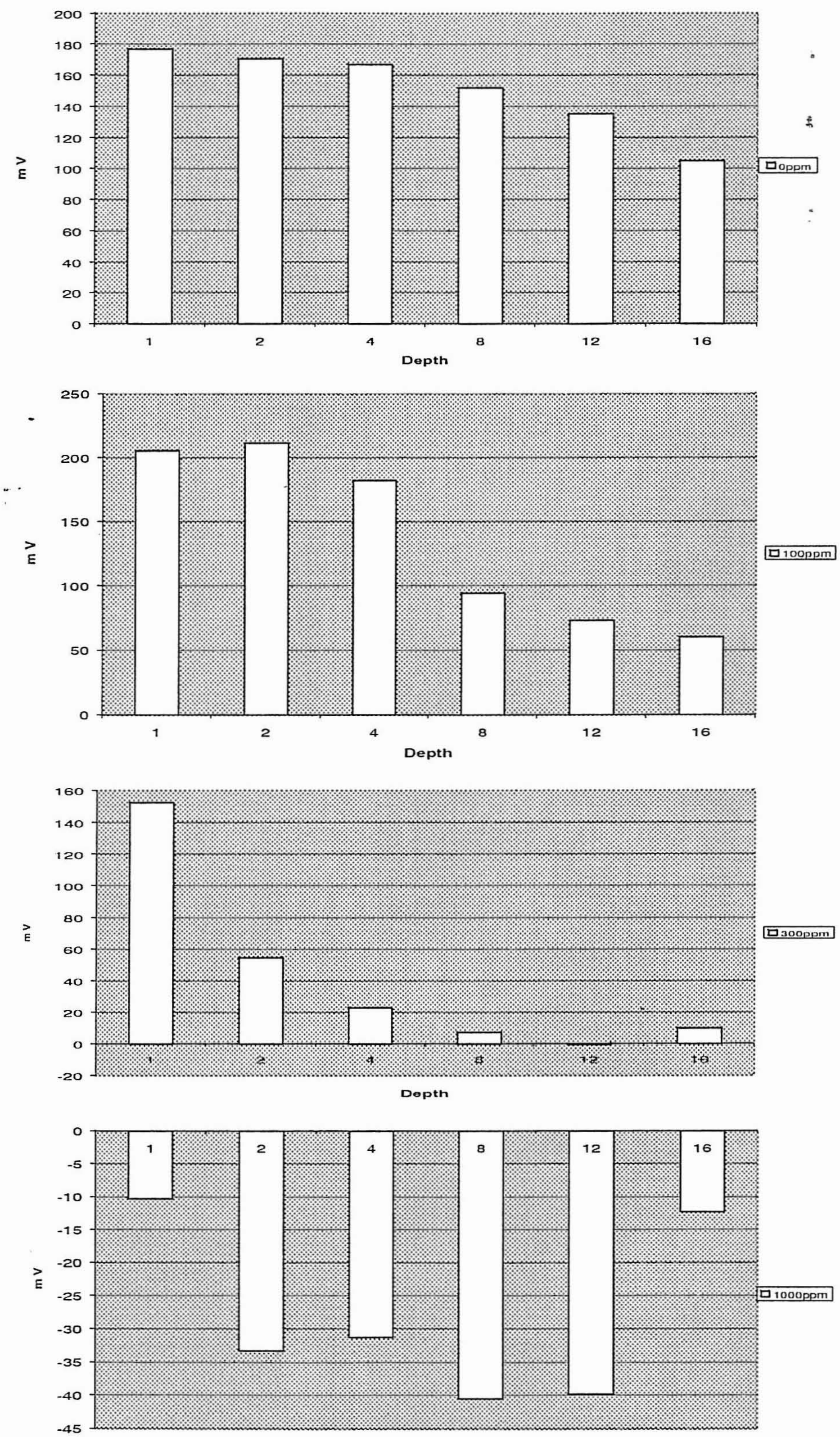


Figure 8. Redox potential of water taken at various depths in mesocosm upon weathering for 12 months.

