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MERCURY IN THE MARINE ENVIRONMENT

Workshop Proceedings

June 1989



U.S. Department of the Interior
Minerals Management Service
Alaska OCS Region

OCS Study MMS 89-0049

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Workshop Proceedings

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MERCURY IN THE MARINE ENVIRONMENT
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MERCURY IN THE MARINE ENVIRONMENT WORKSHOP TUESDAY, NOVEMBER 29, 1988

INTRODUCTION

Welcome, my name is Judy Gottlieb from the Minerals Management Service. We are glad that you were all able to attend today. This workshop is being held to assist MMS in evaluating the effects of mining activities that may occur if MMS leases Outer Continental Shelf (OCS) lands near Nome.

The process leading to this workshop started about 12 months ago when WestGold wrote a letter to the Department of the Interior requesting the opportunity to lease OCS lands. Shortly after, the State of Alaska requested that a task force be established to review Environmental Impact Statements and other related documents which MMS normally prepares prior to offering lands for lease,

The State has gained valuable experience in leasing and regulating its offshore lands for mining near Nome over the last four years. A joint Coordination Team was established last February, and, as you may know, a Team meeting will take place here this Thursday. The Draft Environmental Impact Statement, of which we have many copies on the side table, has identified mercury in the marine environment as a central issue, I understand that many of you did not receive the Draft Environmental Impact Statement in our mailout so if you need a copy, there are plenty, Summaries are available if you were not able to read the EIS before attending the meeting.

Our analysis indicates that in the area being considered for leasing, mercury in the sediments could be suspended in the water column through the mining process. Once in the water column the mercury could bioaccumulate in marine life consumed by humans, such as crab and fish. The central questions on this issue are:

- Could this process happen in such a way that marine resources would be detrimentally affected, and
- Could human health ultimately be at risk?

At a Coordination Team meeting held in July, it was requested that MMS bring human health experts into the EIS process. Subsequently, MMS staff has organized this workshop focusing on human health aspects as well as the related issues of mercury in sediments and water, bioaccumulation of mercury in the food chain and regulatory aspects. Jerry Imm, who heads our Environmental Studies Section at MMS here in Anchorage, has been in charge of arranging the conference. Joy Gieselmann is the Conference Coordinator, Helen Armstrong from Environmental Assessment and Tim Holder, our liaisons to the Coordination Team, have also been instrumental in developing the agenda. Kathy Mitchell and Rick Ware from MBC Applied Environmental Sciences are our contractors for logistics of the meeting and for summaries of these discussions. Kathy will be in charge if there are any messages for people attending. We need to make just a few more announcements. Jerome Nriagu was unable to attend from Canada due to illness. Tom Gosink from the University of Alaska, Fairbanks has graciously substituted and will give us an overview of the topic as well as discussing the Norton Sound Sampling Program which we were able to participate in last month. The focus of this workshop is for the Environmental Impact Statement writers and experts who are seated at the front table, and the rest of us will just be observers. So please, if you are in the audience, if you would hold your questions and give them to the moderators at a break or at the end of the day. If there is time at the end of the session, the moderators will ask the audience for questions, But if not, the purpose of Thursday's meeting with the Coordination Team will be to inform the Coordination Team of the results of these meetings, summarize those results, and answer the audience's questions.

MERCURY IN SEDIMENTS AND WATER

RECENT MERCURY DATA OFF NOME, ALASKA

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The EPA Method for mercury analysis was followed. For a detailed evaluation of the method see the report prepared by the Mercury Analysis Working Party of the Bureau International Technique du **Chlore (Analytica Chimica Acts 1979)**, This abstract and the Notes at the end offer some added explanation,

Surface and near bottom water samples were taken in duplicate from seven stations using Niskin bottles. They were stored, unfiltered in 500 *ml glass* bottles with 2 *ml* concentrated **Ultrex¹ HNO₃** (See Note 1). A slight amount of sediment was visible in the plume and near bottom samples. Plankton were evident in the surface samples. In addition, intermediate depth samples (5 m) were taken at the two Bima (offshore mining dredge) stations, Plastic bottle (1 *l* plus 5 *ml Ultrex HNO₃*) samples from all water collection stations were also taken.

The sample bottles were shaken to suspend the small amount of sediment and plankton before a 100 *ml aliquot* was withdrawn. Samples were oxidized by the standard acid permanganate (40 *ml persulfate* method (see Notes 2 and 3).

The values are not unreasonably high considering that these are unfiltered water samples. (The EPA "total recoverable" is for **unfiltered** water.) Textbook value for mercury in **filtered** seawater range from **<0.03** to **≥0.15 $\mu\text{g/l}$** . Gosink (1980) found mercury in Port **Valdez** (impacted by glacial scour) to range from 0.001 to 0.2 $\mu\text{g/l}$ over a three-year study period. Weiss *et al.* (1972) report 0.02 $\mu\text{g/l}$ in the Beaufort; 0.1 $\mu\text{g/l}$ for Antarctic waters. However, in a recent telephone conversation with Weiss, he now believes his very carefully collected and processed samples may be low by as much as 40% due to the heat during the activation process. The filtered particles in **Gosink's** past study corresponded to a range of 20 to 120 (a few up to 900) ppb for a liter of water passing through the filter. The "normal" mercury range from marine particulate in a liter of seawater is considered to be **40-500+ ppb**. The average is **≤0.1**, but nature is Poisson, not Gaussian in its distribution, so 1 ppm is not an unreasonable high end of the natural spectrum.

Usually concentrations of mercury in sediments ranging from about 1 to 10 ppm ($\mu\text{g/g}$ dry weight) are considered to be polluted. This is roughly four orders of magnitude greater than the dissolved load in the (**filtered**) water column. See **Nriagu** (1979) for supportive data.

Instances where serious disease, or threat has occurred from mercury, the total mercury concentration in the sediments was much higher. For example, in the St. **Clair** River it was 100 $\mu\text{g/g}$ wet weight, and up to 2010 $\mu\text{g/g}$ in the infamous Minamata case, where some organic as well as inorganic mercury was being dumped.

The major threat is not so much from inorganic mercury, but from the small amount of methylated mercury which naturally occurs in the range of ca. 0.03% (**±0.03%**) of the total mercury. **Methylmercury** compounds are quite stable in the water column, and in **slightly anoxic** sediment where it is probably produced (Figures 1 and 2) as well as by the **biota**.

The **biota** pick up **methylmercury** compounds significantly faster than inorganic mercury, either from the water column, or from their food. Roughly 75% (**±25%**) of the mercury in the **biota** is the **methylated form**, and usually firmly attached to a **sulfide** molecule, such as **cysteine**.

Mercury in the Marine Environment

The natural formation of **methylated** mercury in the sediments is favored by higher temperature, higher E_h , pH, higher total mercury, and the presence of **methanogenic** bacteria in the presence of organic nutrients, principally sewage. We did not perform any total organic tests, but the Biological Oxygen Demand (BOD) numbers indicate that there is almost no organic matter being oxidized in the water column, either from the plume or the clean water side of the Bima. (BOD = 0,042 to 0.050 *ml/l* per day).

The west coast of Alaska (the lower Yukon and the Nome area) is known to have natural cinnabar which has naturally enriched the **biota** and people in these two elements. A point to keep in mind, there is a 1:1 correlation between selenium and mercury in **biota**, which appear to counteract the adverse effects of both. (Selenium is a required essential element in low dosage.)

The EPA Method is not capable of reaching the newly desired detection limits of 0.025 ppm (see Note 3). I would recommend gas chromatographic methods for **methylmercury** because: a) this is the more dangerous form, b) it is the primary form in the **biota**, c) potential contamination by mercury vapor is virtually eliminated, and d) the **detection** limit is on the order of 0.005 ppm. It is also possible to analyze for inorganic mercury by this technique, with similar sensitivity, but problem (c) returns.

Preliminary results of our recent study off **Nome**, Alaska are shown in Tables 1 and 2. The final report will be submitted before mid-December.

The current was from west to east, Bima clean water = Station 1. The plume samples Station 2. (It was not possible to safely operate at the requested 100 m range because of the numerous anchor cables surrounding the Bima.) Station 3 was the inshore farthest east transect; Station 4 intermediate, Station 7 was the center station from the center transect, Stations 10 and 11 were from the transect closest to Nome and the Bima, on the clean water side. Station 11 was closest to shore.

There seems to be a trend of increasing mercury from west to east in the bottom water samples. The Bima was at the farthest west point of the study, and at the time of sampling was temporarily dumping the wash water to the surface rather than at depth, thus the slightly higher, but quite normal mercury numbers for the plume.

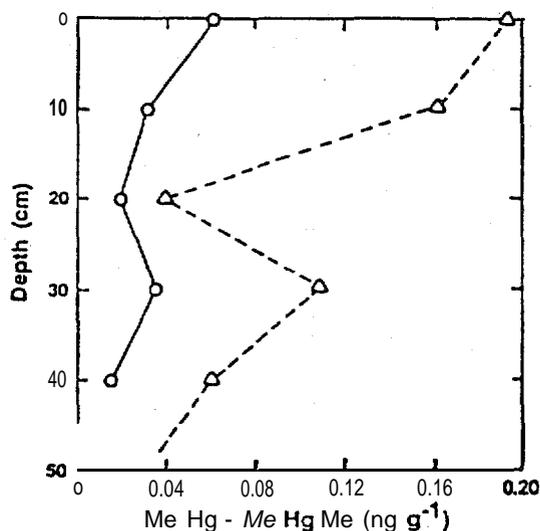


Figure 1. Distribution of methylmercury with depth in sediment cores from Mobile Bay, Station 16 = O ; Station 19 = Δ. (From: Andren and Harriss 1973.)

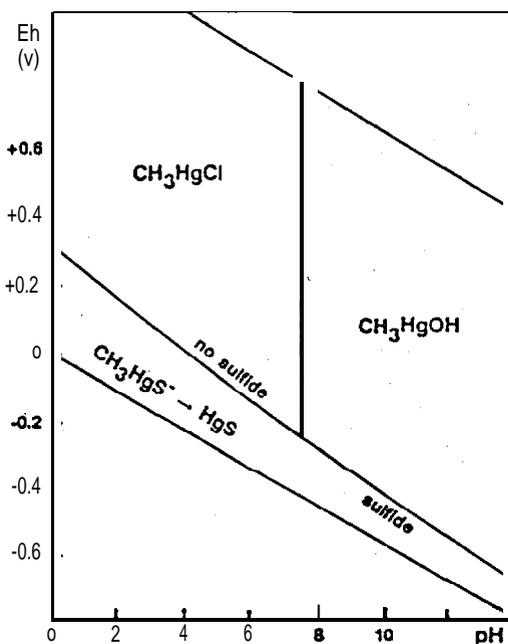


Figure 2 E_h -pH plot of the stability relations among methylmercury compound. (From: Wollast, Billen & Mackenzie 1975.)

Gosink: Recent *Mercury Data off Nome, Alaska*

Unoxidized (**permanganate**) water samples from Station 11 and both **Bima** bottom samples were analyzed for mercury employing only the **hydroxylamine** and **stannous** reduction steps. (The samples had been stored in ca. M **HNO₃**.) The values for Station 11 surface and bottom samples were 70 and 30% of the oxidized values; those of the **Bima** bottom samples were 22 and 40?? for the clean and plume sides, respectively. These data indicate that the balance is strongly associated with the particulate material,

For those present at the meeting, I made two errors concerning the sediments. One was to mis-read **Nriagu** on the normal concentrations of mercury in the sediment. The numbers in this revised abstract are correct. The other was due to my haste in trying to present some data for the site in **question**. The **hydroxylamine** extracts I had been given had too high of a blank to be **useable**. All of the data below are for the standard EPA Method. The promised **biota** samples were not received until 1 December. A limited number of **biota** analyses will be in the final report.

Table 1. Results^a - Concentrations of Hg in water (µg/l).

MMS Station ID	Surf ace	5m	Near Bottom	Depth (m)
1 BIMA Clean	<0.05 - <<0.05	0.15 ± 0.05	0.48 ± 0.05	13
2 BIMA Plume	0.12 - 0.22	0.22 * 0.02	0.23 ± 0.03	14
3 (East)	0.39^b ± 0.05		0.44 ± 0.01	18
4 (East)	0.33		0.33	21
7 (Mid)	0.25		0.22	28
10 (West)	0.12		0.22	29
11 (West)	0.22		0.16	12

a Where a "**± figure**" is shown, it is **±1σ** for N=3; a range = 2 samples.

b This is from the spiked samples, which showed *no* sign of loss or **contamination**. (See Note 4.) Glass bottle surface samples from Stations 1 and 3 were destroyed in transit.

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Table 2. sediment analyses (µg/g dry wt).

Station	Oxidized Surface	Anoxic (ea. 10-20 cm)
3	0.070	
4	0.054	
7	0.045	
8	0.097	
9	0.043	0.040
10	0.041	0.046
11	0.032	0.056

NBS **Estuarine** Sediment: 0.063 ± 0.012 **ppb**.
Our value: 0.066

NBS **River** Sediment: 1.1 ± 0.5 **ppb**.
Our value: 0.81

Mercury in the Marine Environment

Weiss, H. V., Chew, and Hope. 1972. Mercury in the environment of the North Slope of Alaska. Pages 228-273 in WEBSEC 71-72. An ecological survey in the Beaufort Sea. DOT Coast Guard Oceanogr. Rep. CG373-64.

Wollast, R., F. Billen, and F. T. MacKenzie. 1975. Behavior of mercury in natural systems and its global cycle, Page 150 in A. D. McIntyre and C.F. Mills (eds.), Ecological Toxicology Research. NATO Science Committee Conference on Eco-toxicology, Plenum Press, NY.

Notes

1, Ordinarily storage of water samples is preferred in acid-cleaned plastic bottles. However, for mercury, sample storage in plastic containers is not considered stable beyond two weeks since mercury vapor from the lab or elsewhere penetrates plastic bottles. Glass storage is considered safe for five or more weeks,

2. Contrary to some directions, it is not necessary to remove all of the chloride as chlorine during the 2 hr oxidation procedure, It is necessary to be sure that there is no free chlorine gas in the sample. Aerate the cooled sample, and blow out the headspace gas after the hydroxylamine is added, Adding sodium chloride to the hydroxylamine reagent is not recommended in that the presence of chloride (already present from the seawater) slows the final stannous ion reduction process.

The manganese precipitate must be completely cleared. Wait *at least* a minute after complete clearing. Shake vigorously to relieve some of the gas supersaturation. Aerate as described above, and by the Mercury Analysis Working Group (Analytica Chimica Acts 1979), Gas over pressure can completely stop the pump in the closed loop Perkin-Elmer Mercury Analyzer System (MAS-50). Also wait *ca.* 1 minute after adding the stannous ion before hooking bottle to the stripping pump mechanism.

The stannous solution is stable for two or three days at most and should be prepared fresh daily, as should the mercury standards, The hydroxylamine solution is stable for up to two weeks, but should be made fresh weekly,

3. The recorder was set up for 20 mv full scale, and then operated at 20 mv to afford a 10x expansion. [n this fashion *ca.* 0.15 μg is full scale (1 O major divisions), Noise was less than ± 1 small division. Drift was less than 1 small division per sample,

There was a trace of mercury (4 ± 1.7 small chart divisions) in the total reagent blank, A sample containing 0.32 $\mu\text{g/l}$ (0.032. μg in the aliquot) corresponded to 18.5 ± 2 small chart divisions, The limit of detection in the aliquot was 0.005 μg Hg (0.05 $\mu\text{g/l}$). Recent claims for $<0.01 \mu\text{g/l}$ (e.g. Temmerman *et al.* 1985) for gold foil preconcentration are due in part to the 1 liter sample size.

4. Several 'surface water samples from Station 3 were spiked with known amounts of a mercury standard to track the loss, if any, during storage until the time of analysis, Spikes were: 8, 1,6, and 0.25 $\mu\text{g/l}$. No loss or gain was evident. Inter-1 laboratory comparison data will be in the final report,

RECENT MERCURY DATA OFF NOME, ALASKA

Thomas A. Gosink
Questions and Discussion

_: Have you analyzed the information sufficient'y to say that there isn't any mercury problem?

Gosink: No, this was a very quick, cursory look, but from what I see there isn't a problem. But I would like to do it at least once more, and do a little more extensive work.

Fitzgerald: A couple of comments about mercury in seawater. Your value for seawater, what you call "average" for oceanic determinations, is about a half of a nanogram per liter, which is much below the detection limit of your methodology.

Gosink: You are talking about open ocean?

Fitzgerald: Well, no, inshore. I'll show you some data just south near Kodiak. There the level we are talking about is nanograms/liter not micrograms/liter. The levels that we find are below your analytical detection limit.

Gosink: Yes. I was asked to do the EPA technique. So I used an EPA technique, cold mercury mass analyzer, the cold vapor technique.

_: Do you use a "clean laboratory" approach?

Gosink: It's a standard laboratory. Yes, this is a problem to worry about, but we do keep our samples in glass so that there isn't any vapor diffusion into them.

Fitzgerald: My comment was to emphasize why it is necessary to use clean collection techniques. Seawater is very clean generally, even in impacted areas. You just can't approach that in the way which you approach other things. And, in general, you have to use clean techniques.

Gosink: I agree. Herb Weiss did some work in the Beaufort Sea His technique is very, very clean. He reported about 0.1 µg/l for Antarctic waters, and a little less than that, about half, for the Beaufort Sea. We talked to him about two or three weeks ago. He says his numbers are low, by as much as 40??, because of the heat involved in activating the mercury. So his numbers are low, but still in the literature value of about 0.03 to about 0.1 µg/l.

Prentki: You said that the level of mercury is the rate of 1-10 ppm.

Gosink: That's on the sediment, not in the water.

Prentki: That seems a little bit high compared to some of the other numbers we've seen. Is there a difference in the methods?

Gosink: I don't know. I never studied the other methods. Like I said 1, or the low side of 1 is what you normally find. We're finding about 2 and 3. And again I said that nature is Poisson, it's not a nice, symmetrical little curve.²

Prentki: Most of the other data I've seen in the report from Norton Sound, they were 0.01 to 0.2 ppm.

²See statement second paragraph of page 5.

Mercury in the Marine Environment

Prentki: *Would cinnabar be analyzed as mercury?*

Gosink: It's oxidized, strong oxidizing, permanganate, nitric acid, persulfate, it chews up everything,

Scheuhammer: *For my own information, you were speaking about the mercury levels in the sediment as being normal. Do you mean normal for offshore Alaska or do you mean normal for marine sediments in general?*

Gosink: High end of normal. I'm talking about marine sediments in general. It's **also**, as far as I am concerned, high for Alaska too. But as I said, the Yukon Valley is known to have natural cinnabar and it is dumping out into Norton Sound and is sweeping north,

Scheuhammer: *Did you have other labs working with you for quality assurance and reproducibility of results when you did all your analyses?*

Gosink: Yes. We haven't received the results yet.

Emerson: *You were saying because of the low **organics**, that was a contributory factor to not having a mercury problem, is that because of the **methylation** process or what?*

Gosink: Yes, you need **methanogenic** bacteria along with sufficient organic nutrients, and I'm talking about sewage levels or at least diluted sewage levels of organic nutrients in water, to act upon the mercury in order to produce either **dimethylmercury** or **methylmercury** chloride or hydroxide, whatever. And I see no evidence for enriched organic material out there, Certainly the **methanogenic** bacteria are there, but mercury levels just aren't high, like 50-100 or something like that,

Emerson: *Do you think that there could be a seasonal phenomenon that could contribute any **more viable organics** for that process?*

Gosink: It's conceivable, yes. But again, as far as I am concerned the places that have had troubles have been around **anthropogenic** input of sewage including mercury.

Fitzgerald: ***Methylmercury** is produced **in oligotrophic** lakes, in the water column, low in nutrients, low in organic matter.*

Gosink: It **exists** in very low concentrations and it gets picked up very rapidly by the **biota**, an order of magnitude, even two orders of magnitude faster than the inorganic mercury. So even if it's in the water column, even if they aren't hitting it, they will pick it up and enrich it.

Fitzgerald: *We really know **very little** about **methylation** of mercury in the marine environment.*

Gosink: Yes.

