EL1043514E

TD
899
P4
M33
1984
c.2

DEPARTMENT OF THE ENVIRONMENT
ENVIRONMENTAL PROTECTION SERVICE
PACIFIC REGION

REVIEW OF EFFECTS OF DRILLING FLUIDS AND CUTTINGS ON MARINE ORGANISMS

By

S. Madill

June 1984

LIBRARY
ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
PACIFIC REGION

1008

DRILLING FLUIDS AND CUTTINGS

INTRODUCTION

Oil exploration has increased dramatically over the last decade. Along with this comes an increase in the potential amount of environmental disturbance. While the effects that oil rigs and crude oil have on marine life have been studied for some time only recently was research focussed on the effects that exploratory drilling has on marine communities. Drilling fluids contain high concentrations of many heavy metals and oil products. The exact composition of these fluids (or "muds") varies with each "brand" name, but they all contain basically the same components (Table 1). Of these, chromium is one of the major constituents, and therefore of greatest concern. The cuttings left from drilling may also have environmental effects upon the benthic community due to large amounts of shattered and pulverized sediments and underlying native rock covering the ocean floor.

This report is a summary of findings from studies on effects of drilling fluid and cuttings on the marine environment and on sublethal effects of the various constituent of the fluid.

TABLE 1 COMPONENTS OF DRILLING MUDS WHICH ARE NORMALLY DISCHARGED INTO THE SEA

SUBSTANCE	SOURCE	USE	COMPOSITION	KNOWN HAZARD
Attapulgite clay	Quarry	To cause gelling of salt water based muds	A light green magnesium - - rich clay, quarried as "Fuller Earth"	None
Bentonite clay	Quarry	To cause gelling of freshwater based muds	A light-colored montmorill-onitic clay; slippery sticky when wet; swells to 10-20 times its dry volume	None
Caustic soda	Electrolysis of sodium chloride brine	For pH control	Sodium hydroxide, NaOH	Corrosive in concentrated form; not harmful after mixing into mud at low concentration and allowed to react
Ferrochrome lignosulfonate	Digestion of wood by sulfonate process removal of cellulose; reaction with chromium compounds	Dispersant and emulsifier	Ferrochrome salt of ligno-sulfonic acid; content: Fe-2.6%, Cr-3.0%, S-5.5%	Possible chromium toxicity in pure form, none known from diluted from in muds
Organic polymer	Chemical processes with plant starch, wood fiber as raw materials	Conditioner, texturizer	Starch, cellulosic derivatives	None
Proprietary defoamer	Soap making process	Defoamer	Aluminum stearate $Al[Ch_3(CH_2)16]3$	None

Continued...

TABLE 1 COMPONENTS OF DRILLING MUDS WHICH ARE NORMALLY DISCHARGED INTO THE SEA (Continued)

SUBSTANCE	SOURCE	USE	COMPOSITION	KNOWN HAZARD
Barite	Mined as the mineral	Weighing agent	Barium sulfate $BaSO_4$	It is recommended that public water supplies contain no more than 1 mg/l barium
Gypsum (Plaster of Paris)	Mined as the mineral	Flocculant and calcium source	Calcium sulfate $CaSO_4.2H_2O$	Potentially hazardous
Tennin	Extracted from the Quebracho tree	Thinning agent	Complex organic compound, $5(C_{14}H_9O_9).C_6H_7O$	None
Carboxymethyl cellulose	From stalks and stems of plants	Fluid loss agent	Complex organic polymer	Potentially hazardous
Sodium acid pyrophosphate	Reaction of sodium with pyrophosphoric acid	Thinning agent	$Na_2H_2P_2O_7$	None
Siderite	Mined as the mineral	Weighing agent	$FeCO_3$	None
Formaldehyde	Oxidation of methanol	Bactericide	HCHO	Potentially hazardous
Penta chlorophenol	Reaction of hexachlorobenzene with sodium hydroxide	Bactericide	C_6CI_5OH	Potentially hazardous
Potassium chloride	Mined as the mineral sylvite in carnallite	Flocculant	Potassium chloride KCl	None
Sodium bicarbonate	Passils carbon dioxide thru a solution of normal carbonate	Precipitate soluble calcium, pH control	$NaHCO_3$	None

Source: Rogers (1963), Robichaux (1975), Land (1974), USDI (1975c,d,i).

SUBLETHAL EFFECTS OF DRILLING FLUIDS AND CUTTINGS ON MARINE ORGANISMS

General Conditions

1. No significant change in benthic communities due to effects of drilling operations (Lees and Haughton, 1980; Houghton et al, 1980).

2. No inhibition of 1° productivity, as measured by ^{14}C uptake in phytoplankton occurred in the mud discharge plume (Thomas, 1979).

3. No mortalities were recorded that could be related to the discharge plume (Houghton et al, 1980).

4. No correlation between metal levels in sediment and levels in infaunal organisms (Cripper and Hood, 1980; Menzie, 1980).