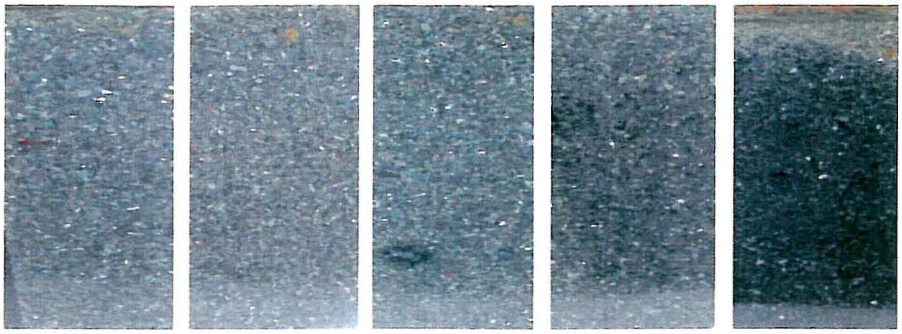
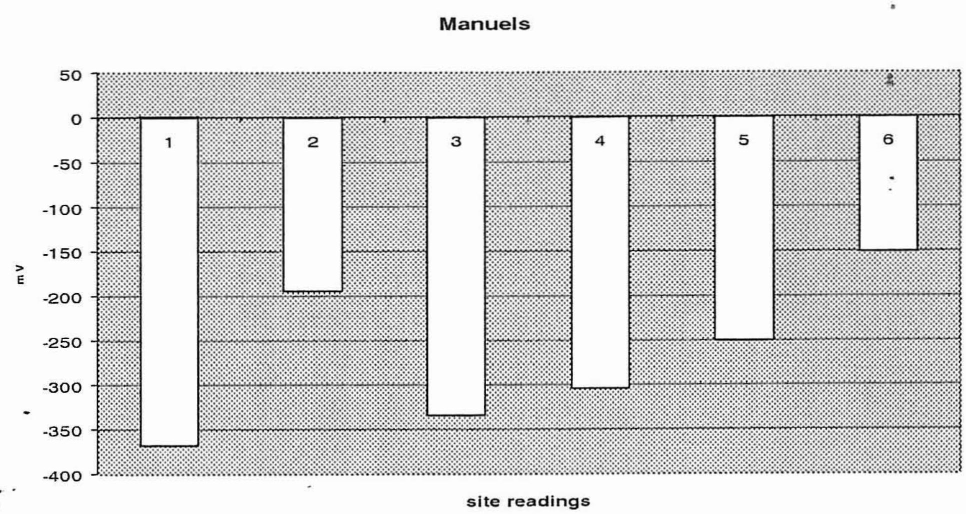
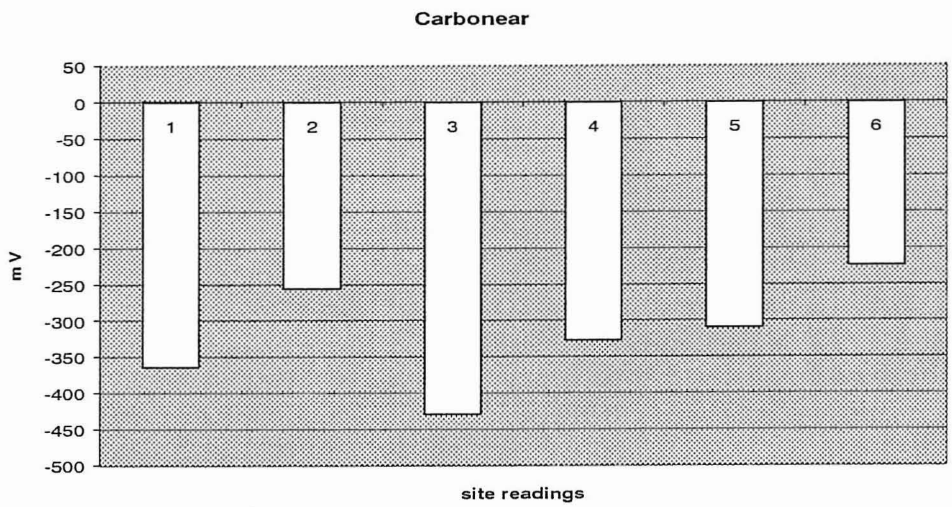


Figure 9. Visualization of anaerobic conditions in sediment (darkening from sulfides) upon weathering for 12 months.