Tornfeldt: *When were these samples taken?*

Gosink: Mid-October,

Eisler: *Do you have any data on the relation between levels in sediments and those in sediment dwelling organisms?*

Gosink: Not for mercury, I don't,

_: *During your sampling was the dredge working on the overburden or was it actually working in a high gold bearing deposit where would you expect to find possibly different concentrations?*

Gosink: Questions and Discussion

Gosink: I have no idea. Dick, you were on there, do you know? They are still exploring, they are just making these passes.

*Prentki: My understanding is that they consider **all** the dredging to be old gold.*

_: But there is a layer where you do have a higher concentration of all of your metals. Where the gold bearing deposit is.

Prentki: They are just going out with the dredge and taking the top 7-10 m of material and it is mixed up in buckets.

*Rusanowski: We were actively **mining** at the time the samples were taken.*

*_: Did you collect and analyze **biota** and **analyze** them for total and **methylmercury**?*

Gosink: We collected a few, about five other samples. We have not received all the others that we were promised. No, we are not looking for **methylmercury**, *per se*. We are just simply looking for total.

*Emerson: The organic fraction, was that what you were basing your BOD, is that your measurement for **organics** in the sediment?*

Gosink: We did not measure **organics**. I am simply saying that the BOD is so low, that it is indicative that the **organics** are low,

*Prentki: Tom, would you like to guess whether you might have **seasonal** trends in mercury values in water?*

Gosink: There is nothing that I am aware of. You get a lot more sunlight out there and I don't know how much production goes on out there, raining down the material in spring and summer. Other things certainly change drastically between winter and summer out there. Yes, there is probably some change. Yes, in fact I've seen one study, a diurnal study, day-night study, there was a significant variation in both the total mercury but mostly in the **methylmercury**.

*Prentki: Didn't you have a problem on the cruise in that you were not able to obtain cores to the depth that the dredge was working? Do you have any feeling at **all** of what you might expect to find farther down?*

Gosink: I would expect that we would see more mercury deeper down. It's naturally percolating up and it gets slowed down by the sulfide, **virtually** stopped. But we just didn't have the time to get the right kind of coring device. You just can't lower a **vibracore** from a rolling ship and expect to get it back.

_: How far down did your cores go?

Gosink: They were only about 25 cm or so. We got the oxidized layer and the bottom portion which was anoxic.

*Emerson: Do we know that there is a relationship between bacteria that are **in** demand for oxygen and those bacteria that are involved in **methylation** of mercury? **It** seems to me quite a different potential... If you are going to make the correlation of **BOD** to potential for **methylation**, there should be some basis for that other than just the fact that they are bacteria.*

Gosink: The bacteria are undoubtedly there, but they also need organic material to work on, a significant amount of organic material to work on in conjunction with a significant amount of mercury. I just don't see a significant BOD there, and I just don't see a threatening significant amount of mercury.

*Emerson: You really won't see BOD in open ocean waters unless you are near an **organics** or sewage discharge. **We** knew we didn't have that. So I **wouldn't** expect to see **that** correlation.*

Mercury in the Marine Environment

Gosink: Right.

_: *You are talking in terms of **Minamata** with 2000 ppm.*

Gosink: Yes, as an example.

_: *I'm also interested in the lower level-type chronic events. I had understood those could occur even within the normal distribution, as **long** as **it** was at the high end.*

Gosink: Oh yes, It doesn't have to get up to 2000 ppm. The St. **Clair** River, in the Great Lakes, they were more like 100 ppm or 50 ppm or something like that. I don't think that anyone came down with a disease but it was threatening. Well it's like the radon problem. They are saying that it's 4 **picocuries** per liter. That doesn't mean that you are going to come down with cancer next year. If it gets up to about 5-10 ppm in the sediments it doesn't mean that everything is grossly contaminated. It means that you ought to consider **it**.

Prentki: *Do you have any feel if the mercury was inorganic or organic?*

Gosink: I have no feel for that. **Sathy Naidu, University** of Alaska Fairbanks, might, but I don't.

MERCURY IN SEAWATER

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Simulations of the global mercury (Hg) cycle, while often quite divergent, have generally shown the atmosphere to be the primary vehicle for the transport and dispersion of Hg at the surface of the earth (Garrels *et al.* 1975, Wollast *et al.* 1975, NAS 1978, Lantzy and MacKenzie 1979, Slemr *et al.* 1981, Slemr *et al.* 1985, Fitzgerald *et al.* 1983, Lindqvist and Rodhe 1985). Recent investigations (Table 1) place the total annual Hg flow through the atmosphere in the 25-30 megamole (5-6 x 10⁹ g) range, with perhaps a third of the Hg emissions contributed by anthropogenic activities (Slemr *et al.* 1981, Fitzgerald *et al.* 1981, Fitzgerald 1986). The pluvial Hg flux estimated at 1.7x 10⁹ g/yr is considerably larger than the average fluvial input of about 0.18 x 10⁹ g/yr to the oceans, thereby demonstrating the atmophilic nature of Hg and potential importance of atmospheric processes in affecting the distribution and transfer of Hg to the oceans from the continents (Gill and Fitzgerald 1987b). These fluxes yield a relatively short mean residence time for Hg in the ocean of 350 years using a simple steady-state box model and a mean oceanic Hg concentration of 2.5 pM (0.5 rig/t). This value, which is less than the oceanic mixing time, is indicative of a high biogeochemical reactivity and rapid removal of Hg from the water column. Thus, the vertical and horizontal distribution of Hg in the oceans will reflect the magnitude of localized sources and the intensity of removal processes in the water column.

The role of oceans in the Hg cycle is of major significance. However, marine related studies of Hg have presented a substantial analytical challenge. Consequently, there has been a very gradual increase in reliable oceanographic data for the amounts and distribution of Hg in seawater and with the determination and understanding of fundamental aspects of the marine biogeochemistry of Hg (Gill and Fitzgerald 1985, 1987a and b; 1988). Contemporary investigations incorporate modern ultra-clean trace metal protocols and techniques for the collection and analysis of Hg and Hg species in seawater. Discussion of problems and techniques associated with the accurate measurement of Hg in natural waters can be found in Gill and Fitzgerald, (op. cit.). Here we note that, in general, Hg measurements in seawater have been experimentally divided into two fractions: reactive and total Hg. Reactive Hg measurements are broadly defined as representing those species of Hg that are readily reducible (e.g. with SnCl₂) in acidified seawater. Thus, a reactive Hg determination will include dissolved inorganic species, labile organo-Hg associations, and Hg easily leached from particulate matter in the unfiltered samples. Total Hg usually refers to the amount of Hg measured in seawater samples that have been subjected to either prolonged acid digestion or strong oxidation using photochemical (Baker 1977, Olafsson 1983) or chemical means (Bloom and Creclius 1983). Operationally, the difference between a reactive and total Hg determination is a measure of the presence of stable organo-Hg associations, e.g. methyl- and dimethylmercury, which require photochemical or prolonged acid digestion to cleave covalent C-Hg bonds and liberate inorganic Hg for reduction and detection. No reliable determination of methylated Hg species in seawater has yet been accomplished. Current oceanographic investigations are revealing relatively little difference between the reactive and total Hg determinations in open ocean waters (Gill and Fitzgerald, op. cit.) and even in "clean" coastal waters (Bloom and Creclius 1963, Vandal and Fitzgerald 1988 unpublished data for Narragansett Bay),

Mercury concentrations in the low picomolar range (<20 pM) have been reported for the North Atlantic and Pacific Oceans (Gill and Fitzgerald, op. cit.; Dalziel and Yeats 1985; Olafsson 1983) for surface waters of the North Sea (Freimann and Schmidt 1982), and for the coastal northeast Pacific Ocean (Bloom and Creclius 1983). These concentrations are much lower than most earlier studies which suffered from a variety of contamination problems. Moreover, it is becoming increasingly evident that Hg concentrations in other natural waters such as lakes approach the small concentrations found in seawater (Fitzgerald and Watras 1989). Further, recent oceanographic studies (Gill and Fitzgerald, op. cit.; Gill and Bruland 1987) are beginning to reveal patterns consistent with the large atmospheric depositional fluxes and significant particle reactive behavior predicted for Hg species in seawater. Vertical profiles for Hg from the North Atlantic and North Pacific Oceans (Figures 1 and 2) illustrate major features of the marine biogeochemical cycle of Hg. The surface water concentrations of Hg from the northwest Atlantic Ocean (2.6 -6.5 pM) are generally

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higher than those in the northeast Pacific Ocean (0.95 -2.8 pM) consistent with an enhanced atmospheric supply of Hg in the northwest Atlantic Ocean. In the northeast Pacific profiles there is a striking evidence of atmospheric inputs and temporal variability in surface water concentrations.

Further evidence of the reactive nature of Hg in seawater is found in the productive waters of the central equatorial Pacific Ocean. Here, in a 1980 study, reactive Hg was found depleted in surface waters due most probably to the combined interactions of biologically mediated particulate scavenging and gas transfer of volatile Hg (elemental Hg) from the surface water to the atmosphere (Fitzgerald *et al.* 1984, Gill and Fitzgerald 1987 b). A more recent investigation (Figure 3) of the partitioning of gaseous Hg between the atmosphere and surface waters in the equatorial Pacific revealed a general pattern of supersaturation with respect to elemental Hg (Kim and Fitzgerald 1986, 1988). The highest concentrations of dissolved gaseous Hg occurred in cooler, nutrient-rich waters that characterize equatorial upwelling and enhanced biological productivity. A significant flux of elemental Hg to the atmosphere is predicted for this marine region. In summary, oceanic distributions of Hg would appear to be governed by a competition between the local source strengths (e.g. atmospheric deposition) and the intensity of water column scavenging and removal processes that include losses at the sea-air interface.

Table 1. Global Hg "Budget",

Hg Deposition	-5-6x10 ⁹ g/y - 1	Fitzgerald (1986)
	-6	Slemr <i>et al.</i> (1981)
Hg Emissions		
Anthropogenic	-2	Watson (1979)
Natural		
Volcanic	-0.06	Fitzgerald (1986)
Other Continental Sources		
Crustal degassing		
Forest fires	-1-2	By difference
Biological mobilization		
Oceanic Sources		
Equatorial Pacific	(-0.2)	Kim and Fitzgerald (1986)
World Ocean	-2	

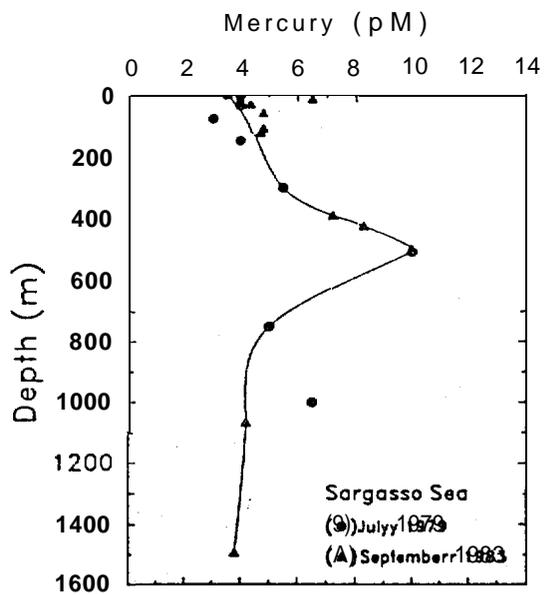


Figure 1. Vertical Hg distribution from the northwest Atlantic Ocean near Bermuda. Samples are from 34°06'N; 66°06'W July 1979 (●), and 32°04'N; 64°15'W September 1983 (▲) (after Gill and Fitzgerald 1988).

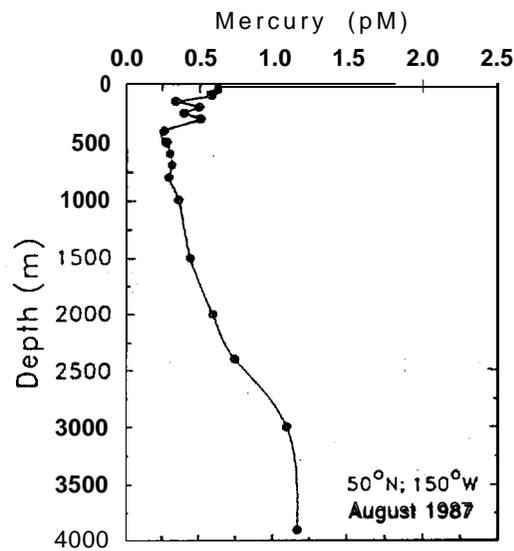


Figure 2. Vertical Hg distribution in the northeast Pacific Ocean 50°N; 150°W (after Gill and Bruland 1987).

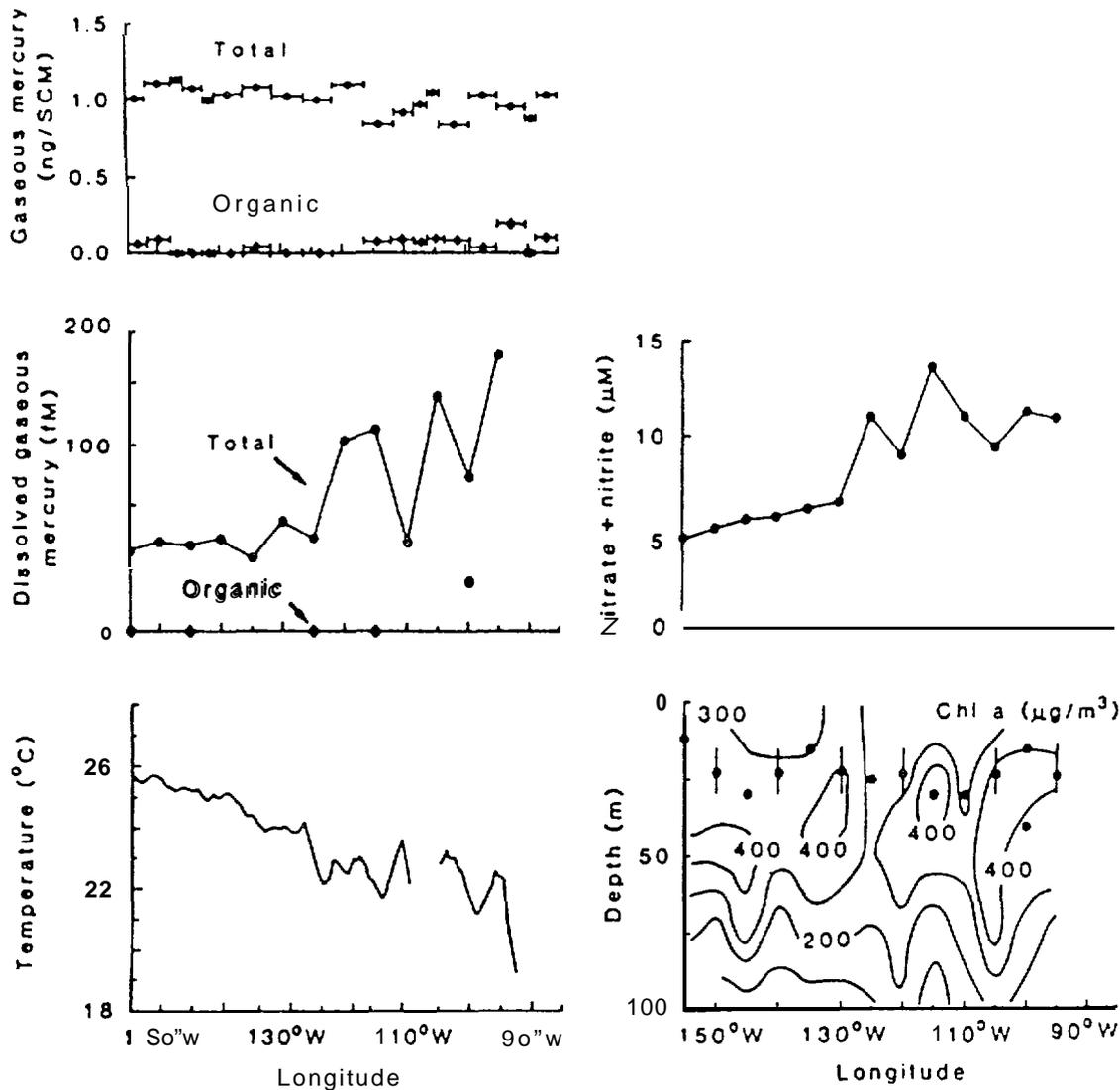


Figure 3. Experimental results from the equatorial Pacific Ocean are plotted versus longitude from 155°W to 93°W along the Equator (after Kim and Fitzgerald 1986).

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MERCURY IN SEAWATER

William F. Fitzgerald
Questions and Discussion

*Gosink: I am totally in agreement with him. You heard two **quite** different stories. The way I did my mercury ten years ago, was quite different from what you asked me to do here. You asked me to do a technique which ties my bawds behind my back. I also used **the** Go Flo Bottles that open at 10 meters underneath the surface, pre-c/caned, and I have a factor of 30 less **in my** mercury ten years ago than what **I** got in this study, because **I** was asked to adopt a different technique. **If** you are going to ask someone to do something, a standard EPA technique, and give him two weeks notice, you can 't even **clean** your bottles properly in that amount of time. **If** you want consistency, if you want to call it that, with the EPA that is what you get.*

*McCrea: Dr. Gosink was talking about **initially** having the wide range in the Poisson distribution of 1 to 10 ppm being considered a normal amount of **mercury in** seawater.*

Gosink: No, in sediments.

McCrea: In sediments. So that would not have changed over time with your better technique?

Fitzgerald: The sediment analysis should be good, in general.

*McCrea: What we saw in that slide was that the amount of **mercury** that people are now detecting in samples is going down and it is not because things are cleaner, it is because of technique.*

Fitzgerald: Yes. But that has leveled off, we are now getting mercury distributions in seawater that are **oceanographically** consistent. This has happened for all trace elements. The message, and it's a very important message, is that before 1975, you might as well disregard any trace metal data from the marine environment. Just think about the amounts of time, effort and money that went into accumulating the data that were no good, This is true for many trace metals such as iron, zinc, copper, and lead; mercury is just one trace metal.

_: Question for Dr. Gosink: Are you saying that sediment sampling data are good over the past 20 years?

*Gosink: When you have 3 orders of magnitude more **concentration** to play with, it just simplifies things in general.*

Fitzgerald: The sedimentary analysis in general is probably pretty good. This is because you are dealing with much higher concentrations, **although** it is dependent on sample size. Interstitial water is another question. Somebody mentioned core waters. Making mercury measurements in core waters may be quite challenging as well.

*_: In the marine environment, do we see a corresponding problem with mercury contamination in sediments and uptake of mercury by marine mammals that are consumed by man? You showed some examples for freshwater habitat where apparently these habitats had different conditions in the water, where you got different sediment to fish tissue **concentration** ratios. Do you see the same thing in the marina environment, particularly as you get away from some of these **highly** polluted coastal areas where you have large populations of people?*

Fitzgerald: I don't know for sure. One thing that has always puzzled me is why some open ocean tuna in the central Pacific will have mercury concentrations that approach 1 ppm in muscle. It's possible that there has been an increase in atmospheric deposition to the oceans in this century by a factor of 3-4. Whether that has some influence on the levels we see in open ocean fish, I don't know. I formerly thought that the high concentration of mercury was **obviously** natural. One interesting contrast is that lead, where almost all the lead in the ocean is anthropogenic, coming from automobile exhaust, does not concentrate in tuna. If you sample tuna flesh, the lead concentration is very low and the mercury concentration is very high, yet

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their concentrations in the water are about the same as I think that is an indication of the role the methylation processes play. You have lead at about the same water concentration as mercury, with no concentration nor amplification in the soft tissue of biota. The! , tuna have relatively low concentrations of lead, but the mercury concentration is up by a factor of 1”

Eisler: But actually there are increases in lead in tuna but it is in the vertebrae, It seems to concentrate in a different tissue. In fishes, the mercury seem accumulate in the muscle, lead in the bony tissues, and it is true for most marine vertebrates. In fact: i can make a case for different metals accumulating in different specific sites - cadmium in the viscera, etc.

Fitzgerald: That's a very good point. Lead tends to allow calcium or barium.

McCrea: Does that indicate then if there were other metals to detect in the water that it would be a good thing to look at other metals and other bone structures?

Fitzgerald: In general I would say that to look at one metal in isolation is not the best approach. You can learn from what you find for other elemental patterns. Often we have people looking only at one metal simply because one metal is so difficult to do. But if you can, it makes more sense to have additional elemental determinations.

