Northeast Fisheries Center Reference Document 90-02

Monitoring the Effects of Sewage Sludge Disposal at the106-Mile Dumpsite Using Mid-Water Fish as Sentinels of Contaminant Metal Uptake: A Feasibility Study

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Table of Contents

List of Figures

List of Tables

ABSTRACT

A survey was conducted to investigate the feasibility of detecting effects of sewage sludge disposal at the 106 Mile Deepwater Municipal Sewage Sludge Disposal Site (106 MDS) using mid-water fish as sentinels of the introduction of sludge-derived contaminants into the offshore food web. Metal concentrations in the myctophid, *Benthosema glaciale*, collected in the dumpsite were statistically significantly higher than concentrations in the same species from a control station near Block Canyon and concentrations in other species collected in the dumpsite and control areas. Results suggest that uptake occurred through direct (short-term) exposure to sewage sludge dumped at the site. Additional field sampling and laboratory analyses are necessary to verify this inference.

INTRODUCTION

In 1984, the 106-Mile Deepwater Municipal Sewage Sludge Disposal Site (106 MDS, Figure 1) was designated to receive sewage sludge from the New York City-New Jersey metropolitan area. Phased relocation of dumping from the 12-Mile Dumpsite in the New York Bight apex (Figure 1) to the 106 MDS began in March 1986, and by December 1987 all ocean-dumped sludge (about 8 million mt per year) was being disposed of there. Between 1972 and 1986, prior to sludge disposal, the entire 106 MDS was available for the disposal of industrial chemical wastes. A small, circular (4.8 km diameter) site remains available for that purpose, but has not been used since March 1987.

Concerns about potential environmental and biological impacts of sludge disposal at the 106 MDS have been voiced by the fishing community, citizens groups, state agencies and federal agencies, principally the Environmental Protection Agency (EPA). A plan to study and monitor the impacts of sludge dumping at the site has been jointly developed by three federal agencies (National Oceanic and Atmospheric Administration [NOAA], U.S. Coast Guard [USCG], and EPA), and preliminary aspects of the plan have been implemented by EPA.

The present study was conducted to assess the feasibility of monitoring the effects of sewage sludge disposal at the 106 MDS using mid-water fish to detect sewage sludge derived contaminant metals. Specifically, we wished to answer the following questions:

1. Can a 3 m Isaacs-Kidd trawl collect sufficient numbers of mid-water fish for analysis of metal body burdens?
2. Can metals be detected in mid-water fish tissues by analyzing whole specimens using the analytical capabilities available at our Sandy Hook Laboratory ?
3. Can differences in metal body burdens be detected in fish from different locations around the 106 MDS ?
4. Are differences in metal body burdens attributable to sewage sludge disposal at the 106 MDS ?

The purpose of this report is to convey the findings of this study.

OCEANOGRAPHIC SETTING

As described by Ingham, *et al.* (1977) and Bisagni (1983), the 106 MDS is located over the outer-continental slope and continental rise in depths of 2400 to 2700 m, approximately 37 to 74 km south of the mouth of the Hudson Canyon. Average long-term currents at all depths are toward the southwest, approximately parallel to the bathymetry,