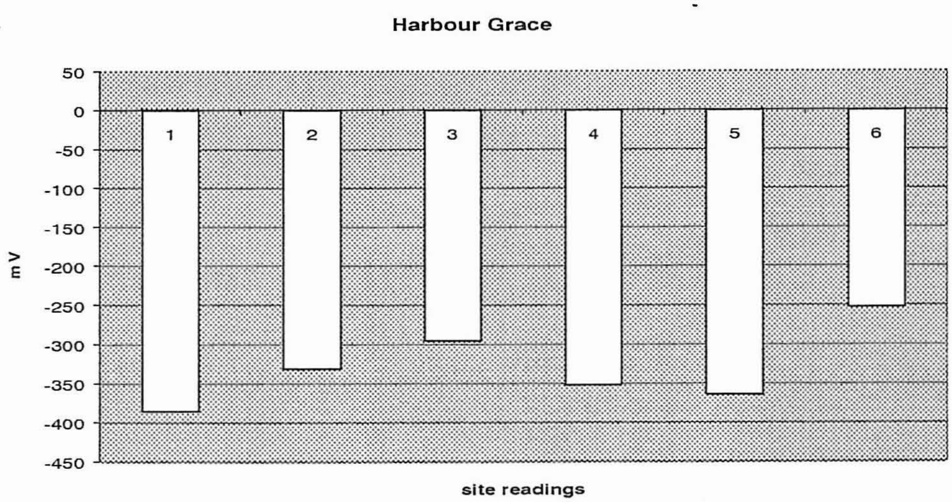


Figure 10. Notation (for perspective) on anaerobic conditions normally associated with sandy/silty sediments in the natural environment: redox results from 3 sites on the Avalon Peninsula, Newfoundland. The bars represent individual readings.

CONCLUSION: EXPERIMENT 3

Distinct anaerobic conditions as determined by negative redox potentials did not occur after a year of weathering until concentrations of diesel range hydrocarbons (from IPAR) in sediments reached the 1000ppm range. This study provides a guideline for linking any major change in benthic communities around rig sites to the presence of hydrocarbons from IPAR type fluids. Given hydrocarbon concentrations found around rig sites after extensive drilling, it can be deduced as for tests on sediment toxicity, that any major changes in sediment communities stemming from use of IPAR type fluids in the Newfoundland offshore should be quite confined around rig sites. Also noted from studies at a few coastal marine sites is the common occurrence of negative redox potentials in sediments in the natural environment.

PURPOSE: EXPERIMENT 4

To assess hydrocarbon loss over several months in sandy/silty sediments spiked with IPAR.

METHODS

Intertidal sediment consisting of a mixture of fine sand and silt was collected at a site in Placentia Bay on March 6/03. Sediment was added to two rectangular mesocosms (30cm x 18cm x 5cm) to a depth of 2cm and they were stored at 4°C overnight. On March 7/03, 5 ml of IPAR-IA-35 was added to one of the mesocosms and the other mesocosm served as a control. Care was taken to ensure full homogeneity while mixing the sediment with the IPAR. The two mesocosms were then placed in a 180L flow through tank at the NWAFC aquarium facility, and the same afternoon, a ¼ section was taken and placed in the freezer in the lab. On July 28/03, silt was removed from the surface of the mesocosm by swirling the water immediately above and sweeping it to the side. On July 30/03 a "fresh" edge was formed by cutting away the sloped exposed edge. Another ¼ section was removed for alkane analysis and grain size. On October 15/03, silt was removed from the surface as above. Silt was removed one final time on April 23/04 and the mesocosms were taken down for Microtox® and alkane analysis.

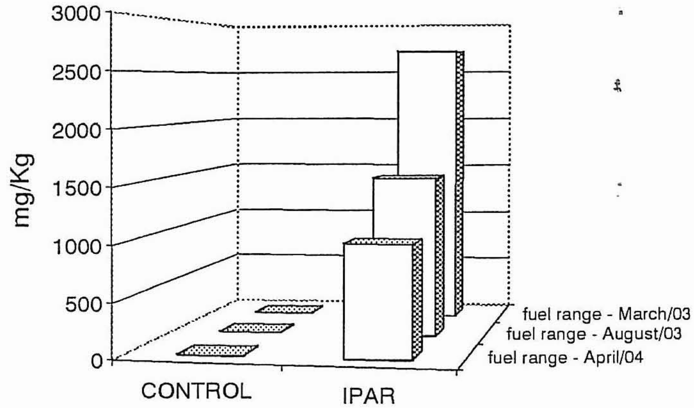


Figure 11. Mesocosm comparing loss of fuel range alkanes after weathering periods of 5 and 12 months.

RESULTS

Loss of hydrocarbons from silty/sandy sediments after a year of weathering are noted in Fig. 11.