McCrea: What would be on your menu of metals to look at?

Fitzgerald: In addition to lead, look at thallium, which I think also methylates, and see if it behaves similar to mercury.

_: You showed quite a few pathways of movement at the beginning of your talk. Do you have any budgets to go with those pathways to indicate relative importance or major trends of movement?

Fitzgerald: We have the atmospheric deposition pathways pretty well supported, including movement through the water column for the Pacific Ocean. There are now some sediment trap data that measure the flux of mercury from surface waters through the water column. These fluxes are very close to what we estimate for the atmospheric deposition. This consistency is satisfying. As far as the movement between any of the other reservoirs, we have, unfortunately, very little information. I said it was a conceptual model, because that is what we have used to formulate the experimental design.

_: Can the isotopic ratios be used to determine anthropogenic sources of mercury? Has there been any studies done on concentrations of metals in arctic haze?

Fitzgerald: You can't use isotopic ratios. Although there are five natural isotopes of mercury, it doesn't fractionate very well. It would be nice if you could, in a similar manner to lead. I don't think anyone has looked at mercury in arctic haze.

Gosink: I think Shaw and Rahn at Rhode Island have.

Fitzgerald: I know Ken Rahn. I didn't know that he had mercury data, that's interesting. It was to be done by neutron activation, and they do not usually make mercury measurements by neutron activation analysis at the University of Rhode Island.

_: Considering that MMS has to make a decision about whether or not bringing sediments that may contain mercury to the surface and disposing of them at the surface through a wash for gold mining, is going to harm the environment and potentially harm man. What type of study, what type of investigation would you recommend to get at those specific points?

Fitzgerald: That's a difficult question, I'm not sure I can answer. You can get some idea of what's going to happen by remobilizing mercury in the laboratory. It doesn't give you exact answers, it gives you a scale. If you suspend sediments in seawater and look at the increase in the dissolved particulate fraction, it gives

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you some indication of what the impact could be like. The next questions are how long is mercury remaining in the water column and how **rapidly** is it being taken up by biota? I can't answer those questions.

_: *But can you take a look at **biota directly** and see if there are alarming levels?*

Fitzgerald: Sure, you could, but you have to have the right type of **biota**. I don't feel that I can answer that type of question.

Eisler: Tomorrow.

Wright: This afternoon.

Fitzgerald: You need some indicator type of organism that responded rapidly . . .

Wright: We do it all the time, hundreds of times a year, thousands of times a year.

_: *Do you use the organisms to determine the true biological **availability** of contaminants associated with the sediment where you really don't understand the **bioavailability** process?*

_: *What I saw here is that the process is so unbelievably complicated with mercury, to get at the actual mechanisms to figure out what the end point might be may take years and years.*

Fitzgerald: Yes, and that is what you have to do to understand the process...

Wright: In effect, on page IVB44 in the DEIS, that has been done by looking at what is in the organisms in the area. I can't vouch for the values, but at least there are some numbers there. As we will talk about later, there are some additional ways of getting at it. This is one way to look at what is in the animals everyday.

*Emerson: I think there were some numbers indicating some of the **speciation** pathways and that sort of thing and the **methylation** process. Could you give any indication as what percentage of the **methylation** process is occurring in the bottom sediments as opposed to the water column?*

Fitzgerald: . . .**more** data for lakes where they are looking at the **methylation** occurring in the water column and in the sediment. In terms of the scale, I don't remember, but I'd say that they are at least comparable. You have as much potential of producing **methylmercury** in the water column as you have in the sediments. Then the question is "can you remobilize it?"

*Emerson: Is it conceivable that in previous talks, where we were **talking** about **organics** being a key factor in the **methylation** process, that maybe we need to be looking at the organics associated with the sediments at that interface, as opposed to **BODs** for example, and suspended fractions?*

Fitzgerald: It's not **very** hard to identify **organics**, but it's not something that can be ignored, The point that I was making was that in the lakes, we were surprised that what we considered to be a total measurement of mercury, strong acid digestion, was not. When we added the bromine **monochloride**, which is a much stronger oxidizing agent, we have a lot of mercury being released. We now have analyses of **methylmercury**, which were made in the water, and these represent a very small fraction of the total mercury, so that cannot account for that large amount of mercury released in strong oxidation. That fraction represents the bulk of the **mercury**. It has to be a primary player in what's going on and we know nothing about it, frankly. I was very surprised to see it, because in the open ocean you see very little difference when you add a strong oxidizing agent. If you simply just digest the sample in acid over an extended period of time and then you oxidize that sample, you see no difference in these two measurements. And that's within **10%**, so you don't find a strongly organically bound fraction in the oceans as we find in freshwater. So in between these two regimes you should see some of that. I would be particularly interested in what role sulfur plays in this (**organosulfides, cysteine**), and what role this has in the **biogeochemistry** of mercury? Again we can now ask these questions, because we are getting data that allow us to speculate more on what's happening,

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rather than finding just how much is there.

*Emerson: We didn't do total **organics** with the sediments analysis?*

*Gosink: No, we were not asked to do any **organics** in the sediments.*

Fitzgerald: There is a very strong correlation with mercury. I've not done much in the way of sediment analyses, but in the lake work, there is an absolute correlation with organic matter. As the organic matter goes up, the **mercury** concentration goes up.

*Prentki: One paper references **methylation**, where mercuric sulfide is photo-oxidized into **methylmercury** through disturbing sediments contained in the **water column**. Have you heard of that?*

Fitzgerald: You can't do that. You have to **methylate** it someplace along the line. All that means is if you had mercuric **sulfide** being remobilized, oxidized, then it could be **methylated**.

*Prentki: Australian gold mines have used **mercury** amalgamation and/or cyanide. When they go back and try to analyze the sediments for mercury and use metallic mercury in the processing, they did not chemically identify the metallic **mercury** as coming **through** the uninhabited portion even though they think they can see some liquid mercury in the stock?*

Fitzgerald: You mean they can't measure it?

Prentki: It doesn't react with the chlorides,

Fitzgerald: They have to dissolve it. You would reduce ionic mercury to elemental mercury by adding tin chloride.

Prentki: Well, they are using it somehow.

Fitzgerald: They have to dissolve the mercury, the elemental mercury, then reduce it. You don't really have to do that, you just purge elemental mercury out and analyze it directly.

*Prentki: I think they did something like that. **It** works for most sediments, but it did not work for Norton Sound for some reason.*

Fitzgerald: Well, did they see elemental mercury?

*Prentki: They think they detected it. They know it **was** used, they don't think it changes form that quickly.*

Fitzgerald: There's something peculiar with the whole thing. That shouldn't be too difficult an analysis...

GENERAL DISCUSSION
TUESDAY MORNING, NOVEMBER 129, 1988

Prentki: One of the topics that I would like to have our speakers discuss with audience participation is whether with what we've heard about mercury analysis, is it possible to use EPA's methodology at the limit of detection that the EPA requires, 0.025 ppb? If not, what techniques should be used and is it feasible at all to monitor mercury levels in a dredging situation? Should we just drop that and try to use biological samples to look for accumulation? I'd like Tom Gosink to please describe what the EPA Method is.

Gosink: in brief the EPA technique simply says, you assume you have a clean bottle, that you go out there and you get some water and you dump about 2-3 cc of nitric acid in. Some people will say just sulfuric acid, nitric acid is a little safer, in that you keep things oxidized and you try and prevent them from going into the wall of the bottle. The EPA doesn't say anything about whether it should be a glass bottle or a plastic bottle. I'd highly recommend that it be a glass bottle. The big problem is bringing it back to the laboratory where somebody broke a thermometer last year and there is mercury in there. The longer you wait the more mercury vapor goes through that plastic bottle wall or maybe that plastic bottle cap and contaminates your sample. The EPA technique says **take 100 ml** of this water, acid digest it in a BOD bottle and pass it either through an atomic absorption (AA) device or this little mercury analyzer system. It's inadequate, it's totally inadequate. I used to use 1 liter samples. I used to use dithizone extracts. I used to use the Go Flo bottles that opened up 10 m below the water and then came back up to the surface. This is the way you have to go out there and start to approach this thing, but you are going to lose this whole body of information **about** this EPA technique. You are going to have to set up something new, you are going to have this curve going along and all of a sudden there is going to be this drop, by at least an order of magnitude, by doing this. You are opening yourself up to risk. Do you want to abandon this base of literature, or do you want to go through with it? I would say that you definitely need to filter the water because the suspended load is so highly variable. You want to know what's dissolved in the water and you still need to know what's in the suspended load. You need to do two analyses, on the suspended particulate and on the water. You need to go to a liter sample, that is, extracting the mercury from that, rather than taking this **100 ml** and pushing it through the standard EPA technique. Almost everybody I see in the literature these days that have the very low concentration detection limits are using a liter of water and they are **preconcentrating** it on gold foil. It either goes into an AA device or in some cases it goes to a gas chromatography (GC) device. If you want **methylmercury** it's almost invariably extracting it into some benzene and shooting it through an ECD-type of gas phase chromatography. You can get down to those concentrations with an **ECD-type** of detector. It's always been known that the simplest part, the grunt work, going out and collecting the samples, is where you can mess up the worst. You've got to have experienced people out there collecting the samples or it's lost. No matter how clean your laboratory environment is, how good your technique is back at the laboratory, unless you get a good clean sample to begin with, forget it.

Prentki: Dr. Fitzgerald, would you like to add to that?

Fitzgerald: In general, I agree, but there have been some additional improvements in technology that make rapid analysis possible. And that's a combination of gold trapping and atomic fluorescence analysis. Atomic fluorescence is much more sensitive than atomic **absorption** by about a factor of 100, So it is possible to use **100 ml** sample, collected **carefully** as you indicated, and filter and separate into a dissolved fraction and particulate fraction,

Prentki: Are there **very** many labs that can do the analysis to the level you are talking about or is that a limitation?

Fitzgerald: **There** are not a lot in the United States, maybe less than ten, maybe less than five, with a lot of experience.

Prentki: Is this something that you would recommend that rather than going to someone and giving them X amount of dollars to start up his own lab that you go to an experienced lab?

Fitzgerald: Yes.

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Prentki: Is mercury more of a problem than other trace metals that way?

Fitzgerald: It is a little different because the gas phase is so important. Ordinary clean laboratories are not necessarily clean from a mercury point of view because gaseous mercury will pass through the filters. In general, the techniques that you would use for lead are **perfectly** all right.

Prentki: One of the concerns that has been raised here in Alaska about trying to do low levels of mercury is that the reagents have too much mercury in themselves. Is there a way that they can avoid that? I have seen some reports where they are getting 50 ppm mercury in some of the reagents.

Fitzgerald: It is part of the normal protocol that all of your reagents must have very low amounts of metals. You have to start out **with** very low quantities. That's just standard analytical procedure, it can be done, but you have to be careful.

Ordinary chemical laboratories which use mercury can have 30,000 nanograms per cubic meter of atmosphere. Ordinary air outside this building is 3. So you go up by about a factor of 10,000. So if you work in a laboratory like that with acidified solution and you talk about levels of **picomolar**, you very quickly add mercury from the atmosphere.

Prentki: I would guess, maybe trying to force a conclusion on you both, if you take good care and use a proper laboratory with experience in these techniques, then we could probably get **useable** data in the monitoring program.

Fitzgerald: Yes absolutely. We are doing this right now in Wisconsin; we are looking at five lakes and making total mercury measurements. We are able to separate the dissolved fraction and measure **methylmercury** in the water column, sediments, the interstitial water, and look at the air-sea transfer. This is done on a routine basis. We are getting measurements every month.

Prentki: Do sulfides, **organics** in interstitial waters cause any particular problems with metals?

Fitzgerald: Yes.

Prentki: I believe that is one of the problems that they have had **with** some of the water column data from the **Bima**, at least this summer when they are working in deeper water sediments. They are apparently getting some organic interference from the sediments mixed with the water.

Fitzgerald: In atomic absorption, one of the problems is **organics**, and in the analysis you may volatilize **organics** that interfere with mercury. So you may be looking at a decrease in transmission. Whereas in atomic fluorescence, you look at fluorescence of mercury, so it is specific analysis. The fluorescence technique alleviates some of the problems that you sometimes run into with atomic absorption analyses with high sulfides and high **organics**.

Prentki: Do either one of you have a feel for how reactive cinnabar would be in the oxidized, reduced sediments to the water column?

Gosink: It's quite labile. It changes form. The sulfide to the oxide to the free is a facile move.

Prentki: How about metallic mercury, would you expect that to persist in the sediments if they are somewhat reduced or would you expect that to be converted at some rate of speed to a different form?

Gosink: Metallic mercury is known to occur naturally in very small quantities. It just depends on the amount of sulfides there, as to whether it's going to stay that way or go back to sulfides.

Prentki: Is there a difference between authigenic cinnabar in that aspect and the stuff that has been incorporated in older mineral forms, Cinnabar formed *in situ* in the sediments versus that which may have come in **detrital** matter. Is that perhaps a stronger mineral form?

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Gosink: I have no idea. I would say that they would be about the same. It depends on whether it is trapped in other materials.

Hansen, David: What would you say the difference would be in quantifying mercury concentrations in water using total recoverable methodology that you referred to as the EPA methodology that is recommended by Cincinnati and the acid extractable methodology which is the recommended method within the Water Quality Criteria?

Gosink: I'm not sure I know what the acid extractable technique is. Can you define that?

Hansen, David: Well, it asks for the addition of nitric acid, pH 1.5-2...

Gosink: Standard fitter preservation?

Hansen, David: Filtration within a period of 1/2 hour to 24 hours.

Gosink: You can lose it to the walls quite rapidly if you don't process it on the ship right away, like in a matter of 1/2 hour to an hour or two.

Hansen, David: It's immediate acidification.

Emerson: You do a rinse on the container, don't you?

Gosink: Oh, sure. You've got precleaned, soaked bottles that you are using...

Emerson: It's not necessary to process the samples within a 45 min period...

Gosink: It's not that critical but you don't want to let it sit there till the next day and then process it

Emerson: Were you suggesting that we use glass process containers?

Gosink: Yes.

Emerson: I thought we kind of had a problem with borosilica glass leaching fractions?

Gosink: Generally when you are dealing with all the other trace metals you prefer to go to plastic. The danger with plastic and mercury is that if you are going to come into a contaminated lab, a broken thermometer or they have been dropping mercury electrodes, and it is going to sit around for a while, the sample will pick up mercury. If you come in and do it the next day or the next two days or something like that there is no problem. But if you are going to let it sit there for a week or a month, mercury will diffuse through plastic,

_____It comes in from the air?

Gosink: Yes, if you have a contaminated lab.

Emerson: I think Patterson at the California Institute of Technology has solved the problem for trace amounts of lead in the air. He probably has the best analytical clean technique available.

Gosink: This vapor problem is unique for mercury.

Fitzgerald: Not so much with it going through the sides of the vessel, but around the cap. Therefore, you have to hermetically seal these bottles. We've always used teflon bottles. It takes two weeks to clean a bottle. With teflon it is very expensive to begin with, but we have found over a number of years that it is less expensive. We number every bottle, and they all are logged. If you get an unusual concentration, you

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can reprocess the same bottle to see if there is a problem with it. You must trace down unusual data. That is the only way you can figure out what's going on.

Gosink: An ordinary mercury analysis is roughly five times more expensive than say zinc or calcium type of analysis. **With** the technique that we are talking about here, we are talking another factor of five more expensive. It requires that much more care in order to prepare these bottles and to carry it through. And the longer you wait between collection and analysis the bigger the problems get to be. It can go both ways, you can lose it to the walls as well as stuff coming in, double bagging and everything else like this is one way of getting around it.

Fitzgerald: As a matter of fact, Gary Gill already did a lot of this work. He looked at samples sealed for over a year and a half, samples of seawater with spiked amounts of mercury, and they didn't change much over the year and a half.

Gosink: We spiked some of our samples out there and we did not see any increase or decrease in quite a few weeks or even the beginning of the week when we started the analysis and the following week when we did the replicate,

Emerson: Will some of our samples be going to an **intercalibration** lab?

Gosink: We **will** be getting some U.S. Geological **Survey** (USGS) analyses to compare with. We have not seen any of their data yet.

Emerson: Are they part of an **intercalibration** effort? You don't have that ongoing then? It is not like the lead study at CalTech?

Gosink: No. Not for this quick study that you authorized last month.

Emerson: I mean just for standardization of samples; is anybody standardized here?

Gosink: Nobody has standardized us. They came to us quickly and said can you go out in two weeks and do this,

Emerson: You can always do the sample later.

Gosink: Yes, we have replicates sitting around that we can send out.

Prentki: USGS is doing water analysis also?

Gosink: They are doing water, sediment, and I think they are doing **a few biota**.

Prentki: So you have comparison with their mercury numbers? Also, I believe that WestGold took water splits too.

Gosink: Who?

Prentki: WestGold, the **Bima** folks.

Gosink: Not from me they didn't.

Prentki: They took some by the dredge, I think they were going to do some trace metal analysis with those water samples.

Rusanowski: We were on the same cruise that obtained some splits and some duplicate samples that we are running through our laboratory.

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Prentki: So we will have **intercomparison** of at least three different labs. Do you know what technique USGS is using?

Gosink: They are using our samples and they are running them through an **AA** device. Whet exactly I don't know.

Prentki: So we will have some sort of **intercomparison** but it's not with a gold foil technique. Another question I would like you to address, under the current monitoring requirements for the **Bima** that's out there now in state waters, the EPA is having them composite samples over a period of four days to a week in order to essentially not have to analyze multiple samples a day or multiple samples a week. With **compositing**, is there any way to do that and still come up with good numbers, with the low levels of mercury that you would expect to find? They are **compositing** samples too, rather than have to analyze every day, maybe just get one analysis they can do per week?

Fitzgerald: They certainly could save the samples, save them each day.

Prentki: Rether than five, just do one. How would you have to preserve them or treat them?

Fitzgerald: You could **filter** the samples, acidify them, and put them in sealed bottles, and then do them whenever you want.

Prentki: Okay, so you could mix them up later?

Fitzgerald: It's no problem.

Prentki: But the samples shouldn't be staying out there the whole week to get the last 100 *ml*?

Fitzgerald: Take a sample and seal it and put it away **and analyze** if **at** your leisure. You don't have to do it right away.

Prentki: Another thing they are having them do under their permit, on samples coming out of the dredging effluent, they are supposed to allow the samples to settle out?

Fitzgerald: Maybe I misunderstood what you just asked about preserving composite samples? Why would you want to do this? You really want to see what is happening day by day.

Prentki: When you have a long term monitoring program, which is going to go on for three years, it gets very expensive if you are requiring samples every day. What the EPA has done, and Paul might want to correct me on this, is they initially require samples every day, then after a certain time period, if it doesn't show any problem, they allow you to go to weekly composites.

Rusanowski: We use a 24-hour composite technique, so the samples are only composite over that time interval, that constitutes one analysis. But **it** is done daily for **fifteen** days, then weekly after that. So we have one composite sample per week, that only represents a 24-hour time interval within that week.

Prentki: Another thing they are having the monitoring program do is when they get samples of the dredge effluent, with all the solids in it, they are having them analyze only the **non-settleable** fraction. They allow the sample to settle for an hour before they decant it off and analyze the stuff that is decanted. Do you foresee any problems with that technique? Is it glass fibrous **filters** you usually use for **filtering** these samples?

Fitzgerald: Yes.

Emerson: Were the numbers on the sediments, mercury content, were those total digested or acid extracted or how were those numbers generated?

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Gosink: I think Sathy **Naidu** did an acetic acid **hydroxylamine** extract, that is the available surface metals. Then gave that to **me**. We oxidized it, put it in nitric acid. There were still some **organics** in it, because I had to do a lot of digestion to tear up that organic to get to these numbers, I want to go back and just take a few dry sediments and do the straight EPA Method which puts it in a little aqua **regia** for a few minutes and then goes through the usual procedure and see if there is any significant change.

Emerson: It would be interesting to see if we make assumptions on what's biologically available by your acetic acid extraction and your aqua **regia**; what the total mercury number might be, total sediment digestion number.

Gosink: No, we did not do a total digestion, I don't know if that is really necessary because...

Emerson: I wouldn't say it would be all the time, maybe we might want to know,...