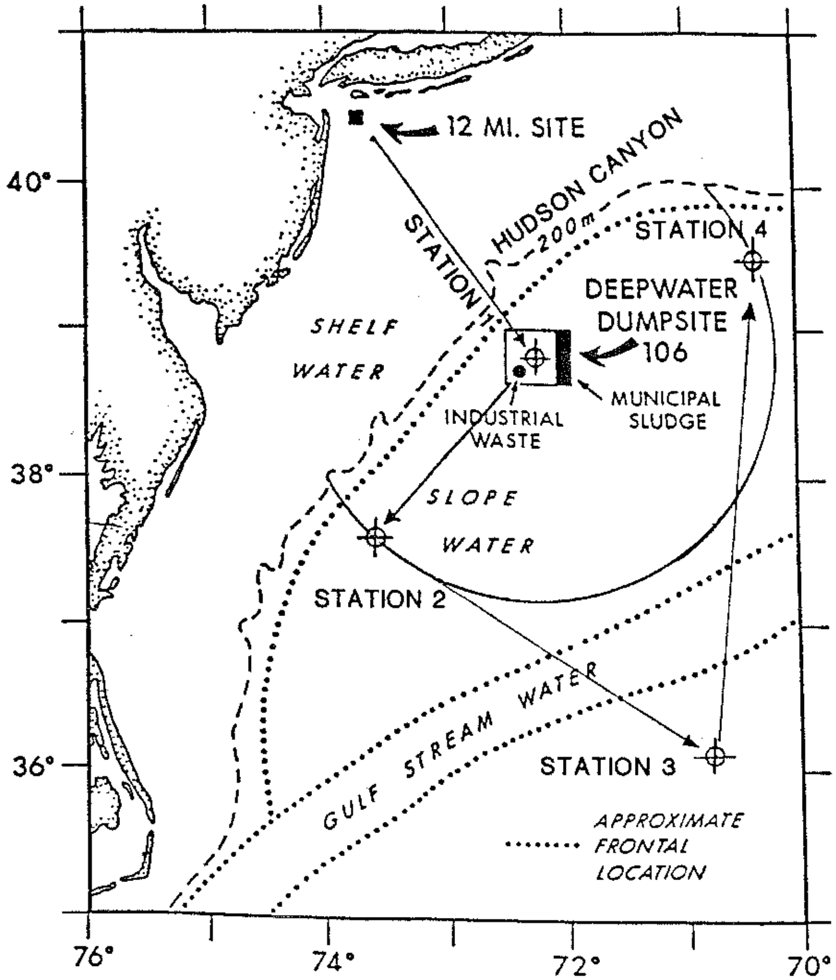

Figure 1. Approximate locations of mid-water trawl sampling stations (crossed circles) on *Delaware II* cruise 89-04, June 1989.

ranging from approximately 10 cm per sec in the surface layer to less than 5 cm per sec near the bottom. The average flow is aperiodically interrupted by episodes of strong currents (up to 100 cm per sec) in the upper 1000 m of the water column, which are associated with the passage of Gulf Stream rings. Currents near the bottom are weak, resulting in a relatively tranquil condition, with little sediment resuspension and transport except in canyons, where currents up to 27 cm per sec occasionally occur and cause sediment erosion.

The 106 MDS is approximately 37 km seaward of the average location of the surface front that separates continental shelf water from slope water, and is usually (about 67 percent of the time) located in slope water. Occasionally (about 18 percent of the time), the front moves seaward and the site is covered by a shelf-water mass of highly variable characteristics, producing a very complex vertical structure in the surface layer. Less commonly (about 12 percent of the time), it is covered by Gulf Stream-ring water (Gulf Stream and/or Sargasso Sea water), as a ring slowly crosses the site, moving toward the southwest.

The annual meteorological cycle causes density stratification in the upper water column during the warming season, beginning in May, and persisting until October or November, when it is destroyed by cooling of surface water and increased wind mixing. During this period of stratification, a thermocline develops beneath the warm surface layer, which is approximately 30 to 40 m deep in late summer. A permanent thermocline is found in the 100 to 200 m depth range, and a layer of weak thermal gradients exists between the two thermoclines, apparently a remainder of winter conditions.

MID-WATER FISH AS SENTINELS OF CONTAMINATION: RATIONALE

Mid-water fish, primarily lantern fish (Family Myctophidae) and hatchet fish (Family Sternoptychidae), are potentially good sentinels for monitoring the introduction into the food web of contaminants derived from sewage sludge discharged at the 106 MDS. This is based on the following rationale:

1. Both are relatively abundant throughout the slope-water area. Trawls in the vicinity of the dumpsite in summer 1975 and winter 1976 (Krueger, *et al.* 1977) showed them to be the most abundant of the mid-water fishes, comprising 95 percent of the nighttime catch in the upper 200 m and 90 percent of the daytime catch in the upper 800 m. Specimen capture rates, for all bathypelagic species, ranged from approximately 150 to 950 per hour of trawling.
2. These fish migrate vertically, moving to the surface layer at night to feed and returning to 200 to 700 m depths before daylight, thus bringing them into contact with any contaminated water or forage that may be present in the upper water column each time. They are weak swimmers so their vertical motions are accomplished by buoyancy adjustments, whereas their horizontal distribution is determined by currents in the depth range they occupy.
3. These fish prey on zooplankton, and may concentrate any pollutants that might have been taken up by phytoplankton and zooplankton which have been exposed to a sludge discharge. However, they are easier to sort from detritus than plankton are, making them more suitable for collection and chemical analysis.

RECONNAISSANCE SURVEY

A reconnaissance survey was conducted between 11 and 14 June 1989 aboard the NOAA research vessel Delaware II. Fifteen sample collections were made at four stations, using a 3-m Isaacs-Kidd mid-water trawl. Stations were situated as follows: within the boundaries of the dumpsite (station 1), approximately 180 km downstream of the site (station 2), in the Sargasso Sea (station 3), and approximately 180 km upstream of the site (station 4). After retrieval, samples were sorted, rinsed with deionized water, and stored frozen in plastic containers. A summary of specimens obtained at each station for metals analyses is shown in Table 1.