CONCLUSIONS: EXPERIMENT 4

IPAR can be expected to effectively degrade in sandy/silty sediments but likely not at a rate which would produce substantial anaerobiosis and sediment toxicity. Any substantial anaerobiosis resulting in sediment toxicity could generate attention under the habitat provisions of the Fisheries Act.

PURPOSE: EXPERIMENT 5

To assess the comparative potential between IPAR and an ester based drilling fluid, Ecogreen®, to generate toxicity in sandy sediments.

METHODS

On March 13, 2003, two L of fine sand was mixed with 5mL of IPAR IA-35 along with 250mL of "seed" (a mixture of silt from an aquarium at DFO and an intertidal sediment from Placentia Bay). The mixture was then halved and added to a1.5L cylinder up to a volume of 1L. The same procedure was followed for Ecogreen® and a control. All three samples were prepared in duplicate and the cylinders were placed in a 180L flow through aquarium. The experiment was terminated on Aug 5/03 and the sediments were assessed with the Microtox® test.

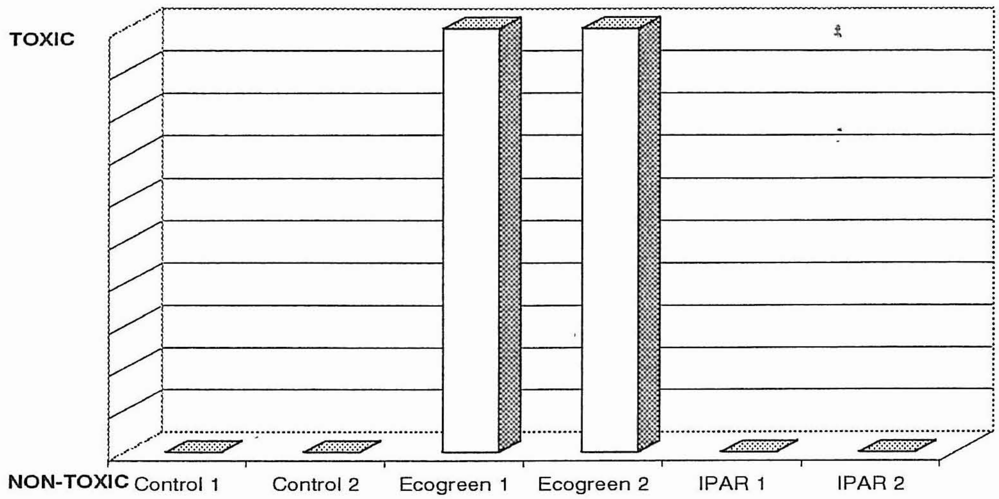


Figure 12. Microtox test on sediments spiked with either IPAR or Ecogreen and weathered for 3 months.

RESULTS

The results of the Microtox® assays are noted in Fig. 12.

CONCLUSION: EXPERIMENT 5

Ester based drilling fluids such as Ecogreen® have the potential to generate higher levels of sediment toxicity than alkane based fluids such as IPAR. Thus, although ester based fluids will degrade faster, they may possess greater potential for habitat alteration, albeit more or less in the immediate area of rig sites.

PURPOSE: EXPERIMENT 6

To assess the potential for barite and bentonite to produce "false" positives in the Microtox® assay.

METHODS

Barite or bentonite were added to fine or coarse sand to give the following percentages by weight: 0% (control), 1%, 3%, 5%, 7% and 15%. Saltwater was added to wet the sediments which were then assessed in the Microtox® assay.

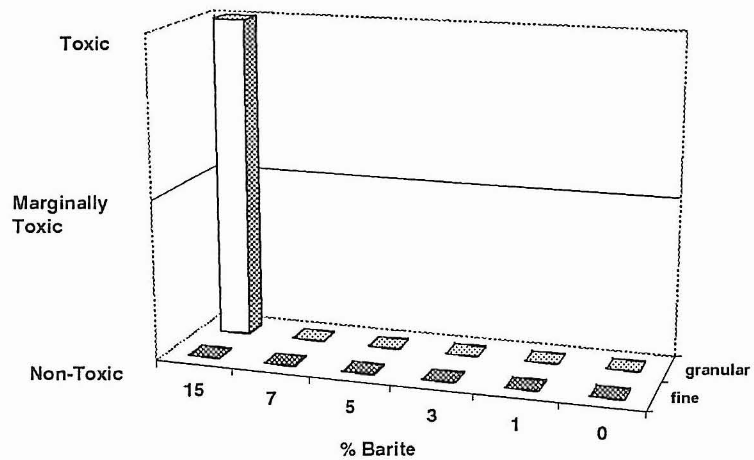


Figure 13. Microtox test with Barite.