Gosink: I mean it's just another criterion, If you want a complete study, it all costs time and money to do these extra steps.

Prentki: Are you talking about a sodium fusion rate or something like that?

Emerson: I was saying a simple acid digestion, heat it up, dissolve it and run it through the same analytical process you are doing with everything else. Sediment is pretty small, pretty fine, and when we are dealing with clay fractions,...

Gosink: Mostly clays, some sands, yes.

Emerson: Those readily digest.

Gosink: Yes.

Emerson: You've done most of your work already?

Gosink: Yes,

_: You want total **settleables**, the dissolved mercury, is that what you are after?

Emerson: No. If you have particles down on the sediment-seawater interface and the animal eats that particle or something, you make an assumption as to what happens with the associated heavy metals that go through the digestive tract, how "much is digested off the surface of the particles?"

Hansen, David: Just measure the animals directly . . .

Emerson: You can't always determine the relationship and you don't always have animals available to measure in terms of what is happening, in long-term monitoring. You get an index of sediment and seawater levels and that may or may not equate to some level of mercury in the particular marine organism.

Gosink: I would say that the data in the literature say that there is a good relationship between total of any kind of metals in sediments and availability. There are too many factors that are sediment specific that are controlling the availability, so I don't think you can answer that question,

Emerson: [t's just another piece of information that's readily obtained, You've taken the samples. You filtered it off, and you've got what you think is biologically available with your extraction technique, Wouldn't you be curious to know what the total mercury budget is within that sediment fraction? if you model the system, wouldn't you want to know that number?

REGULATION OF MERCURY LEVELS IN WATER AND DREDGED SEDIMENTS

MERCURY: TOXICITY, BIOACCUMULATION, AND DERIVATION OF AQUATIC LIFE WATER QUALITY CRITERION

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INTRODUCTION

This report summarizes (1) aquatic toxicological and **bioaccumulation** properties of mercury as contained in the U.S. Environmental Protection Agency water quality criteria (**WQC**) document published in January 1985 (U.S. EPA 1985); (2) the guidelines for derivation of WQC concentrations (Stephan et al. 1985) as applied to mercury; and (3) the implications of the properties of mercury and the WQC relative to the presence of mercury in water, sediment, and **biota** of Norton Sound, Alaska.

ACUTE TOXICITY AND CRITERIA MAXIMUM CONCENTRATION

The acute toxicity of inorganic mercury to freshwater and saltwater aquatic life is summarized in Table 1 in the criteria document. Acute values from a total of 44 tests, using 30 freshwater species, and 56 tests using 32 saltwater species, are listed in this table. The acute values, 48 or **96** hr EC50s or **LC50s**, range from 2.2 to 2,000 $\mu\text{g/l}$ for freshwater and 3.5 to 1,678 $\mu\text{g/l}$ for saltwater species; factors of 900X and 480X, respectively. Invertebrates, including arthropods and **molluscs**, are most sensitive. Ten of the 11 most sensitive freshwater genera and 10 of 10 of the most **sensitive** saltwater genera are invertebrates (Figure 1). **Similarity** in acute sensitivities of freshwater and saltwater genera suggests that the toxicity of mercury to species from both aquatic habitats may be relevant to assessing toxicological concerns associated with mercury concentrations in Norton Sound,

The Criteria Maximum Concentration (**CMC**) is one of the two concentrations **listed** in the criterion statement for saltwater aquatic life in the WQC document (U.S. EPA 1985, p. 23 and 24). It is derived using a statistical methodology detailed in the "national WQC guidelines" (Stephan *et al.* 1985). This methodology uses the rank order of the acute sensitivity of genera (Figure 1), the acute values for the four most sensitive genera, and the total number of genera tested to calculate, using modified regression analysis, the Final Acute Value (**FAV**). This value represents that concentration above which 95% of the acute values for genera would occur. Using this procedure, the FAV is 4.1 $\mu\text{g/l}$ for saltwater aquatic life. Division of this FAV by two, the average ratio of LC50 to LCO, results in a CMC of 2.1 $\mu\text{g/l}$ for saltwater aquatic life. The intent of the guidelines methodology is to develop a criterion that protects most aquatic species most of the time and not all of the species all of the time from acutely lethal concentrations of a substance. This intent is reasonable because communities are resilient and can recover from minimal insults.

CHRONIC TOXICIN AND FINAL CHRONIC VALUES

The chronic toxicity of mercury to freshwater and saltwater aquatic life is summarized in Table 2 in the WQC document, and Table 1 and Figure 2 in this report. The only **saltwater** species tested chronically is the mysid, *Mysidopsis bahia* (Lussier *et al.* 1985). Freshwater fish and amphibians are more chronically sensitive to inorganic mercury than are freshwater and saltwater invertebrates. This is the reverse of the order of acute **sensitivity**; invertebrates are most acutely sensitive. As a result, acute-chronic ratios are low, 3.1 for mysids, and 3.9 and 5.2 for cladocerans (*Daphnia magna*), and high, **>646** and **>652**, for fathead minnows (*Pimephales promelas*). The most sensitive chronic effect of mercury on aquatic life is to reduce reproduction in life-cycle tests and to increase incidence of mortality and deformities in tests with embryos and larvae of several fish species and a toad.

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Table 1. Acute and chronic toxicity of inorganic mercury II and methylmercury to freshwater and saltwater organisms. Chronic toxicity tests include early life-stage (ELS), life-cycle (LC), and other tests.

Test ¹⁾	Acute Value g/L	Chronic Value g/L	Acute Chronic Ratio ²⁾	Effect	
Mercury II					
Freshwater:					
Cladoceran, <u>Daphnia magna</u>	LC (FT)	5	0.96	5.2	Reproduction
Cladoceran, <u>Daphnia magna</u>	LC (R)	5	1.3	5.9	Reproduction
Fathead Minnow, <u>Pimephales promelas</u>	ELS	150	<0.23	>646	Weight
Fathead Minnow, <u>Pimephales promelas</u>	LC	168	<0.26	>652	Weight
Rainbow Trout, <u>Salmo gairdneri</u>	28 day	-	<0.1		Survival, Deformity
Goldfish, <u>Carassius auratus</u>	7 day		0.7		Survival, Deformity
Channel Catfish, <u>Ictalurus punctatus</u>	10 day		0.3		Survival, Deformity
Toad, <u>Xenopus laevis</u>	11 mos	-	0.16		Survival
Saltwater:					
Mysid, <u>Mysidopsis bahia</u>	LC	3.5	1.1	3.1	Reproduction, Survival
Methylmercury					
Freshwater:					
Cladoceran, <u>Daphnia magna</u>	LC (FT)	-	<0.04		Reproduction
Cladoceran, <u>Daphnia magna</u>	LC (R)		0.67		Survival
Rainbow Trout, <u>Salmo gairdneri</u>	24 day		5.0		Survival, Deformity
Brook Trout, <u>Salvelinus fontinalis</u>	LC	74	0.52	140	Reproduction, Weight Deformity
1) FT = flow-through exposure, and R = renewal exposure. 2) Dashed line indicates that no acute-chronic ratio was calculated because no acute value was available or the chronic test did not meet requirements of the national WQC guidelines.					

Methylmercury may be more acutely and chronically toxic than inorganic mercury in some, but not all, species (Table 2). Effects on reproduction and increased incidence of deformities were also common in chronic toxicity tests with methylmercury (Table 1). There are apparent discrepancies in results of tests using flow-through and renewal exposures of methylmercury to *D. magna* (Biesinger *et al.* 1982). Although methylmercury was added at the start of the renewal period in the test, measurement of test solutions indicated that it was rapidly demethylated to inorganic mercury. The chronic value of 0.67 µg/l from this test is similar to the two chronic values of 0.96 and 1.3 µg/l from inorganic mercury life-cycle tests with *D. magna*. This process may have occurred in other experiments, confounding conclusions concerning the relative toxicities of organic and inorganic mercury.

The Final Chronic Value (FCV) is the concentration derived using the national WQC guidelines intended to protect aquatic life from the chronic effects of substances. For mercury, the FCV was calculated by dividing the Final Acute Value by the Final Acute-Chronic Ratio (geometric mean of the acute-chronic ratio for acutely sensitive *Daphnia magna* of 4.498 and *Mysidopsis bahia* of 3.095) of 3,731. This results in a FCV of 1.1 µg/l for saltwater aquatic life. This value is greater than concentrations of mercury known to adversely affect freshwater fishes (Table 1). The FCV was not lowered in the criteria document to protect saltwater fishes because data on the chronic toxicity of inorganic and organic mercury to saltwater fishes are not available.

TOXICITY TO PLANTS

Inorganic mercury is not as toxic to saltwater plants (Table 3) as it is to animals. EC50 values are 10 µg/l for two species of phytoplankton, 45 to 160 µg/l in 10-day tests for five seaweeds, and 50 µg/l in a 10-day test with kelp.

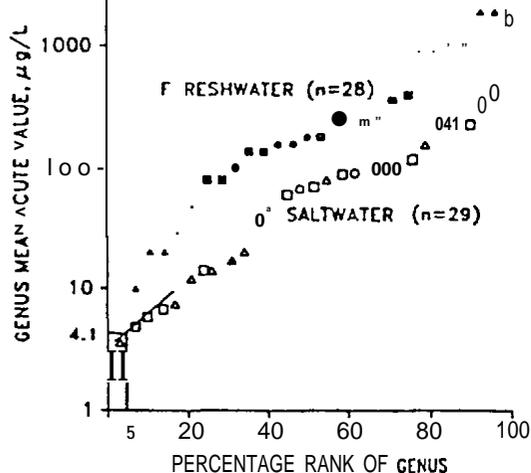


Figure 1. Genus Mean Acute Values for freshwater (shaded symbols) and saltwater (open symbols) aquatic life from Table 3 of the January 1985 WQC.

Arthropods = A, other invertebrates = □, and fishes = O. The Final Acute Value at the five percentile rank of species is 4.1 µg/l.

BIOACCUMULATION AND FINAL RESIDUE VALUE

Bioaccumulation and methylation are probably the most significant environmental properties of mercury. In aquatic ecosystems, bioconcentration of mercury from water and biomagnification from food are both important contributors to the total bioaccumulation of mercury in aquatic life. Bioconcentration Factors (BCF), concentration in organisms divided by concentrations in water, range from 1,800 to 10,000 for inorganic mercury, and from 10,000 to 85,700 for methylmercury in the eastern oyster and fishes (Table 44). The BCF of 129 for the lobster is consistent with the generally low accumulation of the other metals by crustaceans and with low mercury concentrations in king crabs from Norton Sound. BCF values for fishes end molluscs are high because uptake of mercury is rapid and depuration rates are slow. The depuration half-life is two to three years in brook trout and may be mostly due to growth dilution. McKim et al. (1976) observed that brook trout exposed in life-cycle tests to concentrations of methylmercury ≤ 0.29 µg/l were not affected, whereas fish exposed to ≥ 0.03 µg/l contained concentrations of methylmercury greater than the 1.0 mg/kg FDA action level. At low temperatures, uptake, depuration, and BCF of mercury decrease; a factor to consider in Norton Sound. Importantly, inorganic mercury is typically the dominant form in ambient water, methylmercury is the form most toxic to avian and mammalian consumers of aquatic life, and methylmercury typically predominates

Table 2. Comparison of acute and chronic toxicities of mercury II and methylmercury.

Species	Duration/ End point ¹⁾	Concentration, g/l	
		Mercury II	Methylmercury
<i>Chlorella vulgaris</i>	15d EC50	-500.0	-2.0
<i>Daphnia magna</i>	Chronic Value (RM)	1.3	0.67
<i>Daphnia magna</i>	Chronic Value (FTM)	0.96	<0.04
<i>Salmo gairdneri</i>	96h LC50	155 to 420	24 to 85
<i>Salmo gairdneri</i>	24 to 28d (Terata)	-5.0	-5.0
<i>Fundulus heteroclitus</i>	96h EC50	67.0	51.0
<i>Rana pipens</i>	5 to 7d LC/EC50	7.3	8 to 16

1) RM = Renewal exposure with concentrations measured; FTM = flow-through exposure with concentrations measured.

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in tissues of naturally occurring aquatic organisms. It is this **methylation** of inorganic mercury to **methylmercury** in aquatic environments and its **bioaccumulation** in wildlife and human food chains that poses the greatest risks.

The Final Residue Value (FRV) is the concentration intended to protect the uses of aquatic life; i.e. marketability and use of aquatic life as prey of wildlife consumers. To maintain marketability of fish and shellfish, **methylmercury** concentrations must not exceed 1.0 **mg/kg** (wet weight) in edible tissues (U.S. FDA 1984). Mercury concentrations of 5 to 7 **mg/kg** in brook trout were associated with deaths of trout (McKim *et al.* 1976). In addition, ≥ 1 **mg/kg** of mercury in diets proved detrimental to mink (Wobeser *et al.* 1976a,b) and birds (see Scheuhammer, this document). The FRV in the mercury criteria document is derived by dividing the 1.0 **mg/kg** FDA action level by the eastern oyster BCF for **methylmercury** of 40,000. The FRV for **methylmercury** in saltwater is 0.025 $\mu\text{g/l}$. Discussion at the workshop indicated that the FDA may have abolished the action level for **methylmercury**¹. In addition, dietary effects of **methylmercury** on birds and mink at about 1.0 **mg/kg** suggest that a FRV derived, using data from wildlife feeding studies, would be similar to that derived using the FDA action level,

WATER QUALITY CRITERION

The aquatic toxicological and **bioaccumulation** properties of mercury and the criteria derivation process as summarized above were used by the EPA to formulate the criterion statement for saltwater aquatic life for mercury. The Criteria Maximum Concentration (CMC) is 4.1 $\mu\text{g/l}$. The Criteria Continuous Concentration (CCC), the lower of the FCV and FRV, is 0.025 $\mu\text{g/l}$. These concentrations are less than criteria maximum and continuous concentrations for other metals (Table 5). The saltwater criterion statement for mercury is: "The procedures described in the 'Guidelines for Deriving Numerical National Water Quality Criteria for the Protection of Aquatic Organisms and Their Uses' indicate that, except where a locally important species is very sensitive, saltwater aquatic organisms and their uses should not be affected unacceptably if the four-day average concentration of mercury does not exceed 0.025 $\mu\text{g/l}$ more than once every three years on the average, and if the one hour average concentration does not exceed 2.1 $\mu\text{g/l}$ more than once every three years on the average. If the four-day average concentration exceeds 0.025 $\mu\text{g/l}$ more than once in a three-year period, the edible portion of consumed species should be analyzed to determine whether the concentration of **methylmercury** exceeds the FDA action level,"

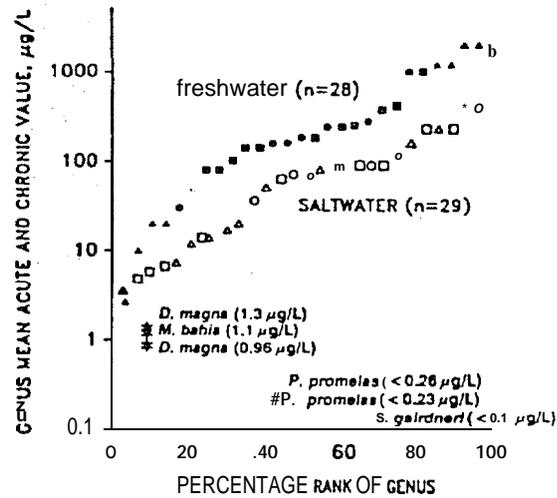


Figure 2. Genus Mean Acute Values and Chronic Values for freshwater (solid symbols) and saltwater (open symbols) aquatic life from Table 3 of the January 1985 WQC.

Arthropods = A, other invertebrates = □, and fishes = O. Chronic values (*) from life-cycle or early life-stage tests are positioned immediately below the acute value for that genus.

¹Upon my return to Rhode Island, I called the U.S. FDA in Davisville, R.I. and they confirmed that their latest Compliance Policy Guide 7108.07 published in March 1987 maintains the 1.0 ppm limit and no other guidance has been published since that date.

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of Aquatic Life Water Quality Criterion

Table 3. Toxicity of inorganic mercury to saltwater plants.

Species	Exposure Duration	Effect	Content ratio 9/1
	(days)		
Alga, <u>Thalassiosira aestivalis</u> <u>Ditylum brightwellii</u>	5	Reduced Chlorophyll EC50	10 10
Seaweed, <u>Fucus seratus</u> <u>F. spiralis</u> <u>F. vesiculosus</u> <u>Pelvetia canaliculata</u> <u>Ascophyllum nodosum</u>	10 10 10 10 10	EC50 EC50 EC50 EC50 EC50	160 80 45 130 100
Kelp, <u>Macrocystis pyrifera</u>	4	EC50	50

Table 4. Bioconcentration factors of mercury in freshwater and saltwater organisms. Bioconcentration factors (BCFs) are the ratios of concentrations measured in tissues divided by concentrations in water.

Species	Tissue	Exposure Duration	BCF
		(days)	
	(Mercury II)		
Freshwater:			
Rainbow Trout, <u>Salmo gairdneri</u>	Whole body	60	1,800
Fathead Minnow, <u>Pimephales promelas</u>	Whole body	287	5,000
Saltwater:			
Eastern oyster, <u>Crassostrea virginica</u>	Soft parts	74	10,000
American lobster, <u>Homarus americanus</u>	Tail muscle	30	129
	(Methylmercury)		
Freshwater:			
Rainbow Trout, <u>Salmo gairdneri</u>	Whole body	60	11,000
Rainbow Trout, <u>Salmo gairdneri</u>	whole body	75	85,700
Brook Trout, <u>Salvelinus fontinalis</u>	Muscle	273	11,000-33,000
Brook Trout, <u>Salvelinus fontinalis</u>	Whole body	273	10,000-23,000
Brook Trout, <u>Salvelinus fontinalis</u>	Muscle, Whole body	756	12,000
Fathead Minnow, <u>Pimephales promelas</u>	Whole body	336	44,000-82,000
Saltwater:			
Eastern oyster, <u>Crassostrea virginica</u>	Soft parts	74	40,000

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The criteria document provides guidance on measurement of mercury in water, The document states that an "acid-soluble" method would provide a more scientifically correct basis for establishment of criteria for metals. However, the EPA has no approved methodology for an acid-soluble measurement. Until such time as this or other procedures for measurement of the biologically reactive concentrations of metals are developed, the criteria document recommends use of the total recoverable methodology for analysis of ambient water or effluents. The EPA recognizes that metals concentrations based on the total recoverable analytical procedure may be over-protective and that the sensitivities of local species may differ from that of species in the criteria document. Therefore, the EPA provides guidance on procedures for derivation of site-specific water quality criteria (U.S. EPA 1982).

Concentrations of total recoverable mercury in water from Norton Sound exceed 0,025 $\mu\text{g/l}$. However, analytical methods used to derive these concentrations should be scrutinized (see Fitzgerald, this document). The most direct procedure for determining if bioavailable concentrations of mercury are excessive is to measure concentrations of methylmercury in local biota as suggested in the criteria statement. Chemical analysis of methylmercury in biota of Norton Sound should emphasize commercial seafood relative to the FDA action level and dominant prey species of local birds and mammals relative to dietary effects concentrations. Limited data available on concentrations of mercury in aquatic life from Norton Sound suggest that ecological risks may be minimal and the FDA action level is not exceeded. This conclusion must be tentative because data on total mercury concentrations in king crab predominate, arthropods are generally poor bioaccumulators of metals, and no data are available on methylmercury concentrations. Additional analysis on fishes, molluscs, and other species would be valuable. In addition, monitoring of methylmercury concentrations in feathers of raptorial birds (see Scheuhammer, this document) and hairs of marine mammals (Marsh, this document) would provide evidence of the extent of food-chain transfer and potential for effects on wildlife.

Table 5. Comparison of criteria maximum concentrations (CMC) and criteria continuous concentrations (CCC) from saltwater quality criteria documents for metals.

Metals	Concentrate ion, g/L	
	CMC	CCC
Cadmium	43	9.3
Chromium	1,100	50
Copper	2.9	2.9
Lead	140	5.6
Mercury (II)	2.1	0.025
Nickel	75	8.3
Selenium	300	5.0
Zinc	95	86

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MERCURY TOXICITY, BIOACCUMULATION, AND DERIVATION OF AQUATIC LIFE WATER QUALITY CRITERION

David J. Hansen
Questions and Discussion

[The following are questions asked during the presentation.]