5. Fish (hake) and crab (*C. borealis*) population increase due to sedimentation (Menzie, 1980).

Test Results

1. Drilling fluids moderately toxic to mysids at 30-100 ppm. Oyster growth decreased, lugworm survival decreased. Colonizing polychaetes excluded in aquaria containing 100 ppm drilling fluids (Rubinstein, 1980).

2. Annelids sensitive to drilling muds and barite. Molluscs particularily affected by chloro-phenol-type biocides (Tagatz et al, 1980).

3. Drilling muds most toxic to larval marine organisms, and though less toxic to adults, sublethal stress was evident mussel growth decreased (Gerber and Gilfillon, 1980).

4. Turbidity from discharge of drilling fluids and drill cuttings may depress photosynthesis of phytoplankton and could result in the clogging of the filter feeding mechanisms of zooplankton, causing decreased filtering and feeding efficiency. Temporary food chain uptake may also occur. Disturbance of the habitat and food source of some species demersal fish (U.S.D.I., 1977).

5. Complete recovery of epifauna after depositing of cuttings ceases could take up to 5 years (Straughan, D., 1971).

6. Polychaetes from nearest (300 m) the Tingmiark glory hole were in poorer condition than those sampled from farther away (1500 m) as indicated by slightly decreased reproductive development, slightly increased reproductive degeneration, moderately increased mucus production and digestive degeneration. Polychaetes from Ukalerk (about 300 m from well head) were in poorer conditions than those from Tingmiark. Ratings of health indices for clams tended to follow the same trends as those for polychaetes (Brown et al, 1979).

7. Mussels in 3% discharge mud remained closed for much of the time and had not begun significant byssus thread secretion after 7 days (some noticed after 14 days) (Houghton et al, 1980).

8. Crustacean more tolerant than Salmon fry (Houghton et al, 1980).

9. Impairment of chemosensory responses in lobsters (Derby and Atena, 1981).

10. Alteration in patterns of embryological or larval development of grass shrimp, lobsters, sand dollars, and killifish (Gerber et al, 1981).

11. Decreased food assimilation and growth efficiency in mysid shrimp (Car et al, 1980).

12. Decreased shell growth and condition in oysters, mussels, and scallops (Gerber 1980, 1981; Neff, 1980).

13. Alterations in rates of filtration, respiration, and nitrogen excretion in mussels (Gerber et al, 1980).

14. Changes in enzyme activity in tissues of several species of marine animals (Gerber et al, 1980, 1981).

15. Histopathological lesions in coonstripe shrimp and salmon fry (Houghton et al, 1980).

16. Polyp retraction and growth in corals (Thompson and Bright, 1977, 1980).

*Notes

1. Significant deleterious sub-lethal responses in marine animlas are observed at drill fluid concentrations only slightly lower than those that are acutely toxic.

2. Impact on mud and cutting discharge on benthic and fouling communities is related to the amount of material accumulating on the substrate, which in turn is related to current speed and hydrographic factors. At most sites these result in dilutions of 1,000:1 (Thomas, 1979) which results in minimal effects and hence general conclusions of minimal impact.

LIBRARY
ENVIRONMENT CANADA
CONSERVATION AND PROTECTION
PACIFIC REGION

Minerals and Sublethal Effects

	CONCENTRATION (mg/l)	SUBLETHAL EFFECTS	REFERENCE
		CADMIUM	
oyster (Crassostrea virginica)	0.1 - 0.2	sublethal: little shell growth, lost pigmentation of mantle edge, coloration of digestive diverticulae after 20 week exposure	*Shuster & Pringle 1969
snail (Australorbis glabratus)	0.05 - 0.1	sublethal: stress reactions	*Hurry & Aldrich 1958
needlefish (Belone belone) eggs	1.0	hatched larvae with frayed fin folds and caudal fins	*VonWesternhagan et al 1975
	< 5.0	reduced pictoral fin activity in embryo	
Atlantic & Pac herring (Clupea harengus harengus & C. h. pallasi) eggs	1.0	reduced eye diameter in yol sac larval stages	*VonWesternhagan et al 1975
	5 - 10	otic capsules absent in newly hatched larvae	
Atlantic herring (larvae)	2 - 3	loss of swimming ability	
Shrimp (Paratya tasmaniensis)		gill lamellae damage, accumulation of granules in mitochondiia	*Lake & Thorpe 1974
		CHROMIUM	
Macrocystis kelp pyrifera	Cr^{6+} 5.0	50% decrease in photosyntheses	*Clendenning & North 1960
Capitella capitata polychaete	0.1	decrease in reproduction output	*Reish 1977

Continued...