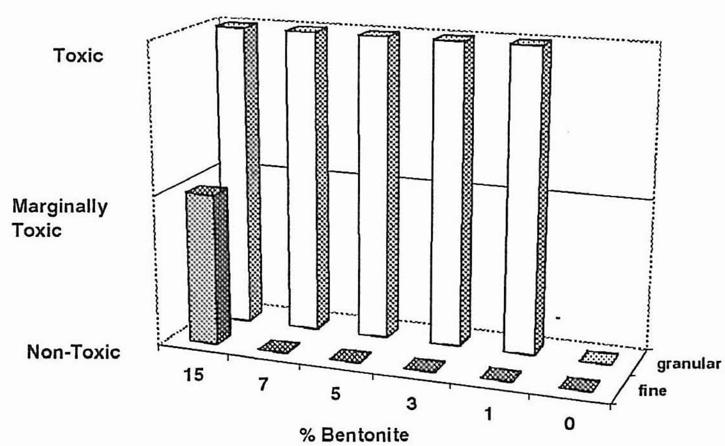


Figure 14. Microtox test with Bentonite.

RESULTS

The results of the Microtox® assays on barite and bentonite are noted in Figs. 13 and 14 respectively.

CONCLUSION: EXPERIMENT 6

Bentonite has considerable potential to provide "false" positives of a "physical toxicity" nature in the Microtox® assay with grain size providing an additional confounding factor. Thus considerable care is warranted when interpreting the results of Microtox® studies on sediments around rig sites. Many naturally occurring fine grain sediments in general can also be expected to be "toxic" in the Microtox® assay.

PURPOSE: EXPERIMENT 7

To assess the potential for acute toxicity in capelin larvae, snowcrab larvae, planktonic jellyfish and flounder exposed to high concentrations of barite.

METHODS

Capelin larvae were exposed to a turbid mixture of 200 mg/L of barite for 24 hrs while snowcrab lavae and planktonic jellyfish were exposed to turbid mixtures of 1000mg/L for 24 hrs. Winter flounder (*Pleuronectes americanus*) weighing approximately 300g were force fed 1000mg of barite on 4 occasions over a period of one month.

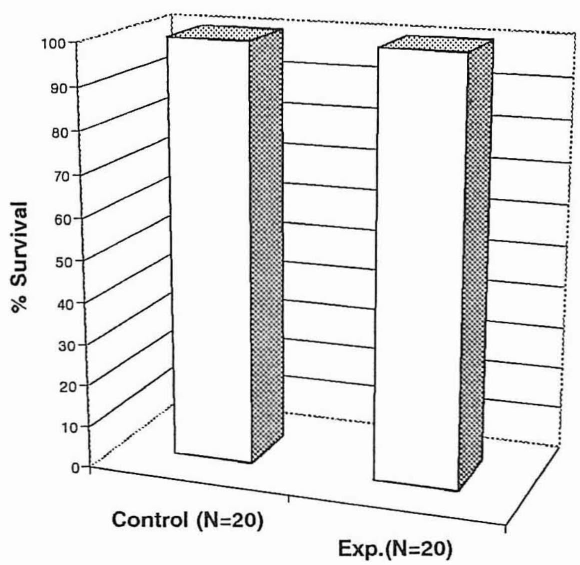


Figure 15. Acute toxicity of barite to capelin larvae. Larvae were exposed to a turbid mixture of 200mg/L of barite for 24 hrs.