_: *Wouldn't you want to rerun the test?*

Hansen, David: Yes, I would want to rerun the test. In developing the water quality criteria documents, quite frequently if there is not a sufficient amount of information available we will retest. The same is true for the fathead minnow test, with mercuric chloride. That was a test where the lowest concentration affected reproduction. In looking at the data, the magnitude of affect at the lowest concentration tested indicated to me that **probably** the next concentration on down would have been the "no effect" concentration or maybe the one below that. But it was probably very close **to** the **no-effect** concentration.

Emerson: Is that arbitrary...? (refers to "use of the factor of 2 divided into the FAV to derive the CMC).

Hansen, David: In preparing the WQC Guidelines, we used all the data that we could find back in 1981 and 1982 on the **LC50** and the LCO values for all species. We calculated the average differences between the concentration that produced no mortalities and the **LC50**. That number was **2**. So it is not an arbitrarily derived number,

*Emerson: i guess they used to think that maybe they could do a chronic criteria test; then they used to require **an** application factor of 10.*

Hansen, David: That is a different thing. The application factor concept is the same concept that is embodied in the acute/chronic ratio. The acute/chronic ratio is a **reciprocal** of the application factor. Arbitrary application factors of 0.1, 0.05 or 0.01 have been applied to acute toxicity data to derive WQC prior to 1980. However, this is no longer used to derive national WQC.

*Emerson: I thought that was on the chronic tests that they were **applying** the 0.1 ?*

Hansen, David: Not in criteria derivation. I could have given a discussion on the guidelines themselves and that would have been a whole different kind of discussion. But in the derivation of numerical water quality criteria, using the national guidelines, there is a requirement of at least three chronic toxicity tests that can be used to calculate an acute/chronic ratio. So that acute/chronic ratio is an experimentally derived value, rather than application factors of 0.1, 0.05, and 0.01 which were used in 1976, in the old Blue Book. We have gone away from the concept of using arbitrarily **derived** ratios. We require that actual data on the relationship between acute and chronic **toxicity** for a chemical be available in order to derive a criteria.

_: *Don't states **still** use that once in a **while** when they want to provide water quality criteria for a compound where there are no chronic data?*

Hansen, David: States may do this but the EPA published water quality criteria documents that do not use an **arbitrary** value.

_: *I'm just saying that when states want to go beyond, when there are no criteria for a **particular** compound, whether it be a metal or organic compound, they have taken 0.1 times the **acute** value to derive the chronic.*

Hansen, David: That may or may not be a mistake, **if** you guess right it's probably fine, but if you guess wrong you are over- or under-protected, or you are too restrictive or not restrictive enough. The average acute/chronic ratio of all the data that I have **looked** at is about 50, or as opposed to the 10 that you mention. For a chemical that you know nothing about, a criterion will be under-protective if the state uses a value of 0.1.

Mercury in *the Marine Environment*

_: I guess the point that I was making is that that concept is still **in** use at the state **level** when there are no criteria documents on a compound.

Hansen, David: We are developing something called Guidelines for Deriving Water Quality Advisories, where the minimum database requirements are not nearly as stringent as they are for the derivation of a criterion. We have looked back at all the historical chronic toxicity test data. Because the criteria documents themselves require that three **chronics** be conducted and that the mean acute/chronic ratio of those three be applied, there are about 30 values for the acute/chronic ratios that were applied in the derivation of water quality criteria numbers. Of those values, only one exceeded 25.

[The following questions and discussion occurred after the presentation.]

*Armstrong: One thing that I am curious about when you use the FDA action **levels**, in the case of our problem **in the** Norton Sound because the FDA action level is set on average consumption of fish in the US, which is something like 18 oz. seafood...*

Hansen, David: FDA action levels are derived in different fashions for different chemicals. You may be referring to the derivation of the water quality **criteria** concentrations for the protection of human health, which is different. Some of the FDA action levels were actually set based on a market basket survey of concentrations so that the people could continue to fish, which is not a very good reason.

*Marsh: On the FDA action level you mentioned the action level for **mercury** of 1 ppm, I was told **very recently** that the FDA has abandoned any action level. I was furthermore told they did that because of fear of litigation. Apparently some outfit was going to start litigation and when the FDA considered whether they could **support** that in a legal action, they found that they could not provide evidence to support that. Do you know if that is true?*

Hansen, David: This is the first that I have heard of **that**.²

*Armstrong: Apparently that is true. One of our staff members talked to someone at the FDA who said that they were taken to court and that is why the level **was** raised and that there is no way they can enforce it. It is just a recommended level.*

Hansen, David: But here is what happens: if there is **an** FDA action level, commercial fisheries can be terminated as a function of it. In fact, that is happening right now in a lot of the places on the East Coast. The water quality criterion for those chemicals that are regulated by FDA action levels is intended to protect for the uses, including the continued marketability of species used as seafood.

*Marsh: No. They backed down on mercury. **Incidentally** the way you talked about the **scientific** basis for action **level** used to be 0.5 parts of **methylmercury** and that was not changed because of scientific investigation. The change from 0.5 to **1.0** resulted from the court action brought against the swordfish industry. The FDA lost that court case and that resulted in a change in the action level.*

Hansen, David: I have not received any official notification that that has been done,

*Marsh: I bring it up because your data was from 1984, prior to **all** this, and it has just disappeared as a basis for any current...*

² I called the U.S. FDA in **Davisville**, Rhode Island upon my return and they stated that the Compliance Policy Guide 7100.07 published in March 1987 maintains the **1.0** ppm limit and no other guidance has been published since that date.

Hansen: Questions and Discussion

Hansen, David: If that was the case, revised criteria concentrations would more rigorously consider the chronic effects of mercury on fishes and effects of **methylmercury** on avian and mammalian predators on aquatic species, Do you have knowledge of changes in FDA action levels for substances other than mercury?

Marsh: As far as I know it is restricted to mercury.

Hansen, David: Do you have a Federal Register publication on this?

*Marsh: No, I don't. With action levels, it is very difficult to know what they ever meant because you've got a slide there of maintenance balance. Of course, what matters is not just the concentration but the amount of **methylmercury** ingested. Some countries have an **advisory** about the action **level**, plus advise about the amount, Sweden, for example.*

Hansen, David: Yes, many of the states have their own **specific** recommendations relative to cleaning and cooking fish to minimize the dose.

*Marsh: Yes, but I don't know if they are based on any data. How do you cook fish to reduce the dose of **methylmercury**?*

Hansen, David: I was referring to the instructions in Michigan, for example, on **PCBs**.

Hansen, Don: For Dr. Marsh: You mentioned that 0.5 ppm, that was based on science?

Marsh: No. That was grabbed, but for years in the United States it was 0.5.

Hansen, Don: That was based on evidence from...

*Marsh: I don't see how you can derive a figure which is supposed to protect people just by the concentration of the toxin in a food source. You can't make that analogy, so there is never a good basis... That has changed as a result of the Florida **court** case in the 70s, without any scientific basis.*

*Armstrong: When you look at what the average American consumption of fish is versus what the average consumption of seafood, seal and fish in Norton Sound is, it is very **difficult** to apply that same **level**. it **would be the same** in water quality too, because the amount that they are consuming is so much more than what we would consume.*

Hansen, David: In **deriving** the human health criterion, that would be important. In deriving the aquatic life criteria, it's not.

Prentki: Then how is that derived?

Hansen, David: Human health criteria are derived at EPA's Cincinnati laboratory. The process is quite detailed and somebody who is a part of that process should be contacted. They use available information on mammalian feeding studies. They try to account for dietary intake. In the case of carcinogens, they use risk factors.

*Prentki: So it really is a factor of concentration of **mercury** in the water, not in the seafood?*

Hansen, David: No, they typically include both. The 1984 **criteria** document does not contain a human health criterion. That is in the **1980** document. I perused through that before I came here and I recall there were three values. One that had to do with drinking water, one with just eating seafood products, and one **with** both ingestion of water and seafood. As I recall, the number was dominated by the dietary dosage associated with fish and shellfish consumption.

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Hansen, Don: Those criteria don't take into consideration marine mammals where concentrations in the liver are much higher levels.

Hansen, David: They are national criteria, not site-specific, and do not consider human populations with high seafood diets.

Emerson: How are we coming since your data is based on 1984, 1985; what are we doing nowadays, in looking at this problem? Is the EPA concerned with any of this or is the FDA concerned with specific **localized** consumption rates that are sometimes four or five times higher than the national average in coastal areas?

Hansen, David: I guess I can't answer what the FDA is doing. As far as the EPA and the aquatic life criteria documents, there is an examination every five years to determine if there is sufficient new data that would require a revision of the national numbers. In fact, that occurred in 1985 with mercury, relative to the 1980 document, In 1980, if somebody decides the criterion should be revised, **all** new data will be considered.

Emerson: Basically, the same methodology is **probably still** in place; you are just looking at other species and other toxic things **to see** what those **levels** are. Is that still basically the state-of-the-art at this time?

Hansen, David: In **addition** to examining the **criteria** documents themselves every five years, the intent is to examine the guidelines, There are certain portions of the guidelines that we are looking at relative to a need for revision. For example, the guidelines don't provide very good insight on how you handle data on plants. That is not important with mercury, but for some of the chemicals such as the herbicides, a strategy for interpreting plant data relative to its implications in criteria formulation is important. The averaging period and return frequencies are largely based on water quality models that address fluctuating concentrations in streams, The marine environment is quite different, Tides, winds, and all sorts of factors that control dilution need to be considered in deriving the saltwater averaging periods and return frequencies. We have been happy with the way we are examining the acute and chronic **toxicity** data for aquatic organisms. I don't think that we are likely to change that.

Emerson: They were at one time considering a variety of **different** bioassay tools, such as protein synthesis on cellular or molecular level, then go **to the** opposite extreme, like the microcosm unit concept... you are still looking **basically** at one organism, a variety of concentrations and making conclusions from that same stuff,

Hansen, David: I think we are always looking for new and better ways to interpret data that provide us with greater insight into concentrations that would be necessary to protect aquatic life. So I don't discount any thing that might be useful. We have several criteria documents **outnow** that use **bioaccumulation** factors derived from field measurements, That is why I was particularly interested in this morning's presentation on mercury concentrations in water and fish. In fact, the accumulation factors are about the same as the kind of numbers I presented. We almost set a criteria for toxaphene and **chlorpyrifos**, based on a colonization experiment that is conducted in some of our research laboratories where chemicals are added to raw seawater; the larvae in the water settle out in sand filled aquaria and we look for effect-no-effect concentrations in not only individual species, but in assemblages of organisms and in some cases, system functioning. We use data in what we call the other data table, Table 6, to derive criteria and we seem to be doing it more and more frequently. Future instructions to **authors** of criteria documents tell them how to incorporate other kinds of toxicological data other than just individual species of toxicity test. It is something that the laboratories that are responsible for criteria document development try to take into account in their evaluation of the data. Just because there are acute data and chronic data doesn't mean that it must be the only data used to derive the effects criteria numbers,

McCrea: Given the importance of marine mammals in the Norton Sound area, do you think it is worth our while, you said initially it is not worth your while to go site-specific, but since marine mammals really haven't been included in either EPA criteria, FDA action levels or anywhere else particularly because they are not "edible" species, would it be good to look at them more closely, trying to get something site-

Hansen: Questions and Discussion

specific?

Hansen, David: Well, maybe Ron **Eisler** is going to talk about that tomorrow. I don't want to steal his thunder, But, beyond what Ron's going to say, I think that you really should call EPA's Cincinnati laboratory and talk to them about the site-specific data that you have and ask them for their input. Because they are the people who are responsible for the human **health** portion of the EPA regulatory process. My comment relative to site-specific had to do with aquatic life and the protection of that, rather than consumption of seals or effects on seals. As to whether EPA guidelines are applicable in this situation, that is a multiple part question. The **biogeochemical** cycling of mercury without perturbation is one thing, and then how that cycling might change as a function of dredging **relative** to the release of **bioavailable** and toxic forms of mercury, may be another. So I think it is important to have **an** undemanding and data to demonstrate what is actually happening at that site. Relative to chemical methodologies, clearly from this morning's discussion there is a variety of approaches. **There** are some very wrong approaches to the measurement of ambient concentrations of mercury in the water. We recognize that that might be a problem, and that is why the chronic **portion of the criterion is** based on accumulation of mercury in indigenous, local fauna. There are, however, ways to directly determine whether the water that is discharged from a dredging operation or from an outfall may be causing toxicity or **bioaccumulation** problems. The complex affluent approach is one of those procedures that is now part of the National Pollutant Discharge Elimination System (**NPDES**). In our laboratory we have developed a whole series of **assays** using organisms which evaluate the toxicity of discharges which can be used in the permitting process. So that is one option that is available to you. Understanding the biological availability of metals in the marine environment is a complex issue.

*_: I can't remember some of the numbers that Tom came up with this morning in terms of amounts of mercury per liter that he found in **the** water. Didn't they approach chronic values?*

Hansen, David: That is right. The concentrations that were measured are total recoverable. That number would be different were one to do acid soluble, which is the methodology that is detailed in the criteria document.

*Wright: I agree **wholeheartedly**. /just hope that one of our **regulators** would understand that, and place it in consideration. There is **a little** bit of a problem because you are discharging into seawater.*

Hansen, David: That is correct, Tom. The environmental chemists from the Duluth laboratory and from our laboratory that were asked the question, "**what** is the appropriate chemical procedure to measure for the available forms of mercury, or forms which might be reasonably **readily** turned into an available form?", and they recommended unanimously the methodology that is in the criteria document.

*Emerson: The answer being, and assuming that is a **particulate** taken into the organisms and not associated with dissolved oxygen...*

Hansen, David: The ultimate goal is to express toxicological data, water quality criteria and monitoring data in a chemical concentration that is measurable and biologically available. That is not possible now.

*Emerson: You mean the bioassay **concentration** that you determine in the lab would equate availability based on the acid digestion process?*

Hansen, David: Yes.

*Emerson: **It** just **seems** like coincidence. **I** don't see a biological relationship then if you don't talk about intake?*

Hansen, David: At sites where metals are being discharged, where there are not high suspended solids loads, where there are not other factors that might cause a **complexation** or whatever, the national criteria should reasonably apply. The chemical analyses would produce numbers that were reasonable relative to laboratory tests, **WQC** and the **bioavailable** concentration. In places where there were good reasons why

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the available concentration would be much different from the concentration as quantified by the acid soluble or total metals methods, there are procedures in the site-specific guidelines document that will allow you to define the water quality effect. **Clearly**, concentrations in water are only part of the total exposure. Dietary intake and particulate association are also important relative to total **bioavailability** of mercury.

*Emerson: I guess I don't understand what you mean by **bioavailable**?*

Hansen, David: That is the fraction that is of importance relative to organisms as opposed to other fractions which are biologically unavailable.

Emerson: And as the uptake process being internal-external or direct-indirect?

Hansen, David: Intake relative to water, **dietary**, and other exposures.

Prentki: On the 1986 version of the criteria it says that the acid soluble procedure hadn't been approved yet and that you should be using the total recoverable technique.

Hansen, David: As I understand it, Cincinnati has been working on the acid soluble techniques.

*Prentki: WestGold is required to do **the** total recoverable. Is that right, Paul?*

*Rusanowski: We are required to do **tots/** recoverable from Region **X's** point of view. That is the methodology that **was** used to derive the water quality criteria.*

Hansen, David: In the toxicity tests that are part of the **criteria** document, total recoverable was the most commonly used method of analytically measuring the concentrations.

Prentki: But you are saying that they are now recommending acid soluble?

Hansen, David: Well, as of a couple of years ago they were in the process of developing and are now dropping the acid soluble technology.

CORPS OF ENGINEERS DREDGED MATERIAL TESTING PROCEDURES

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The U.S. Army Corps of Engineers (CE) has statutory authority to regulate the disposal of dredged material in 'Waters of the United States' (Section 404 of the Clean Water Act (CWA)) and in the oceans (Section 103 of the Marine Protection, Research, and Sanctuaries Act (MPRSA)). In carrying out this authority, the CE has conducted over \$100 million of research on dredging and the disposal of dredged material.

As required by domestic law and the International London Dumping Convention, the suitability of dredged material for open-water disposal is determined by an ecological effects-based approach rather than chemical considerations. The rationale for this is that dredged material is a complex mixture of many substances whose bioavailability and potential interactions cannot be predicted on the basis of the presence or concentration of chemicals of concern.

This ecological approach consists of acute toxicity bioassays and, when appropriate, estimation of bioaccumulation potential. The protocol is tiered, with the first tier being an exclusion from testing because of the benign nature of a particular material such as clean sand and gravel. The second tier is a physical characterization and chemical inventory with the material proposed for disposal being compared to that at the disposal site. This tier takes into account water quality criteria; with the exception of PCBs, there are currently no sediment quality criteria. The third tier is biological testing and addresses the water column and benthic environments.

An important aspect of the tiered protocol is that all tiers need not be completed. Depending on a 'reason to believe' entry may be made at any tier so as to minimize the expenditure of time and resources through the elimination of unnecessary testing.

The basic CE testing procedures are given in the Implementation Manuals for the CWA and MPRSA. Further guidance is provided by 33 CFR, Parts 208 and 335-338 which incorporates the Management Strategy and the Decision-making Framework as well as policy promulgated by the Office, Chief of Engineers, Technical Note EEDP-04-8 (see Appendix D) provides a summary of these documents with regard to testing protocols.

The procedures described above have significant potential for the evaluation of the disposal of sedimentary materials in general. It must be recognized that dredged material disposal is usually an instant event (hopper dredges, dump scows) or very short-term (hydraulic pipeline). However, the primary concerns of the effects of contaminants upon water column and benthic organisms are common no matter what the operational considerations.

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Wright: Corps of Engineers Dredged Material Testing Procedures

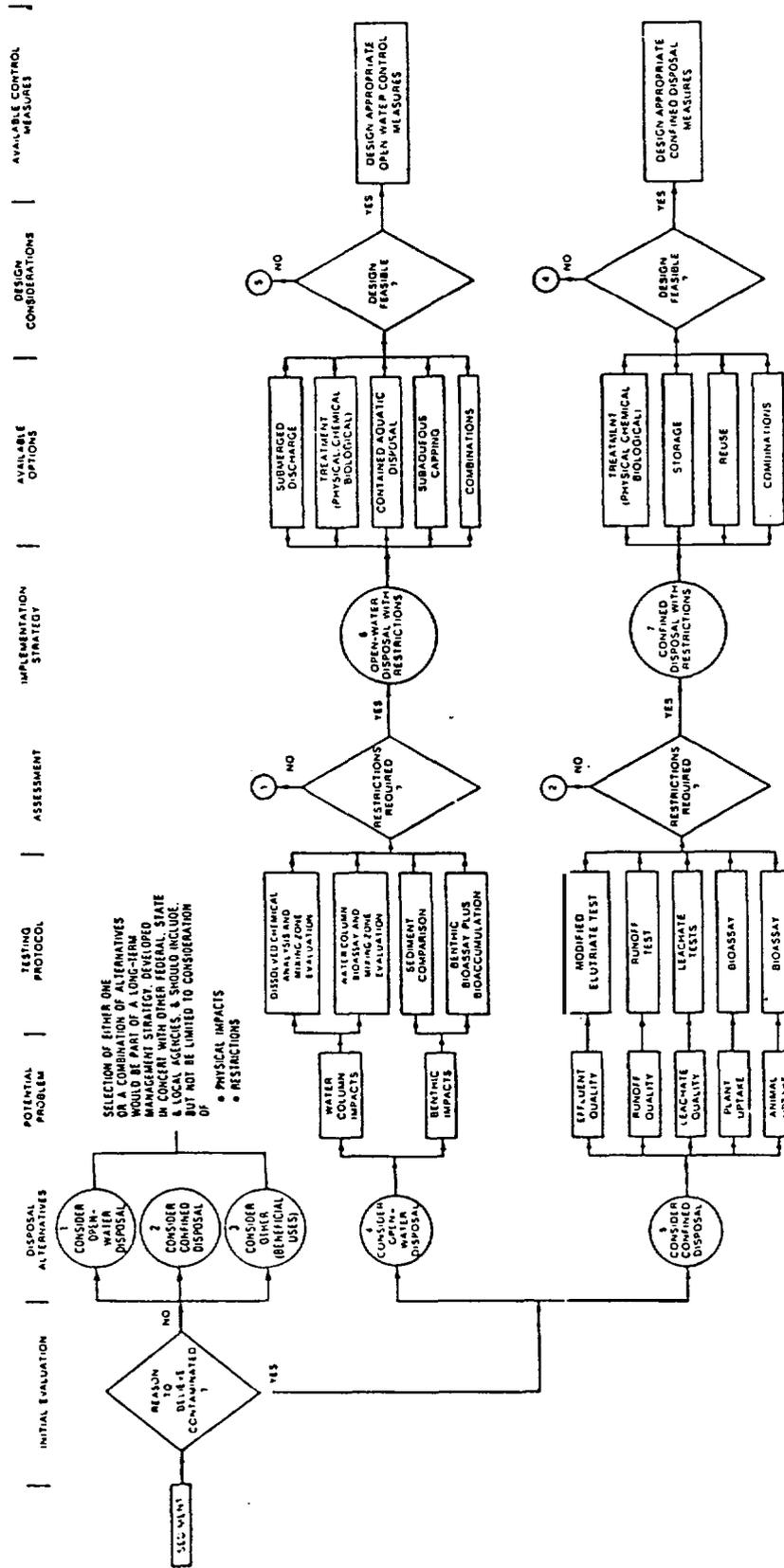


Figure 1. Management strategy flowchart.