Table 1. Number of mid-water fish specimens collected during survey DL8904, 11-14 June, 1989

Species	Sta. 1	Sta. 2	Sta. 3	Sta. 4
Argyropelecus sp.	12[2]	-	12	4[1]
Benthosema glaciale	12[2]	-	-	12
Ceratoscopelus maderensis	12[3]	12	-	-
Hygophum hygomi	12[3]	12	12	-
Gonostoma elongatum	5[1]	-	4[1]	-
Notolepis rissoi	2[1]	12	-	-
Lampanyctus sp.	-	12	3[1]	-
Lobianchia dofleini	-	-	-	6[1]
Chauliodus sp.	-	-	-	12[1]
Collection date	11,13	12	12	14

[1] Not analyzed.
[2] Collected 11 June.
[3] Collected 13 June.

LABORATORY METHODS

Although it would have been preferable to analyze individual fish, two individuals were composited for analysis because most of the individual specimens were small (approximately 0.2 to 2.5 g we weight) and we wanted to insure that analytical signals would be above instrumental detection limits. Samples were digested in Teflon-lined, stainless steel bombs, using ultrapure nitric acid. DORM-1, freeze-dried dogfish muscle, available from the National Research Council of Canada, was used as the reference material. Method blanks were identically processed.

Mercury determinations were made using an Arizona Instruments model 511 mercury analyzer, which employs a gold foil detector. Concentrations of the other metals were measured using a Perkin-Elmer model 5000 atomic absorption spectrophotometer. Copper, zinc, iron, and manganese were analyzed using flame atomization without background correction; cadmium, chromium, nickel, and lead were analyzed using graphite furnace atomization, incorporating Zeeman effect background correction and matrix modification as appropriate.

RESULTS AND DISCUSSION

Results of the metals analyses are shown in Table 2. Since dry-weight data were not available for all the composites, concentrations are reported on a wet-weight basis. Available ratios of dry weights-to-wet weights ranged from approximately 0.2 to 0.3, so dry-weight concentrations may be estimated by multiplying the wet-weight values by a factor of 4.

Table 2. Means and standard deviations of metal concentrations (μg/g, wet weight) in mid-water fish, June 1989. GRP = ANOVA group. N = number of composites. Species codes: AR = *Argyropelecus* sp.; BG = *Benthosema glaciale;* CM = *Ceratoscopelus maderensis;* HH = *Hygophum hygomi;* LA = *Lampanyctus* sp.; NR = *Notolepis rissoi.*

STA	SP	GRP	N		Hg	Cd	Cr	Cu	Ni	Pb	Zn	Fe	Mn
1	AR	6	5	$\overline{X}$	0.021	0.061	0.414	2.470	0.172	0.223	21.818	41.626	1.694
				σ	0.006	0.005	0.160	0.696	0.053	0.096	1.222	8.977	0.270
1	BG	1	6	$\overline{X}$	0.039	0.066	3.033[1]	11.464[1]	1.023[1]	0.786[1]	49.170[1]	180.783[1]	2.535[1]
				σ	0.020	0.038	1.684	4.503	0.578	0.271	13.188	92.243	0.800
1	CM	7	5	$\overline{X}$	0.020	0.048	0.168	0.971	0.065	0.053	16.752	18.408	1.063
				σ	0.004	0.009	0.074	0.242	0.032	0.021	5.288	2.840	0.069
1	HH	2	6	$\overline{X}$	0.018	0.045	0.145	1.210	0.120	0.102	11.488	13.767	1.079
				σ	0.007	0.021	0.038	0.214	0.099	0.093	1.516	2.978	0.283
2	CM	8	5	$\overline{X}$	0.022	0.098	0.509	1.865	0.177	0.101	36.306	48.026	1.306
				σ	0.004	0.041	0.263	0.427	0.077	0.036	13.920	18.335	0.112
2	HH	3	6	$\overline{X}$	0.014	0.114	0.343	1.352	0.062	0.133	14.695	16.900	1.315
				σ	0.002	0.055	0.393	0.365	0.034	0.181	8.611	9.296	0.238
2	LA	10	5	$\overline{X}$	0.016	0.092	0.077	1.477	0.199	0.234	18.604	30.842	1.188
				σ	0.006	0.034	0.045	0.840	0.146	0.150	4.554	8.367	0.370
2	NR	9	5	$\overline{X}$	0.012	0.046	0.061	0.885	0.136	0.366	21.080	34.468	0.691
				σ	0.008	0.028	0.036	0.362	0.067	0.410	11.309	30.437	0.229
3	AR	11	5	$\overline{X}$	0.008	0.295[1]	0.049	1.353	0.243	0.349	16.196	13.366	1.098
				σ	0.003	0.164	0.036	0.371	0.236	0.341	3.333	3.876	0.268
3	HH	4	6	$\overline{X}$	0.030	0.049	0.204	1.197	0.109	0.071	14.183	20.200	1.393
				σ	0.014	0.019	0.116	0.186	0.052	0.028	3.367	5.787	0.258
4	BG	5	2	$\overline{X}$	0.021	0.041	0.017	0.853	0.085	0.084	9.735	8.315	0.739
					0.019	0.034	0.017	0.613	0.007	0.102	5.565	7.191	0.467
DORM-1			6	$\overline{X}$	0.730	0.089	3.480	5.840	1.330	0.313	22.10	73.60	1.460
				σ	0.036	0.007	0.480	0.470	0.230	0.064	0.77	4.70	0.190
Certified values					0.798	0.086	3.600	5.220	1.200	0.400	21.30	63.60	1.320
(DORM-1)				±	0.074	0.012	0.400	0.330	0.300	0.120	1.00	5.30	0.260