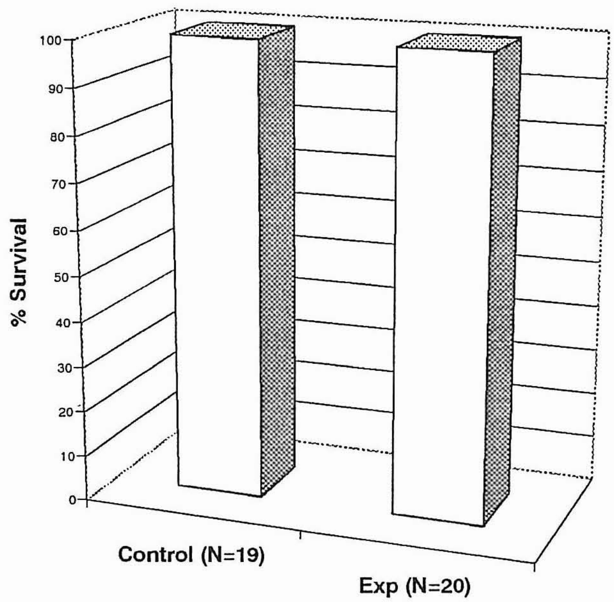


Figure 16. Acute toxicity of barite to snowcrab larvae. Larvae were exposed to a turbid mixture of 1000mg/L of barite for 24 hrs. Also 100% survival in an exposure with 2000mg/L.

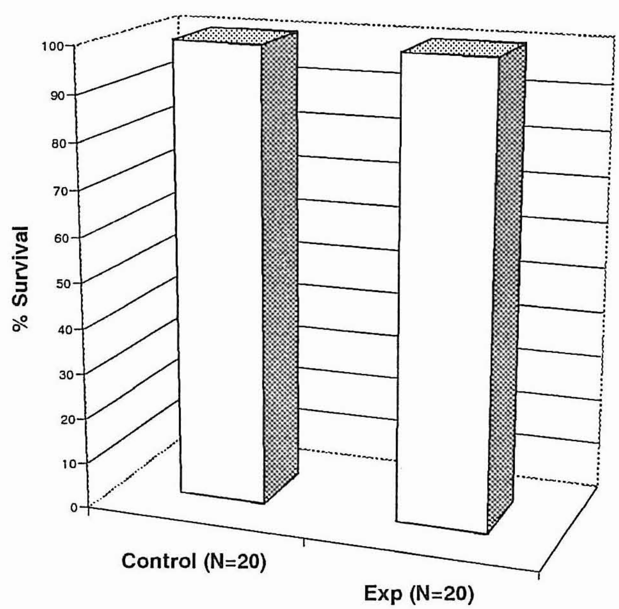


Figure 17. Acute toxicity of barite to planktonic jellyfish. Jellyfish were exposed to a turbid mixture of 1000mg/L of barite for 24 hrs.

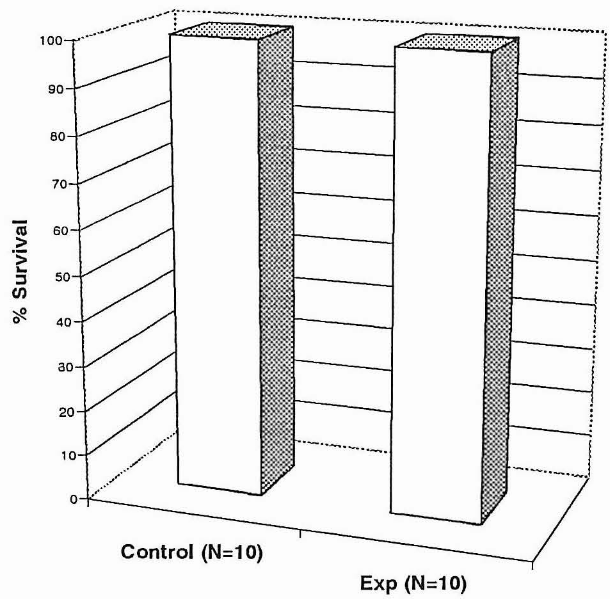


Figure 18. Acute toxicity of barite to winter flounder. Flounder (weighing approximately 300g) were force fed 1000mg of barite on 4 occasions over a period of one month.

RESULTS

The results of the 24 h acute toxicity bioassays with various species are noted in Fig. 15-18.

CONCLUSION: EXPERIMENT 7

Barite is often the primary discharge of interest in association with exploratory drilling. Representative organisms were exposed to particulate barite at relatively high concentrations and exposure times which might occasionally occur in the immediate area of some drilling sites. Results, as displayed in the accompanying figures, generally indicated a negligible acute toxicity potential for the various species studied including capelin and snowcrab larvae, as well as planktonic jelly fish and flounder.

SUMMARY AND CONCLUSIONS

For clarity the purpose and resulting conclusion for each study is summarized:

- To assess dose-response relationships for levels of alkanes in medium to coarse sandy sediments and toxicity in three sediment bioassays – Microtox®, amphipods, polychaetes. Sediments were spiked with authentic drilling mud from Hibernia where IPAR was being used and weathered for 4 months, before testing.