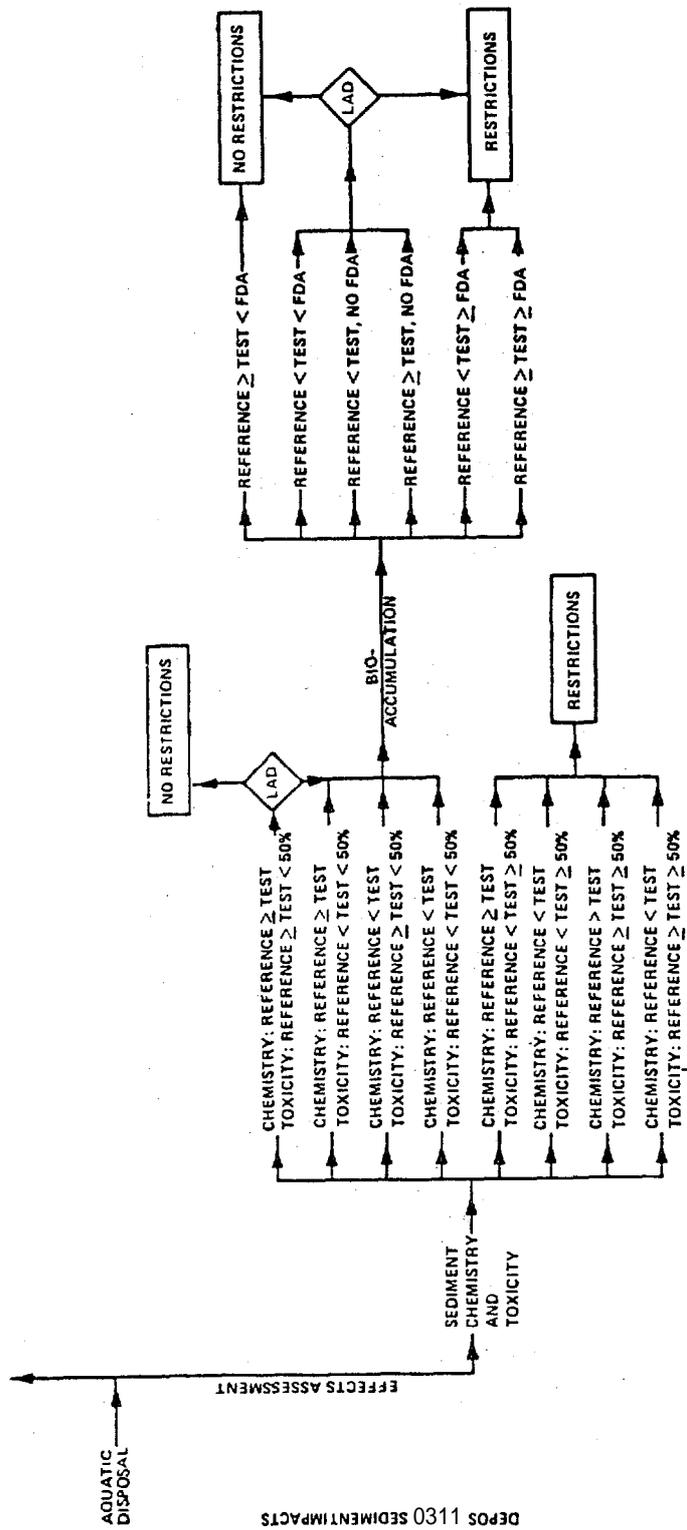


Figure 2. Flowchart for decision-making for aquatic disposal water-quality impacts.

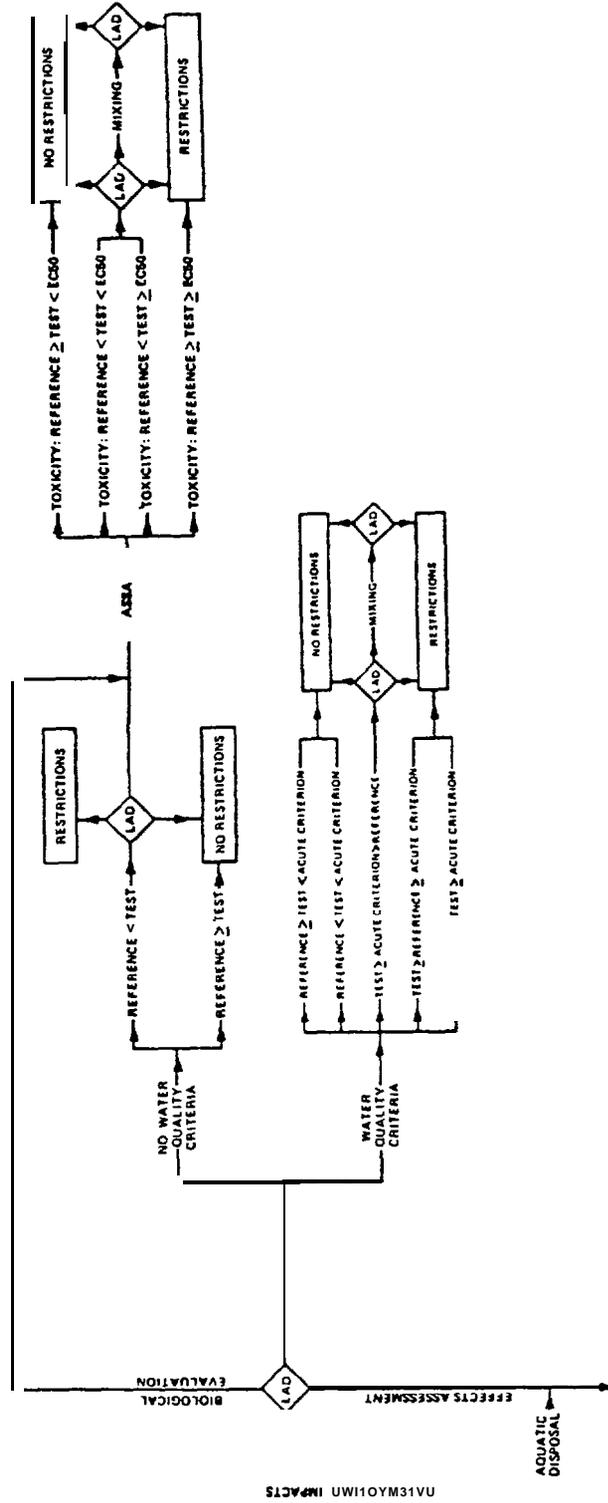


Figure 3. Flowchart for aquatic disposal impacts.

CORPS OF ENGINEERS DREDGED MATERIAL TESTING PROCEDURES

Thomas D. Wright
Questions and Discussion

[Following are questions asked during the presentation.]

*Emerson: You mean, when you prepare the **elutriate** you are not filtering it?*

Wright: That is right. We let it settle and then do it.

Emerson: For an hour or something?

Wright: Hour.

Emerson: And then you put your test organisms into that?

Wright: You pour it off, decant it, and then put your organisms in.

Emerson: Okay, it is still then basically a closed system?

Wright: Yes.

*Emerson: And it **is** mostly glass containers?*

Wright: Yes.

*Emerson: Well, it would seem to me that the problem with that methodology, and the assumption that we don't have a water column problem, is that, **within** the **first half hour** most of your ionic forms adsorb to the container walls anyway. They are taken out of solution or they are bound up with organic **ligands** that aren't available either. **In** any case, the potential **toxicity** is neutralized by the design of the experiment.*

Wright: In part if they are going to be bound up by organic **ligands** in the system, they are going to be bound up by organic **ligands** in nature. Now you can't **do** anything about that which sticks to the wall of the container or adsorbs onto the wall of the container, unless you were to use some sort of an infinitely large container. What you are doing here is when you dispose you don't have any container walls; of course, you have almost an infinitely large dilution system.

*Emerson: We know there is a wall effect on any type of container **like** that...*

Wright: ...the way to find out if it is toxic or **bioaccumulative** is to ask an organism. Persistent, we know what persistence is. Elements are neither created or destroyed, it flips back and forth. We know what things are out there and what matter is persistent. So for ocean dumping we almost always have to go to a bioassay. There is another key phrase, 'unless rapidly rendered harmless' through dilution, sequestration, etc. That is what happens in the water column, either it doesn't come out, or if it comes out, something happens to it. If it is present in the interstitial water and reduced sediments and we dump them in an oxidized environment with 2% organic carbon, which is about a good ballpark average, **zingo**, the **stuff** is gone. It is not there, it is not available. But that is not **all** of the story, I have to give you the rest of the story. These are acute toxicities, by and large they are ten-day tests. The exception being such things as larval fish or oyster larvae which you just can't keep going for ten days without heroic measures and those are usually 96-hour tests. Actually, the existing regulations call for us to look at three animals: a deposit feeder, a burrower, and a suspension feeder. The regulations that we have been revising with EPA and the new implementation manual has whittled that down to two. It has become even more specific. It has said use an amphipod, because we found those to be through research, good, **sensitive** organisms that respond predictably, and use a **polychaete** worm. The advantage to this is that the **polychaete**, assuming it survives, the survivors can be used to get an estimate of **bioaccumulation**. There **are** only two ways to know whether this stuff is toxic or **bioaccumulative**, that is available. Acute toxicity where it kills the things or

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bioaccumulation where it shows up in them, The **amphipods** are a little too small to get enough biomass, to do **bioaccumulation** with, but the **polychaetes** are good, except when you are dealing with things like **polyaromatic hydrocarbons (PAHs)**, most organisms metabolize PAHs. Clams don't. So if PAHs are a concern we recommend going ahead with three of them, the **amphipod**, the clam, and the **polychaete** and do **bioaccumulation** on the clam, Clams are terrible acute toxicity animals, you can't kill them with a hammer. Routinely we run a 1000 of them and get 999 to survive in Circumstances where we might get a **30%** mortality on the amphipods and maybe a 15- 20% **mortality** on the **polychaetes**.

Emerson: What **polychaete** are you talking about?

Wright: We usually have been using **Nephtys** or **Neanthes**. They are obtainable, they are **culturable**, we've had experience, Have you come up with anything new, Dave, or still **Neanthes** and **Nephtys**?

Hansen, David: Those are the two that are easiest to get your hands on.

Wright: For the amphipod, depending on where you are, we are using either **Ampelisca** or **Rhepoxynius**.

Emerson: Nephtys or **Neanthes** on the East Coast too?

Hansen, David: Yes.

Wright: You also don't know if it is **bioaccumulative**. **You haven't taken it back to the laboratory and asked the animals if they are going to take it up.** You have gone out there and looked at what is in the animals out there. I found that in the EIS, and it doesn't look like anything is in the animals out there.

Emerson: How do we know they are **all** out there, since those that aren't out there, aren't there?

Wright: Well, I guess you could always say that if the mercury **wasn't** there we have to dredge the crabs out of the way for the ships to get in. There seems to be a viable crab fishery. The crabs have to eat things and there are annelids and what have you. I don't know what is out there, I am assuming if there was nothing out there no one would care what you did out there,

Emerson: Well, there is "being out there" and there is "being out there". There are the robust fellows that it doesn't matter and there are those that are a little more sensitive to their environment.

Wright: That's correct. If the ones that used to be out there are gone now, how would we ever know? Now we are talking about the dependent-independent variable, go to another area where we don't have mercury for example, or you can go back in here if you want to know about what's going on. Maybe these animals are not sensitive enough for you. Maybe you need to use something more sensitive than an amphipod, I don't know what that would be. Do you know what that would be, Dave, that would work in this?

Emerson: Well, the first criteria is that if you can keep it alive in the lab, then usually that means it's usually not too sensitive.

Hansen, David: **I don't believe that. But in the case of mercury we have some idea of the relative acute sensitivities of organisms and we know that the mysid is particularly sensitive. So I would, in this particular case, if mercury is a concern, I would pick the mysid. I believe that the issue is not really what's going on there now, but is there going to be a change as a result of a mining operation. So what you would want to do is understand the change rather than the existing condition relative to biological health.**

Wright: Well, the change would be measured against existing conditions. What is done is done, what is there is there. So you measure the change against what is there. Again, I have not digested this database since I only got it yesterday. But looking at some of the values in the organisms out there, mercury values...

Emerson: Not only the change but the trend, the **long-term trend**, if there is one...

Wright: *Questions and Discussion*

Wright: In the case of metals, we only run our **bioaccumulation** for 10 days. There is some question if you are dealing with **dibenzofurans; TCDD, dioxins;** or TBT, things like that which have a slow uptake rate. Metals, if they are going to be taken up, they'll do in 2-3 days, it will be essentially a steady state. Do a **ten-day bioaccumulation**, take some animals from out there. You already know what they've got in them, stir this material up, do whatever you want to. Run suspended phases, run solid phase, do it with burrowing organisms or deposit feeding organisms and see if you get some **bioaccumulation**. That is the only way that I know of to answer the question at hand, which is **"what is it going to do?"** Is it going to be toxic or is it going to **bioaccumulate?** if it's not going to do either one of **these**, well it might smother the animal, but that is a physical effect. Putting in a parking lot is a physical effect. Once the operation stops presumably the physical effects stop and the animals will come back. Not so with chemical effects all the time. So there is a way to answer the question. The question is not what is there, the question is what is it going to do? We do this to evaluate 500 million yards of material a year, I am not aware of a problem with any of our open water disposal sites. Not a single one, that anyone has documented anywhere a problem. Which when dealing with 500 million or more cubic yards a year, it tells you that the procedure has some merits.

[The following questions and discussion occurred after the presentation.]

*Hansen, Don: You said you never had any problem with water column, as far as exceeding EPA standards. Have you looked into trends with **bioaccumulation**?*

Wright: We have done **bioaccumulation** and we have done acute toxicity, no problem there either, with either the static exposure or the exposure that we run in the laboratory.

*Hansen, Don: How do you determine **bioaccumulation**?*

Wright: By exposing organisms to a suspension of material where we are going to dispose, and material that we are going to dispose of, and comparing the differential uptakes, if any. Keep in mind, what we largely do is just move, we are not really adding any material to the **system, So if** the animals at the site or the material at the site is such that accumulation is the same as in animals at the site, as in the material, then nothing has happened. There is no change. We put the material out there and it is status quo, there is no degradation. If somebody doesn't want us to put it out there on something like a mass loading, and they pay the cost of putting it somewhere else, we will ship it anywhere you want to ship it, just as long as you pay the freight.

_: Do you think that using the dredging analog for the mining operation is a good analog?

Wright: It is a semi-good analog, in that the key difference is that our operations are essentially instantaneous. The hopper dredge goes out there and within a minute to a minute and a half, when they open those bays, the material is gone. When we have a pipeline, we may discharge, depending on what the operation is, in a given location, unless it is a confined area where the return flow comes over a weir, but if it is open water we might discharge for 2 or 3 days, but then the pipeline gets too long without booster pumps. So we move the pipeline and now we are discharging somewhere else. So the animals are not being exposed to a continuous discharge. I don't **know how continuous the dredge is, I presume it will operate** for 24 hrs a day for whatever **the** season is. Of course it has got to go down sometime for maintenance. It's going to break down sometime. I gather that sometime it will have to go ashore, or stop because of weather. The dredge is somewhere between an effluent outfall that operates 365 days per year and an instantaneous dredge material discharge, **all** year to instantaneous, I don't know where **it** is along that continuum.

*_: What I understand about the mining **operation** is it brings the material up and then it is processed on the ship end it is separated into various sizes, and then put back in. So you indicated that you don't have much interaction between sedimentary material in the water in **normal** dredging operations. I was thinking, for example, sulfides, in that type of processing, **would** probably be oxidizing, going into solution, other things would react and go into **solution**. Then it would be spread out on the bottom and there would*

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be more opportunity for interaction with oxygenated water at the site. From that point of view I thought that the mining operation was distinct, quite distinct from any dredging.

Wright: It depends on what kind of dredging. If it is clam shell dredging, you drop the bucket and you pick up the material in a 6 cubic yard or 9 cubic yard bucket. The stuff maintains its cohesiveness when you go out and dump it. It hits the bottom like a freight car and sits there in a lump. Contrast that to hopper dredging or hydraulic dredging, wherein hydraulic dredging there is much more water, So you are entraining 75 to 80% water, running it through a giant pump and pumping it through a pipeline for a mile or whatever, In hopper dredging, the pipeline is not so long but it goes into a hopper. You do what the engineers call surcharging, which I call overflowing. They overflow the stuff. They keep agitating an overflow, all the fines, which by the way, if there are contaminants present they are probably in the fines, may go overboard, What they are trying to do is build up the sand and the coarser material, Because if they didn't to that, when they go offshore to dump they would be carrying 90% water and 10% solids, That is not very economical, So they will overflow these. The dredge skippers are pretty clever about this. They have basically a plimsol with a staff gauge and they overflow and they watch, as the dredge sinks further and further in the water there is economic break even, When it gets to a certain point, they pull the drag arms and go out and dump and come back. There are certainly some local considerations with regard to what is going to happen to the material from the time it is removed to the time it goes back in. Whether you can do a direct application, what we do, or some modified version, some modification would probably be desirable. On the other hand, we are doing something different, in a sense, we are taking the material from over here and putting it over yonder. What we have found is that the most disastrous thing that happens is when you change the geochemical environment. If you have reduced the marine sediments and put them upland, as soon as they begin to oxidize, you may mobilize contaminants. In the Field Verification Project (FVP), we placed them upland, and we put them in wetland, and we put them in open water. What happened in open water, almost nothing. What happened in the wetlands, some bad things. What happened in the uplands, very bad, We still don't have anything growing on it, do we? We keep trying, We've got cadmium and all sorts of stuff that starts leaching out when this stuff gets oxidized, You are out there picking up material wondering if it will be processed enough to significantly change its oxidation state and it goes back to the bottom, it is going to depend on the BOD as to how long before it goes back to reduced sediments. I presume sediments below the sediment surface are reduced, does anybody know? What's our oxidation layer out there?

_: It is variable. In some of the inshore stations we have several centimeters, 10-20 cms.

Wright: That is pretty good. You ought to be able to figure out if when you dredge it up and run it through the processing and dump it back over if it's largely going to be unoxidized, in other words it's going to be the same or is it all going to become oxidized or what is going to happen to it. Our experience is that if the sediment is reduced and we dump it within a very short period of time, we have 1/2 to 1 to 2 cm of oxidation. The rest of it almost immediately goes anaerobic again. There are some handy monitoring methods. There are sediment profiling cameras. You can go out two days after disposal and drop the gadget and pick up a few millimeters of oxidation beginning to occur, Take the stuff back to the lab and stir it up and see what it does, that would answer your questions. I think what you need to do is more real life work that will give you some answers as to effects, You are again saying what effect will the dredging have on the material? it's a good question, but I don't know. I know how to find out, but it hasn't been done yet,

Emerson: Would you say as this sediment goes through the shaker table in the process you are going to have almost complete oxidation as it settles out?

Wright: I wouldn't be surprised.