[1] Significantly different, by ANOVA for $\alpha = .05$.

The species with the greatest concentrations of metals, especially chromium, copper, nickel, lead, zinc, iron, and manganese, was *Benthosema glaciale* collected at station 1. No other species contained elevated concentrations of these metals at any station, nor did samples of *Benthosema glaciale* from station 4 contain elevated levels. Samples of *Argyropelecus* sp. from station 3 had the highest cadmium concentrations.

Based on species, station, and date of collection, groups were designated for statistical analysis by ANOVA. Results (Table 2) indicated that concentrations of chromium, copper, nickel, lead, zinc, iron, and manganese were significantly higher ($\alpha = .05$) in group 1 (*Benthosema glaciale* collected 11 June at the dumpsite station) than in the other groups, while cadmium was significantly higher in group 11 (*Argyropelecus* sp. collected at station 3) than in the other groups. There were no statistically significant differences in mercury concentrations among groups, although the mean for group 1 was greater than the mean for any other group.

If sewage sludge disposal is manifested as increased body burdens of metals in mid-water fish, we might expect to observe geographic patterns of metal concentrations that are related to the mode of uptake. If exposure to contaminants occurs only in or near the dumpsite, during or soon after a disposal event, and gradual accumulation in fish tissue does not occur, sites might be ranked as follows, based on metal concentrations in fish:

Sargasso Sea	(station 3)	lowest
upstream	(station 4)	low
downstream	(station 2)	low
dumpsite	(station 1)	highest

In contrast, if sludge, though dilute, is present in slope water, resulting in multiple exposures of the fish as they drift with the contaminated water mass, and gradual accumulation does occur, sites might rank as follows:

Sargasso Sea	(station 3)	lowest
upstream	(station 4)	low
dumpsite	(station 1)	high
downstream	(station 2)	highest

Results of the reconnaissance survey followed the first pattern, suggesting that the fish were exposed to elevated concentrations of metals in the immediate vicinity of the dumpsite, and that the fish collected downstream either were not exposed to sludge or did not retain elevated levels of metals long enough to show increased body burdens at the downstream station, about 185 km (approximately 42 days' drift) away.

Since so few samples and stations were investigated, these hypotheses must be considered to be preliminary at this time. The problem with the small number of samples was exacerbated by the fact that no single species was obtained at all four stations, and four of the six *Benthosema glaciale* composites from the upstream station were lost during digestion due to ignition.

CONCLUSIONS

This study demonstrates the feasibility of certain aspects of monitoring sewage sludge disposal at the 106 MDS.

It is possible to collect mid-water fish in sufficient numbers for chemical analysis using a 3-m Isaacs-Kidd mid-water trawl, although other nets might be more efficient and/or less time-consuming and still be deployed from the *Delaware II* and other research vessels.

Current analytical methods, such as those employed at the Sandy Hook Laboratory, are sufficiently sensitive to detect metals (Hg, Cd, Cr, Cu, Ni, Pb, Zn, Fe, Mn) in tissues of mid-water fish. During this study, problems were encountered due to sample ignition during digestion, but these can be overcome by adpoting a microwave digestion procedure, which would afford much greater control over the digestion procedure.

Significant differences in body burdens of Cr, Cu, Ni, Pb, Zn, Fe, and Mn were found between *Benthosema glaciale* captured at the 106 MDS and other groups of fish. The concentrations of iron in the former were about an order of magnitude higher than iron concentrations in other species and at other locations during the survey. Additional surveys should be conducted, however, so that these differences can be established with more certainty.

Finally, differences in body burdens are consistent with a hypothesis of single or infrequent exposures in the immediate vicinity of the 106 MDS. However, this inference requires further sampling and analysis for verification.

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