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Relationship of Mortality of Aquatic Biota from 96-Hour Sediment Bioassays and the Change in Chemical Composition of the Test Water

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Evaluation of the potential ecological effects of dredged material disposal has recently received renewed research interest because of increased concern over toxic substances within our aquatic environments. Various federal agencies currently share the responsibility for the evaluation and ultimate disposal options selected for these dredged materials. Traditional concerns with evaluation procedures have focused on the ecological validity of the procedures used. The U.S. Environmental Protection Agency (EPA), Regions V and IX, have utilized bulk chemical sediment analysis (FWPCA 1968, JENSEN 1971, BOWDEN 1977) for the evaluation of dredged materials while the U.S. Army Corps of Engineers (COE) has used the elutriate test (U.S. COE 1977). Critiques of each procedure have been previously published (LEE & PLUMB 1974, PRATER & ANDERSON 1977a,b, SOULE & OGURI 1974).

In a continuing investigation of these and other procedures as a means of evaluating dredged materials and selecting disposal options, sediment grab samples were collected from five Lake Michigan harbors and analyzed using a 96-h sediment bioassay (PRATER & ANDERSON 1977a,b, HOKE & PRATER 1980d; LASKOWSKI-HOKE & PRATER, IN PRESS: PRATER & HOKE 1980). Bulk and elutriate chemical analysis of the sediments also was conducted, as was an analysis of the pretest and posttest water used in the sediment bioassays.

For each parameter analyzed, the pretest value was subtracted from the posttest value to obtain a value termed the difference chemistry value for that parameter. This value represented leaching from or absorption/adsorption into the sediments during the 96-h bioassay test period. The objective of the portion of the study discussed herein was the correlation of the mortality data from the bioassays and the difference chemical data.

MATERIALS AND METHODS

During the summer and fall of 1977, 40 sediment grab samples were collected from the following Lake Michigan harbors: Indiana Harbor, IN; Grand Haven Harbor, MI; New Buffalo Harbor, MI; Green Bay Harbor, WI; and Marinette-Menominee Harbor, WI - MI; using a standard Ponar dredge. Five L of sediment were collected from each station. Four L of sediment were used in the bioassay

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tests and 0.5 L was used in both the elutriate and bulk sediment chemical analyses. Results of the statistical examination of elutriate chemistry, bulk sediment chemistry, and mortality data have previously been published (HOKE & PRATER 1980d, LASKOWSKI-HOKE & PRATER, IN PRESS).

Sediment bioassay tests were conducted using the procedure of PRATER & ANDERSON (1977a,b) and followed standard guidelines for bioassay tests (U.S. EPA 1978). Test organisms used in the bioassays were *Pimephales promelas* Rafinesque, *Hexagenia limbata* Walsh, *Lirceus fontinalis* Rafinesque, and *Daphnia magna* Straus. *H. limbata*, *L. fontinalis*, and *D. magna* were early instar immatures while the *P. promelas* were adults. *P. promelas* and *D. magna* were obtained from laboratory cultures while *L. fontinalis* and *H. limbata* were collected from natural populations occurring in relatively undisturbed environments.

Water samples for chemical analysis were taken from the pretest water and the posttest water used in the bioassays. The following chemical parameters were analyzed in both the pretest and posttest water: suspended solids, $NO_3 + NO_2$, NH_3, TKN, TP, ortho P, Cl^-, COD, As, Cd, Cr, Cu, CN, Fe, Pb, Mn, Hg, Ni, and Zn.

Bivariate correlations of the per cent mortalities of the test species and the difference chemistry data were performed using the SPSS subprogram SCATTERGRAM on an IBM Model 360 computer. Correlation coefficients ≥ 0.040, $p = 0.05$, $N = 40$, were considered *a priori* as having the most probable biological and ecological meaning in terms of the mortality of the test organisms.