Emerson: And if you are saying you see an anaerobic layer forming of, what did you say, a few centimeters, you don't see a reduction layer?

Wright: *Questions and Discussion*

Wright: Yes. What you will see is the sediment is reduced when you take it out there. When you dump it, it is still reduced, by and large, but then it rapidly oxidizes at least at 1/2 cm or 1 cm. Our experience with black rock, when we dumped that awful stuff, we **had caged mussels out there. We dumped, we saw a signal in the mussels from the water column. We saw a signal and then it went back to ambient, and the mussels stayed longer, nothing happened. Pretty** soon the mound, very soon, started oxidizing and some of the fines went away and some of the coarser material stayed behind, it sort of got an armor on it, because it was sticking up above the bottom. Nothing happened for another 18 months. Just fortuitously, everything was still out there and Hurricane Gloria came through. The Narragansett folks rushed out afterwards and lo and behold the oxidized stuff was gone. It had been stripped off, had a reduced layer right on the surface, maybe 1 mm of oxidation. Lo and behold these caged mussels showed another signal, although a very small one, but **it** was definitely there. Which tells you if you strip that oxidized layer off and churn all this up with a hurricane, the mussels picked it up and went back to ambient and that was the end of it. The stuff is still sitting out there. Animals colonized it. There is nothing alive in the harbor, which might not be due to the material, it might be due to a whole bunch of other conditions. It got colonized, animals were living there, there seems to be no problem.

_: *In your opening comment you **said** that we are essentially nowhere with regard to sediment quality criteria. I beg to differ with that. Many states, New Jersey, Washington, California and **federal** agencies such as EPA and the Corps of Engineers, your program, **all** have established action levels for sediments and soils; 400 for arsenic, 500 for lead, 10 for mercury, in soils and sediments. These are court enforceable **levels** that are used in the Superfund cleanup sites.*

Wright: On Superfund sites?

_: *Right, but those are also levels which have an effect on human health and the environment at any site.*

Wright: I would qualify my remarks that the Corps doesn't set criteria for Superfund sites.

_: *Why should those be applicable to smaller populations **that** don't score high on the HRS ranking system?*

Wright: This falls under the Toxic Substance Control Act (**TSCA**). The only sediment quality values that apply to dredging material is greater than 50 ppm of **PCBs**. That is the only one that I am aware of.

_: *Is it exempt from Superfund if this goes on the uplands?*

Wright: Dredge material?

_: *Right.*

Wright: If it goes upland we do not regulate except if there is a return water flow. For federal material, we apply various management techniques to the **material**.

_: *So is that a default to local authorities then?*

Wright: Yes. **The** only thing that we regulate with upland dumping is, if there is a weir and if we are hydraulically discharging, then we have to meet state water quality criteria under 44)1.

_: *But there are sediment quality criteria, it is just that you don't have the regulatory **authority** to enforce them?*

Wright: No, no these are under Superfund or **TSCA**. You aren't going to really, as a rule, find if it is dredge material that is Superfund or **TSCA**, we don't deal with it, that is EPA's problem. In other words we go in and sample the material, such as Commencement Bay or New Bedford, and it turns out to be Superfund material, we wash our hands of **it**. We can't do anything with **it**. It becomes someone else's problem.

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_: So you do use the sediment criteria to determine if **you** should wash your hands of it?

Wright: Yes. But those numbers are so incredibly high that you would never encounter them, in essence with normal dredge material. Dave Hansen, do you want to comment on that?

_: With the numbers that you mentioned does the Superfund people **call** them sediment criteria?

Hansen, David: They call them action **clean** up levels.

_: And these levels that I mentioned have gone through that **technical** review, they have setup in court, they have all been challenged and they are the levels that are used to establish how clean is clean. Sediments, soils, stream sediments, **surface** sediments, playgrounds, parking lots or in streams, or beaches.

Hansen, David: I **am** unaware of specific levels set by **Superfund**. Can you send me them? Because the approach that Criteria Standards Division (**CSD**) has taken in the development of sediment quality criteria, and there are a variety of approaches that a variety of organizations have tried, involves developing the technical basis that allows one to understand the partitioning process to be able to predict the concentration of the contaminant in the sediment that would ultimately partition into interstitial water, to demonstrate that **interstitial** water is the source of the exposure and that **benthic** organisms have similar sensitivities to water **column** species. Then the water quality criteria can now be applied along with the equilibrium **partitioning** theory to calculate an acceptable concentration in the sediment that takes into account the biological availability of that substance.

_: And then in this risk assessment the water quality is a portion of it, and all the other routes of exposure are considered normal absorption, inhalation, food chain effects, are **all** collectively calculated for risk assessment, in EPA's monitoring.

Hansen, David: We have to demonstrate that the source of toxicity is correlated with interstitial water. However, it's a **little** more complicated than that.

Wright: One of the reasons, upon reflection, we don't encounter this is because the majority of what we do is maintenance dredging. But chances are it's virgin material, **10,000** years old, Some of that turns out to be toxic by the way, So maintenance material means we have been dredging the stuff for years and years and we have been testing it for years and years and years. If we had run into 500 parts of arsenic or 300 parts of PCBS or what have you, we wouldn't dredge **it**. It is also very unlikely that the material will have that because it would have been long since removed. Let's say in the 1960s, we really didn't have to **start** doing this until the 1970s under the Clean Water Act and Ocean Dumping Act, if would have been long since removed. Now we picked up on some of these. **Waukeegan** is a good example, where there is a Superfund site upstream from our project and the stuff keeps washing into the project. It is contaminating the project and we are waiting for EPA to get the stuff cleaned up at the source. I don't know what the PCBS there are; 3, 4, 5 % **PCBs**? New Bedford, do we even have a dredge project there? Perhaps further out there is a navigation channel?

Hansen, David: This week the pilot dredging project was initiated.

Wright: But we don't have a Corps project there so we would have never discovered that. We don't dredge Commencement Bay. Somebody else discovered the problem. Dredging might be a remedial measure but none of our projects fall under these criteria. Now back to your question, if we can set a level of 400 why can't we set a lower level? Mainly because nobody has been able to show a cause and effect with these lower levels. If you get 3 or 4% of PCBS in there, it doesn't take a genius to say that you are going to have an effect. If you only have 1 ppm of **PCBs**, **you** look for an effect and there are 400 other things in there, so you don't know what is causing the effect. When in doubt take an ecological effects based approach. That will give you the answer. That is what you are really asking anyway, Unless it is grossly contaminated material. I doubt it you could find Norton Sound to be a Superfund site, I hope it's not.

Hansen, Don: But this area hasn't been dredged before.

Wright: *Questions and Discussion*

Wright: We have an ocean disposal site there to maintain the channel.

_: *It hasn't been dredged where the work is supposed to be.*

Wright: There is reason to believe again how much of that material is material that could have been **anthropogenically** contaminated since 1900. The top meter, the top 6 m?

*Hansen, Don: We are concerned with both the **anthropogenic** and the natural.*

Wright: I don't know what you are going to do about the natural. I guess worry about it. God put it there, God keeps putting it there. If you divert the Yukon in the other direction and dump it over on Asia or something. It has been there a long time and I doubt if the availability has changed much in the **last** 18,000 years. Folks seem to have been around here at least that long and somehow got along. Not to say that they might not be better without it. But there are a lot of other things that are **anthropogenic** that might be more dangerous to your health. Many of them arrived with the Europeans.

*Prentki: I have a question on **bioaccumulation**. What animals are used for **bioassays**?*

Wright: Normally they are done on an amphipod and a **polychaete**.

*Prentki: Are those critters good **bioaccumulators**?*

Wright: **Polychaete**, yes.

Prentki: Are fish ever used?

Wright: The problem with the fish, or any kind of motile organism, is you don't know where they have been, you don't know how long they were there, you don't know what was there. They may be on uptake or on deputation, you just don't know when you start dealing with motile organisms.

*Prentki: Has your lab done time series studies of **bioaccumulation**?*

Wright: Oh yes

Prentki: How long was the testing?

Wright: Metals - a couple or three days, **Organics** such as TBT, TCDD, dibenzofurans and a few others, ten days is adequate.

Prentki: Is it possible that the organisms can be up to FDA action level for trace metals?

Wright: For metals, yes. But we are not shooting for steady state, we don't have to go steady state. We merely have to show the potential. That is the legal word. It doesn't say do a steady state, it says "show the potential for **bioaccumulation**."

Prentki: Wouldn't your potential for the FDA action level... ?

Wright: Those are the interpretive values. In other words we run enough of these things that we can look at what happens in 10 days and extrapolate on out...

Prentki: You extrapolate...?

Wright: Yea. In other words if the line is sort of like this, we'll say that there is essentially no potential to ever get out to an FDA compliance. If it takes off like that, we'll say that it is going to get there, it might take 15 days, but it is going to get there. That is what we base the decision on.

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Prentki: How many **elutriate** samples do you run?

Wright: That is flexible. It depends on a number of things. It depends above all on the project. **It** is a **site-by-site**, case-by-case, decision. Because if you have a project, I'll give you two extremes: the project covers 100 acres and goes to a depth of 20 **ft**, you can take cores down the project depth, and you wouldn't take an awful lot of them. Now if you had a project that was 300 m wide and 10 km long and winds its way through an industrialized area, the volume might be the same as that first one, the volume would be the same but you must take 10 times as many samples to be sure you cover what's needed,

Prentki: You need to sample the current sediment profile?

Wright: Oh yes. We don't do **surficial** because the dredge doesn't suck up the top, it sucks up the whole sediment column.

Prentki: When you do that do you just take the entire sediment column and mix it up?

Wright: It depends and again it goes back to "reason to believe". If you look at the core and if there is a marked discontinuity in there, or we are on a deepening project, where we are going to dredge 3 **ft** of maintenance material and another 9-12 **ft** of new material, we will sample that separately. It also depends on what the dredge can do. **Because it doesn't do** you any good to know that the top foot is a little gray, a little contaminated, and the rest of it is pretty clean. If the equipment is a 20 cubic yd bucket you can't scoop off the top foot and handle the difference. The bucket is going to integrate some material, just as the dredge will integrate. Now a deep project with a hydraulic dredge and a good operator, you can go in **and** just like slicing a cake or something, you can take the stuff off, and if you have a hot spot, you can handle that separately and then go back and take the other material and handle it a different way, It makes no difference, to get a resolution finer that you can operationally do with **it**. Chances are all that **stuff** is going to get mixed up with everything anyhow. You can't send people out there with ponar and put **400** people on the scene with **ponar** on the water and remove this contaminated sediment.

Prentki: Do you have any problems with **elutriate** tests going **anoxic**?

Wright: If it does, we aerate it so the material doesn't go **anoxic** any more. Obviously, if it goes **anoxic** it defeats the purpose of the bioassay, You are not interested in whether the anoxic kills the animals, most deep material will. So we will aerate it a couple of days,

_: Could you tell me, have you seen any differences in **the metals** that you say go to steady state within a matter of days, which metals are you referring to, is **mercury** one of them, is **methylmercury** one?

Wright: I don't know if we've analyzed separately for **methylmercury**, I think essentially all of them do. In fact at the Cape May meeting, there was a lot of discussion about going to 28 days as opposed to 10, because we couldn't get a strong enough signal on certain things. After discussing it and largely based on one of Rubenstein's recommendations, what came out was that for metals and the lower molecular weight **organics**, we'll stick with 10 days. The EPA sediment committee is going to meet and it is going to come out with some guidance on sort of a band, **...not** a line, that if you've got **organics** on beyond this point you will probably, depending on what's there, want to go to something longer without specifying whether it's going to be 14, 28 or 42 or whatever.

_: Because that observation is quite a bit different from the water-only exposures where at least with mollusks **the** accumulation persists for long periods of time, weeks and weeks as opposed to days.

Wright: Sediment apparently they get from wallowing around in the stuff, eating it, squirming through it and everything else. They get a sufficient exposure, it just goes up like this, The steady state is a misnomer, it's oscillation around a point.

_: What do you think about essentially short-term **biomonitoring** techniques as you mentioned here as **applied** to a dredging operation that **is** continual over a relatively narrow geographic area for months at a

Wright: *Questions and Discussion*

time, as I understand that this one would probably be? Do you think that tier of four tests, chronic tests ?

Wright: You could cage some mussels like we did at the Field Verification Project. We suspected that we had a long term release. You could cage some animals out there and analyze them periodically and see what they are doing. Staying steady or going up. The difficulty in all of these things is going back to the cause and effect. As someone pointed out this morning, there is great **seasonality**, at least in the chemical concentration of mercury. There is **seasonality** in the metabolism of the organisms, There is **seasonality** in storms. There is **seasonality** in all sorts of things. I am not sure how you would sort out a response on the part of the organisms with a cause as a result of the dredging operation. Unless you go to something like we did in New Bedford, you see a response and you atop the operation and see if it goes away. You start if up and see if it comes back. It gives you almost an **R&D** mode, which may run you afoul of the applicants because once you give them permission to go, unless you put some pretty stringent conditions, you shut him down, we are talking dollars now, you need to have a good handle to justify the shut down. If you shut him down and it keeps going up in the animals, you've got to line up with egg on your face, because whatever it was that was perturbing them wasn't due to the action of the dumping barge.

Hansen, Don: That is the reason why you want to know about those natural levels. You don't ignore it.

Wright: You do. You've already gone out there and I think the number of samples look pretty limited. What is the concentration of animals that are out there **living in** that stuff right now? If it's no more than I saw, I don't know why they would pick up any more from the operation. If you are worried about that, bring some more material back to the lab and hit them with the worse case that you can and see what happens. All the chemical numbers in the world aren't going to answer your question: "What happens out there?" You are asking the animal: "What does this mean to you?" Maybe it doesn't mean anything, maybe they all go belly up.

Fitzgerald: But you are just using concentrations as well aren't you? You look at the amounts that are in the organisms, you don't look at tissue or...

Wright: Yes we do. We do not regulate on the basis of concentrations. All we do, all the regulations say **if** you look at the material that you are going to take out there, and you look at what's out there and if the concentrations of chemicals of concern, whatever those are, are substantially different between the two areas, then it is appropriate to go further into biological tests and look into availability and toxicity. We have no numbers, the only number we have is 50 ppm of **PCBs**. If it's over 50 we turn it over to EPA,

Hansen, David: I might spend a minute to discuss the New Bedford Harbor pilot dredging project. We are involved in the chemical and biological monitoring for that project. The Corps of Engineers does not have an experience in this country with handling sediments **that** are as contaminated as those in the New Bedford Harbor Superfund site. Therefore, the Corps of Engineers and their contractor are in New Bedford Harbor conducting a pilot dredging project to see if it is feasible to move sediments, that are as grossly contaminated as those from the bottom of the harbor, to a **confined disposal facility** first, and then secondly, to a confined aquatic disposal facility which involves in-water capping of this contaminated material. Two questions are associated with this dredging operation. The first has to do with the efficacy of the dredging operation **itself** in containing the contaminated sediments. The second has to do with the environmental implications of this dredging operation. While the Norton Sound situation may not be as severe, the solution to answering the question of the environmental significance of the operation, may be quite similar. The Narragansett laboratory is involved in monitoring both the efficacy of the dredging operation and the potential ecological consequences associated with dredging. To do this we spent about a year collecting data on the background chemical concentrations and the background responses of organisms to site water, both through laboratory studies of site water to determine its inherent toxicity, as well as through the placement of organisms at the site at various locations so we could establish baseline conditions relative to effects and **bioaccumulation**. This kind of an approach requires a long period of time and intensive sampling because as everyone knows there is a lot a variance **associated** with background on seasonal basis, on organism state basis and the like. So it is a expensive thing to do. I venture that you probably have spent quite a lot of money already on this project as well. Our approach has been to develop this background data, utilize it to derive what we call decision criteria, which in essence are statistically derived in biological response

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(biological effects, and **bioaccumulation** of contaminants) relative to background, and compare that background mean and variance to what occurs when the dredging operation begins. What we have seen so far is that we can detect an increase in contaminant load and on rare occasions sometimes small biological effects for this really heavily contaminated material. But that the magnitude of the signals are not really sufficient, yet anyway, to exceed the normal variance associated with background. If you have that kind of data and you can demonstrate in this mining operation that you have maintained the conditions that are existing at the site without the mining operation, that is acceptable.

Emerson: Don't you think that is impossible?

Hansen, David: No. **It** is possible and we are doing it in New Bedford.

Emerson: Or even bring the environment into the lab, you have **already** lost it.

Hansen, David: I disagree. The laboratory is not the **field** but some lab studies permit us to understand the **complexity** of the field better than field testing. **In** New Bedford both field and lab test are being used.

Emerson: How can you do that?

Hansen, David: Water from the site is tested immediately. Some of the tests that we use are hour long. They look at what we already know to be the sensitive processes, that is the reproductive process in organisms. We've reduced the required duration of exposure to look at reproductive **effects**, teratology and the like from months to days. So **it is** possible to do. Where **possible**, field studies provide confirmation.

Emerson: Are you looking at long-term, sublethal responses?

Hansen, David: I guess the question here is, are the long-term responses you see in a life cycle toxicity test the function of the total exposure, or total accumulation of the contaminant over a long period of time, or a reflection of a short-term exposure to the most sensitive life stage? With mercury, the answer is likely the former because it is slow to accumulate.

Emerson: When you **say** test it right away, you must be talking about an hour to ten, you must be talking about Daphnia?

Hansen, David: No, we are testing **marine** organisms. We have tests with sea urchin sperm cells and with *Champia* which is a red, **macroalgae**. Both are reproductive tests. Tests with mysids that measure effects on **survival, growth** and reproduction. Tests with fish that are survival and growth tests. No one experiment is the answer. So you must test a spectrum of kinds of organisms, and you need to focus on the life stages that are the most sensitive. The experimentation has to involve more than just **laboratory** tests of site water. It should involve placement of organisms around the dredging operation so you can control their migration, because exposure must be known. You can look at the time, the course of events. A sampling of **sessile biota**, as you have already done, is also **an** important part of the monitoring process. But it must be done beforehand with sufficient rigor to understand the normal background variance. It is not a cheap thing to do. In the New Bedford Harbor, monitoring costs exceed dredging costs. There is a lot of research associated with it, but as **I** think you have **all** heard today, there are serious **technical** difficulties in understanding the relationship between chemical concentrations, and the complexities associated with them from analytical methods and changes of forms of mercury and maybe other contaminants, to the **relevance** of biological tests that do not use those exact forms and those exact ratios as end points. So maybe in a case like this that has a large economic **value**, unless the price of gold has gone down an awful lot since this morning, that this kind of detailed monitoring, at least at the onset, is justifiable. This will be one way to demonstrate that there is or is not a cause of concern.

Marsh: What were the contaminants in New Bedford?

Hansen, David: The dredging site is contaminated with **PCBs**, metals, and other substances. We picked a relatively uncontaminated site where the sediments contain 100-200 ppm of **PCBs**.

Wright: Questions and Discussion

Marsh: **Did** it include mercury?

Hansen, David: As far as I know, it does not include mercury. It includes **dibenzofurans**, PAHs at high concentrations. We haven't analyzed mercury, so I don't know if it is present.

Wright: Norton Sound compared to New Bedford, taking the New Bedford approach would sort of be a bear because you have the river coming in carrying apparently natural mercury, you have the **atmospheric** deposition, which is seasonal, you have storms which stir things up. There are, I assume, floods and then it returns to flood stage. One of the things that we were concerned about at New Bedford, is what we are trying to do is to see if dredging is feasible way of removing this junk without unleashing it all over the environment. So you mention developing decision **criteria**, one of the big obstacles is what happens if we **start** dredging and there is a flood or storm or any number of natural events? And there was.

Hansen, David: There was. The very first day of dredging exceeded the decision criteria by about 20% for **all** of the metals as well as the **PCBs**. But in being there on the site you can use your **brain**. What happened was the tide ebbed for 8 hours that day. **Mudflats** that had never been exposed before in an entire year of monitoring were exposed. In fact, the tide not **only** ebbed but it also flooded and ebbed **all** during the time of expected flood tide. So it was a severe weather **event**. We said this is something that we haven't **modelled**. So let's continue dredging. The **next** day background conditions returned. So you have to have people who can make a rational decision in light of the data in order to say, yes something went wrong but we have good reason to believe that it is not part of the norm and not part of the dredging operation. So, therefore, let's continue and confirm or refute those hypotheses. It is an expensive **way** to attack the problem, but it is one that/ believe has a lot of merit and power.