  Conclusion: Microtox®, amphipod and polychaete bioassays are commonly used in sediment monitoring programs and are presently being used at some petroleum development sites on the east coast of Canada. Dose response relationships were derived for these monitoring surrogates in studies with Hibernia source cuttings containing an aliphatic hydrocarbon based synthetic fluid. The sediments were weathered for several months so as to "include" toxicity stemming from any degradation byproducts and possibly anaerobiosis. Given hydrocarbon concentrations presently found around rig sites after extensive drilling, any significant sediment toxicity directly linked to hydrocarbons from use of IPAR type drilling fluid in the Newfoundland offshore, should be confined to a range of tens of meters from any cutting piles found in the immediate area of rig sites.

- To assess the potential for toxicity generation in medium to coarse sandy sediments containing IPAR in relation to hydrocarbon concentration and sediment depth. The sediments were spiked with authentic drilling mud from Hibernia and weathered for a period of one year.

  Conclusion: Pore water was non-toxic in the Microtox® test at all sediment depths and hydrocarbon concentrations after a year of weathering. Distinct toxicity was observed in the solid phase test at concentrations of diesel range hydrocarbons (from IPAR) in the 3000ppm range and sediment depths of 2, 4, 8, 12 and 16cm. This further supports the hypothesis that any significant sediment toxicity stemming from use of IPAR type fluids should be confined to a range of tens of meters from any cutting piles found in the immediate are of rig sites.

- To assess the potential of IPAR to generate anaerobic conditions in sediments over a 12 month period in relation to hydrocarbon concentration.

  Conclusion: Distinct anaerobic conditions as determined by negative redox potentials did not occur after a year of weathering until concentrations of diesel range hydrocarbons (from IPAR) in sediments reached the 1000ppm range. This study provides a guideline for linking any major change in benthic communities around rig sites to the presence of hydrocarbons from IPAR type fluids. Given hydrocarbon concentrations found around rig sites after extensive drilling, it can be deduced as for tests on sediment toxicity, that any major changes in sediment communities stemming from use of IPAR type fluids in the Newfoundland offshore should be quite confined around rig sites. Also noted from studies at a few coastal marine sites is the common occurrence of negative redox potentials in sediments in the natural environment.

- To assess hydrocarbon loss over several months in sandy/silty sediments spiked with IPAR.

  <u>Conclusion:</u> IPAR can be expected to effectively degrade in sandy/silty sediments but likely not at a rate which would produce substantial anaerobiosis and sediment toxicity. Any substantial anaerobiosis resulting in sediment toxicity could generate attention under the habitat provisions of the Fisheries Act.

- To assess the comparative potential for IPAR and Ecogreen®, an ester based drilling fluid, to generate toxicity in sandy sediments.

  <u>Conclusion:</u> Ester based drilling fluids such as Ecogreen® have the potential to generate higher levels of sediment toxicity than alkane based fluids such as IPAR. Thus, although ester based fluids will degrade faster, they may possess greater potential for habitat alteration, albeit more or less in the immediate area of rig sites.

- To assess the potential for barite and bentonite to produce "false" positives in the Microtox® assay.

  <u>Conclusion:</u> Bentonite has considerable potential to provide "false" positives of a "physical toxicity" nature in the Microtox® assay with grain size providing an additional confounding factor. Thus considerable care is warranted when interpreting the results of Microtox® studies on sediments around rig sites. Many naturally occurring fine grain sediments in general can also be expected to be "toxic" in the Microtox® assay.

- To assess the potential for acute toxicity in capelin larvae, snowcrab larvae, planktonic jellyfish and flounder exposed to high concentrations of barite.

  <u>Conclusion:</u> Barite is often the primary discharge of interest in association with exploratory drilling. Representative organisms were exposed to particulate barite at relatively high concentrations and exposure times which might occasionally occur in the immediate area of some drilling sites. Results generally indicated a negligible acute toxicity potential for

the various species studied including capelin and snowcrab larvae, as well as planktonic jelly fish and flounder.

In summary, various types of synthetic drilling fluids are increasingly being used by the oil industry in different geographical regions. A number of studies are provided which will be of interest for assessing risks associated with the use of isoalkane based drilling fluids in the Newfoundland offshore. Information is also provided for assessing the acute toxicity potential of barite for selected planktonic species of ecological or commercial importance.

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APPENDIX

Water temperature from mesocosm experiment.