RESULTS

A total of 76 bivariate correlations were performed. Of these, 14 met the *a priori* criteria established to identify a potentially meaningful correlation. The mortality of *P. promelas* was significantly correlated with difference chemical $NO_3 + NO_2$, NH_3, TKN, and TP; *H. limbata* mortality was significantly correlated with difference chemical suspended solids, NH_3, Cd, Cr, CN, Hg, and Zn; *D. magna* mortality was significantly correlated with difference chemical CN and Zn; and *L. fontinalis* mortality was significantly correlated with difference chemical NH_3 (Table I).

DISCUSSION

The relationship between mortality of *P. promelas* and the difference chemical parameters $NO_3 + NO_2$, NH_3, TKN, and TP may have been a function of the redox potential of the sediments used in the bioassays. The redox potential of sediments influences the denitrification of $NO_3 + NO_2$ and the release of NH_3 and P (WETZEL 1975, MORTIMER 1941, 1942). The negative correlation between difference chemical $NO_3 + NO_2$ and mortality of *P promelas* may represent varying states of denitrification within the sediments, while the positive correlation with NH_3 represents the concommitant release of NH_3 from the sediments. The positive correlation of *P.*

Table I. Correlation coefficients (r) > 0.40 from bivariate correlation analyses of difference (posttest water minus pretest water) chemical data* and mortality data from 96 hour sediment bioassays.

Difference Chemistry Parameter	% Mortality			
	Pimephales promelas	*Hexagenia limbata*	*Daphnia magna*	*Lirceus fontinalis*
Suspended Solids (105°C)		-0.41	---	---
$NO_3 + NO_2$	-0.61	---	---	---
Ammonia	0.43	0.42	---	0.54
Total Kjeldahl nitrogen(TKN)	0.50	---	---	---
Total phosphorus (TP)	0.46	---	---	---
Ortho phosphate	---	---	---	---
Chloride	---	---	---	---
COD	---	---	---	---
Arsenic	---	---	---	---
Cadmium	---	-0.41	---	---
Chromium	---	0.65	---	---
Copper	---	---	---	---
Cyanide**	---	0.68	0.63	---
Iron ---	---	---	---	---
Lead	---	---	---	---
Manganese	---	---	---	---
Mercury**	---	-0.53	---	---
Nickel	---	---	---	---
Zinc	---	0.60	0.68	---

*mg/L **µg/l

promelas mortality and TP was undoubtedly an artifact caused by the simultaneous release of P and NH_3 from the sediments while the correlation of mortality and TKN was a result of NH_3 being the dominant component of the measured TKN. Agitation of the sediments through the burrowing activity of *H. limbata* may have facilitated release of P and NH_3 from the sediments (ZICHER et al. 1956).

The negative correlation of *H. limbata* mortality and difference chemical suspended solids, Cd, and Hg reflects the affinity of Hg and Cd for organic material (LEUTHART & SPENCER 1977, LELAND et al. 1973, SHIMP et al. 1971, KENNEDY et al. 1971, SCHINDLER & ALBERTS 1977, KEMP et al. 1976, SOULE & OGURI 1974). As particulate formation and suspension decrease, fallout of these particulates with incorporation into the sediments may adversely affect burrowing organisms (LEE & PLUMB 1974). The positive correlation of difference chemical NH_3 and mortality of *H. limbata* and *L. fontinalis*, difference chemical Cr and mortality of *H. limbata*, and difference chemical CN and ZN and mortality of *H. limbata* and *D. magna* may illustrate an impairment of respiratory functions. Cyanide and Zn in water interfere with respiratory functions and the toxic effects of these substances on *Daphnia* have been reported (BIESINGER & CHRISTENSEN 1972, MALACEA 1966).

Although the elutriate test predicts short-term water column effects as a result of dredged material disposal, chemical procedures alone cannot address the impact of such an event on the organisms inhabiting the disposal site and surrounding area. Elutriate bioassays, or sediment bioassays coupled with difference chemical analyses provide more useful information in terms of the potential impacts of disposal events on the biota. Sediment bioassays not only enable the investigator to assess the actual impacts of the sediment on indigenous organisms, but when coupled with difference chemical analyses, they also enable the investigator to examine potential leaching effects from the sediments.

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