	CONCENTRATION (mg/l)	SUBLETHAL EFFECTS	REFERENCE
		COPPER	
diatom (Nitzshia palea)	0.01	complete inhibition of growth	*Bryan 1976
copepod	.005 - .05	reduction in feeding rates	*Reeve et al 1976
Macrocystis pyrifera	0.06	30% decrease in photosyn after 2 days	*Clendenning & North 1960
Clupea harengus fry herring	0.09 - 0.3	impaired activity	*Baxter 1977
		LEAD	
Skelotonema	1×10^{-2}	decreased growth rate and altered cellular structure	*Rivkin 1974
oyster (Crassostrea virginica)	0.1 - 0.2	change in gonadal and mantle tissues after 2 weeks	*Pringle 1972 unpublished
crab (Uca pugilator)	0.1	no effect on regeneration	
	(ug/l)	**MERCURY**	
phytoplankton	0.1 - 0.6 (alkyl merc.)	inhibition of photosynthesis	*Ukeles 1962
Asterionella Frasilaria	370	cell division totally inhibited	*Tompkins & Blinn 1976
	37	reduced rate of cell division	
Macrocystes	50 (mercuric chloride)	50% decreased in photosynthesis	*Clendenning & North 1960

Continued...

Minerals and Sublethal Effects (Continued)

	CONCENTRATION (mg/l)	SUBLETHAL EFFECTS	REFERENCE
		ZINC	
Artemia salina (brine shrimp)	0.1	suppression of growth	*Bernard & Zattera 1975

*Cited in EIS support document (E.S.L. 1982).

REFERENCES

Brown, P.A., K.A. Thompson, D.J. Thomas, 1979. C.A.N.M.A.R.: A histopthological evaluation of organisms from Tingmiark K-91, Ukalerk C-50, Ubalerk 2C-50, and Kenalooak J-94. Arctic Laboratories Lmt. Inuvick, N.W.T.

Carr, R.S., L.A. Reitsema, and J.M. Neff, 1980. Influence of a used Chrome-lignosulfonate drilling mud on the survival, respiration, growth and feeding activity of the opossum shrimp, *Mysidopsis almyra*. *In* Proc. Symposium Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Washington, D.C. (Courtesy Associates) pp. 944-963.

Crippen, R.W., S.L. Hood, 1980. Metal levels in sediment ad benthose resulting from a drilling fluid discharge into the Beaufort Sea. *In* Symposium: Research on Environmental Fate and Effects of Drilling Fluids and Cuttings. Lake Buena Vista, Florida. Washington, D.C. pp. 636-664.

Derby, C.D. and J. Arena, 1981. Influence of drilling muds on the primary chemosensory neurons in walking legs of the lobster, *Homerus americanus*. Can. J. Fish. Aquat. Sci., 38: 268-274.

Environment Sciences Limited, 1982. The biological effects of hydrocarbon exploration and production related activities, disturbances and wastes on marine flora and fauna of the Beaufort Sea region. Beaufort EIS support document. Prepared for Dome Petroleum Int. pp. 186-223.

Gerber, R.P., E.S. Gilfellan, J.B. Hothan, L.J. Galletto, and S.A. Hanson, 1981. Further studies on the short and long term effects of used drilling fluids on marine organisms. Unpublished. Final report (Year II) to the American Petroleum Institute.

_______________, _______________, B.T. Page, D.S. Page and J.B. Hatham, 1980. Short and longer term effects of used drilling fluids on marine organisms. In Proc. Symposium on Research and Environmental Fate and Effects of Drilling Fluids and Cuttings.

Houghton, J.P. D.L. Beyer, and E.D. Thielk, 1980. Effects of oil well drilling fluids on several important Allaskan marine organisms. In Proc. Symp. Wash. pp. 1017-1043.

Lees, P.C., J.P. Houghton, 1980. Effects of drilling fluids on benthic communities at the lower Cook Inlet C.O.S.T. well. pp. 309-320.

Menzie, C.A., 1980. An environmental monitoring study to assess the impact of drillign discharges in the mid Atlantic. The effects of drilling discharges on the benthic community. In Proc. Symp. Wash. pp. 499-536.

Neff, J.M., 1980. Effects of used drilling needs on benthic marine animals. Publ. No. 4330. (Washington, D.C.: American Petroleum Institute).

Rubinstein, N.I., 1980. Acute and sublethal effects of whole used drilling fluids on representative estuarine organisms. In Proc. Symp. Wash. pp 828-834.

Straughan, D., 1971. In Western Gulf-Kodiak draft. FSDI. p. 100.

Tagatz, M.E., J.M. Ivey, H.K. Lehman, M. Tobia, 1980. Effects of drilling mud on development of experimental estuarine macrobenthic communities. In Proc. Symp. Wash. pp. 828-834.

Thomas, D.J., 1979. The effect of discharged drilling fluid waste on primary productivity at Nerlerk M98. Arcti Lab. Int. Inuvik N.W.T.

Thompson, J.H., Jr., T. Bright, 1980. Effects of an offshore drilling need on selected corals. In Proc. Symp. Wash. p. 1044-1078.

U.S.D.I., 1977. Western Gulf-Kodiak draft. Environmental impact statement. Bureau of Land Management. Vol. 2. 502 p.