Wright: It's being done in an R&D mode, not the **regulatory** mode. If this were a dredging project..

Hansen, David: You wouldn't let us do this.

Wright: We couldn't do it. We've had **projects** where we have only been allowed to dredge on ebb tide, and a **few** little things like that. It is really **neat** to go in the Gulf of **Mexico** where you don't have diurnal tides, you have weird tides. We just don't dredge when it silts up, you just walk ashore, you don't boat ashore. It is expensive and it is **R&D**. You need to think about it before you invoke this approach, operational or regulatory mode.

Hansen, David: But it **actually** is not much different from what you talked about Tom. At least in my mind in terms of using organisms to be a detector of the **signal** of an operation. The approach that you talked about uses short-term lethality end points rather than reproductive ones and does not monitor what is actually going at the site. It tries to make decisions before the **operation** occurs.

Prentki: Earlier you were talking about your water quality criteria, the Corps of Engineers dredge uses mixing?

Wright: We do. I don't know what EPA does. We have our own mixing criteria that are written right into the regulations. It is a little different, it is basically 20 m or depth to the **thermocline**. What we basically do is, four hours are allowed rather than a distance. You go through and compare the ending concentrations of the contaminant of concern to the **elutriate** concentration of the contaminant of concern, etc. to see if the volume is great enough to get you down to or below the criteria.

Prentki: Does that work for the chemistry...?

Wright: **Yes**, it sure will. I have the formula right here if you want it. **We** had it for potential discharges.

_: I am concerned with the washing of hands attitude of the tailings and the dredging. If we look at historic practices in **Norve**, we know there's current dredging therein marine sediments, on these pockets in the **wetlands**. What we see is the Corps of Engineers has washed their hands of the tailings, EPA doesn't care. The state doesn't care.

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Wright: We don't have the authority regulate,

_: *Well, right. So everybody says we don't have the **authority**, but what we have **in** Nome is 450,000 ppm mercury and 470,000 ppm arsenic dumped on the ground, that nobody cares about. That nobody regulates because it falls through this loophole and everybody washes their hands of it.*

Wright: We don't dredge the ground, A dredged material disposal area or what?

_: ***Well**, see, **that** is the thing. **Everybody** washes their hands.*

Wright: Where did they come from?

_: *It **is** old marine sediments that are on the uplifts.*

Wright: How did they get there?

_: ***It** was uplifted.*

Wright: Oh, God put it there, we didn't put it there. So we can't do anything unless Congress authorizes it.

_: *Mercury amalgam was used in a lot of that stuff, and man did put it there.*

_: *But the arsenic is a derived concentrate.*

Wright: Our dredging is associated with any a) navigation, if it is an upland there isn't much navigation as a rule; b) flood control; or c) water supply, Those are basically the three reasons for dredging. We also dredge, as Dave has pointed out, under such things as **Superfund authority** where dredging is authorized by Congress, You need one of my little brochures, because we do all sorts of upland hazardous waste stuff, We have a background in this, mainly because our skirts are not entirely clean, The Department of Defense has been known to manufacture munitions. Some of these munitions manufacturing places are not the nicest areas in the world. We look at that, but if there is no federal interest by EPA, in your bailiwick, what **you need to do** is go to **your congressman "sic him" on Region X, tell him to "get moving". Either EPA has got to handle it or the state has got to handle it, or whoever put it there has got to handle it.** If your congressman decides the Corps would be good folks to handle it, he could so direct, We are good soldiers, we follow orders. We don't give them, we just follow them,

Anderson: *Mercury, that this **gentleman** was **talking** about, has nothing to do with our topic...*

_: *But it is from gold dredging.*

_: *No, it is from refining. A part of mining process. The arsenic definitely is directly related to dredging.*

_: ***Is** there some direct information that **it is** actually causing a problem?*

Anderson: ***It** is not a problem, we **both** grew up there and we played on it.*

MERCURY ACCUMULATION AND EFFECTS IN ORGANISMS

THE SIGNIFICANCE OF MERCURY RESIDUES IN MARINE VERTEBRATES

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Currently recommended criteria for mercury (Hg) in fish and other seafood products for the protection of human health, in mg total Hg/kg fresh weight edible tissue, are <0.4 in Japan, <0.5 in Canada, <1.0 in the United States, and <0.25 for expectant mothers. However, Hg concentration in tissues of various marine species frequently exceed the proposed guidelines for human health protection - without observable adverse effects on the organism. For example, concentrations of total Hg in liver of older individuals in several species of pinnipeds normally exceed 10 mg/kg fresh weight.

At present, most authorities agree that Hg accumulation and retention in marine vertebrates, and ultimately its hazard to the host organism and to its consumers, is governed by many factors. In coastal and marine populations of elasmobranchs, fishes, birds, and mammals, these factors include the age of the organism, life span, tissue specificity, diet, general health, uptake rate, ability to discriminate among different chemical forms of Hg, availability of selenium, and proximity to anthropogenic pollution. One result of the action of biological and abiotic modifiers is an extremely wide range of Hg concentrations both within and between species.

Among sensitive species adverse effects have been reported - in mg total Hg/kg fresh weight - in birds at >5 in feather, >0.9 in egg, and >1.0 in diet; and in teleosts, based on very limited data, >5 in whole fish. For most species of mammals, total Hg concentrations >1.1 mg/kg fresh weight liver, kidney, brain or blood are usually considered indicative of an environmental Hg problem",

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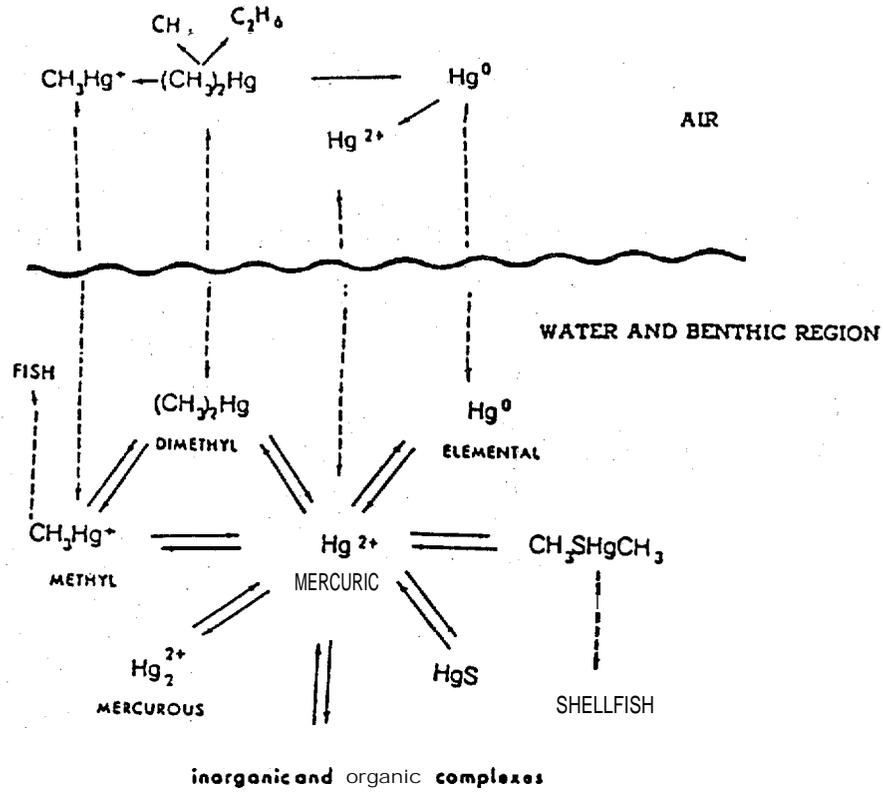


Figure 1. Major transformations of mercury in the environment (modified from Beijer and Jernelov 1979).

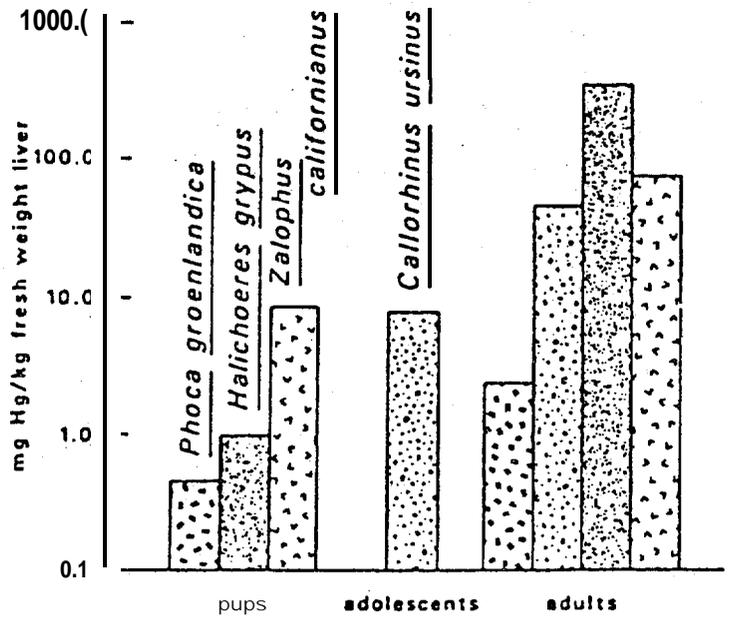


Figure 2. Mercury concentrations in livers of four species of pinniped mammals (from Eisler 1984).

THE SIGNIFICANCE OF MERCURY RESIDUES IN MARINE VERTEBRATES

Ronald **Eisler**

Questions and discussion

*Armstrong: When you talked in the very beginning about the levels of mercury for pregnant women being 0.25, I just wondered, is that a U.S. figure or where **did** that come from? I haven't seen that **in** the literature.*

Eisler: That is a medical question, we have a very well qualified physician here, Dr. Marsh.

*Marsh: I can't give you **any** reference to that 0.25. Incidentally it was in the same paragraph where you mentioned a few seconds **later** a figure of 6 ppm. That of course is after the safety factor of 10. The **magical** number claimed as the lowest effect levels, 50 or 60 ppm in **hair** in Japan. That doesn't count the safety factor of 10. That is where the level 5 or 6 comes from. But there is no data to suggest human sensitivity at the 0.25 level.*

Armstrong: Where did you get it?

Eisler: There is a reference to that in **Eisler** (1987),

*Armstrong: I know that it says right now that next month, in December, **World Health Organization (WHO)** is considering a level that they consider safe. That is why I was just wondering if it had been established yet. The other thing that I was wondering is if, and you **probably** can't answer this one either, but if in seal liver there is 3-4 ppm of **methylmercury**, then presumably if somebody ate **that** liver that would be of consequence. But what about the inorganic mercury that is there in the seal liver? Wouldn't that also be of concern?*

Eisler: The inorganic mercury is bound to selenium. It is unavailable to the host organism as indicated earlier. I don't know what would happen, what kind of digestive processes would be used to split that bond and make it available. It is one of the gaps in the literature. The **reference** to pregnant women is by **Khera** 1979. It was in a chapter in Jerome **Nriagu's** book on the **biogeochemistry** of mercury.

*Marsh: Could I make a comment about **the** inorganic part **it** sounds terrible, if you have seal with **100** ppm total mercury, most of that is inorganic and probably bound to selenium, but it is not absorbed. The **methylmercury**, organic mercury is almost **entirely** absorbed through the **gastro-intestinal tract**. So if you eat **methylmercury** over 95% is absorbed. But inorganic is almost the opposite. Some tiny part of that is absorbed.*

*Armstrong: Can inorganic mercury become **methylated**, though, in the intestines?*

*Marsh: Yes it can. But not if you consume inorganic mercury. **It** goes through the gastrointestinal tract and comes out in the urine and feces essentially.*

***Tornfeldt:** I have a question, does the liver **purify** the other parts of the body, is that its function?*

Eisler: I regard the liver as a giant hotel of all contaminants. Many contaminants **translocate** to the liver. There, one of the body's responses is the "solution to pollution is dilution". So what happens is that in many groups of contaminants, the liver is greatly enlarged, it has a much higher wet to dry weight. It is going to dilute out these contaminants. Also the bile is getting ready to be passed out through the feces.

***Tornfeldt:** Could you say then that, this is just a hypothesis, the **methylmercury in the** other parts of the body has been diluted and changed to mercury associated with **selenium**?*

Eisler: In sharks and **teleosts**, Hg relocates to the muscle tissue but in the higher organisms to the liver. I don't know why.

*Emerson: Do we have some references to the effect that the inorganic mercury bound with selenium, going through our own bodily processes, with a variety of the **pH** conditions in the stomach and so on; there*

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isn't some disassociation constant there that **could** cause a problem. Let's say mercury associated with selenium, there must be a study that has done some definitive work like that?

Marsh: i wish I could say that there was. But when you get into human effects of selenium, I am not aware of any human data on mercury-selenium bound compounds; Inorganic mercury in general is very poorly absorbed upon ingestion. I don't see why any possibility of binding to selenium would change that. If anything, it would be likely that the binding would make it unavailable. If you ask for references, there are no references that I am aware of.

Emerson: I don't see how a bond of another chemical species with mercury can be compared to the bond with selenium. They are two different compounds.

Marsh: Well, the difference in terms of species of mercury is that organic forms are well absorbed and inorganic are not. So if I had to guess, I would say that inorganic mercury bound to some selenium complex would probably not be well absorbed. If you ask questions about the human metabolism of mercury-selenium, I don't think that there are any such data. If you look at the animal data, it is quite confusing. It is not simple. But for the humans there are no data.

Hansen, David: I just want to point out in the literature as far as natives eating seal, there have been studies in Greenland that have correlated blood mercury levels with consumption of seals. Whether it is mostly inorganic or methylated, there is a correlation there.

Eisler: It is probably from the methylmercury in the seals. I can't make any statement about the inorganic mercury bound with selenium, but the evidence is overwhelming that it is the methylmercury that is passed through different food chains,

Armstrong: Actually, the study in Alaska was correlated to eating seal meat and seal oil too. There are elevated levels along the coast in the Yukon-Kuskokwim area of women and infants significantly higher than people in the interior of Alaska and in Anchorage; they did a comparison.

Emerson: Do they have disassociation constants for these compounds in the updated handbook?

Eisler: When I was preparing this review on mercury I thought that I could go to a handbook and find out what the volatility of methylmercury chloride was in water or in any organic solvent, It didn't exist. I called the manufacturer. I called people who work with methylmercury chloride. I finally had to do a few studies to determine its volatility. So there are such gaps in the literature, even the physical chemistry of this compound is not well known,

Prentki: Is that mercury-selenium complex an inorganic complex or is it an organic complex?

Eisler: I don't know. It probably is a selenite, inorganic mercury, it is probably inorganic selenium, But now the people at Patuxent are conducting research on organo-selenium compounds; there is an interest in some refuges where we have agricultural wastewater. Organo-selenium compounds are extremely toxic. I would say that it is probably an inorganic selenium compound.

Prentki: I would think that would make a difference in how well it would be taken up.

Eisler: I don't know if it is selenate, or selenite, or selenide, it is probably selenite, but it is probably not an organo-selenium compound based on its toxicity. if it was an organo-selenium compound, it probably would be able to be taken up or be more lipid soluble than the inorganic compound.

Irvine: Can you talk about the dynamics of half lives and how that may vary between invertebrates and groups such as fishes? Is it just related to age or what?

Eisler: The half life, from what I can gather, the time it takes to deplete 50%, remains fairly constant. The actual numbers are here, but the accumulation apparently is constant with age and the depuration is

Eisler: Questions and Discussion

essentially constant with age. It takes it up faster than it can **depurate** which accounts for the accumulation. I recall in oceanic sediments that the half life is very long, about 1000 years. It is much shorter in freshwater systems. There are many interesting questions, when you apply this dredging situation in Norton Sound to mercury dynamics. There are people who believe that the levels of silt are sufficient to damage, let's say, the gills of bivalve mollusks (clams) to the extent where they will eventually die or at least have impaired reproduction. I noticed a level here of 7.5 g//. Others (this is back in the 1960s, at least) on the East Coast working with oysters and clams have reported that 4 g// of silt is enough to damage the gills, the filtering mechanism of the bivalves. Of course it is these clams that form the food for the walrus. They have enormous accumulation potential. I don't know what form the mercury is in the bivalves. The half life varies and among fishes it "is somewhere between 200 and 1000 days in vertebrates,

Irvine: Are there figures for other invertebrates?

Eisler: Yes. There are figures for other invertebrates but it varies by species and I can't recall the values offhand, but they are listed in **Eisler** (1967).

*Irvine: How about long lived crustaceans as **bioaccumulators**?*

Eisler: Crustaceans are **probably** the worst indicators of metal accumulation. There is one case in Berry's Creek, New Jersey that I worked on for a number of **years**, where they were using crustaceans **as** accumulators, As soon as the animal molts, almost **all** mercury is lost in the shed exoskeleton. And so you are off to a brand new, pristine area, I think the best indicators would be **sessile** organisms on site. I am partial to bivalve mollusks.

Irvine: What about predatory snails, large predatory snails that we have in Norton Sound?

Eisler: Which snail?

*Irvine: Neptunea and large **neptunids**?*

Eisler: They don't have the capacity to accumulate as do bivalves who filter the medium. That is very difficult, as to how much it accumulates up the food chain. You are better off with a bivalve, In some cases it goes down. **With** some **transuranic** isotopes it goes down as you go up the food chain. With others it stays the same, I've done some work with some drills on the East **Coast** and the West Coast and the Red **Sea**, but I haven't done anything with residues. Incidentally, in order to have a legal action you have to have a measurable residue. It just isn't sufficient to state that it looks like the population is crashing or in fact that the population has crashed, unless you can link it to a residue. **A** residue that will stand up under proof of impartial, any twelve people picked off the street here, evidence has to convince them, It is not enough to say the mercury is carcinogenic or mutagenic or **teratogenic**, you should have a residue. That is the fact of life at this juncture. Sometimes you might **be** able to get by with a biochemical indicator like amino **levulinic** acid dehydratase (**ALAD**) in lead, But then you have to link that to lead residue, **ALAD** as a biochemical indicator of lead contamination. I don't know of any biochemical indicator of mercury contamination at this point. Perhaps some others could shed some light. But you must have a residue. This is the point, you can have the entire population disappear, you can have residues that are elevated in the sediment, you can have residues that are elevated in the water column and this is good circumstantial evidence that there is a problem, but eventually you must produce an organism which is the **ultimate** arbiter of its environment with elevated Hg residues. **Pinniped** mammals have high levels and are unaffected; levels that would be fatal in other species of furbearers. **Life** isn't simple.

*Irvine: But where you run into **problems**, as I see it with **something** like that, is that the most sensitive organisms are the younger stages. So you might cause lethal or sublethal effects on the eggs and embryos, in that you could get effects on recruitment into the population.*

Eisler: That is always an interesting point, We were talking earlier about your thesis on coral reefs. I believe that in order to protect the population you have to protect the integrity of the brood generation. **With** coral embryos, you can destroy them and yet on the next tide, the area could be replenished, But if you destroy

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the coral reef, you've eliminated the brood stock and you've also destroyed the ecosystem in the process. So I have a lot of problems with the effects on embryos. As long as the parent stock is thereto replenish. It is certainly an indicator that something is happening, but with marine embryo assays where a normal mortality is usually 90% in the control group, I have real problems trying to separate subtle effects masked by high mortality.

Irvine: It is hard to separate right?

Eisler: For me anyway, others have no difficulty.

Anderson: It might be interesting for the group to understand that the people on the Norton Sound when they take a seal, they will eat the liver first. It is a delicacy. When the same people get a polar bear, they will eat all the bear except the liver.

Eisler: Polar bear liver is unusually rich in vitamin A and people have died from overdosing on vitamin A from polar bear liver. It may have very high levels of mercury **also**. Incidentally, people in Norton Sound are not unusual in consuming seal. I worked in Narragansett, Rhode island for many years and one of the people there was from Newfoundland, where seal seemed to be a daily staple, passing around a flipper now and then, it is an acquired taste.

Wright: But what do we do here in the case of these more or less highly mobile animals, where we capture an animal here and it has a high residue, in trying to relate that back to some environmental contamination where the animal might have picked it up 70 or 50 or 100 miles away. Has anyone tried to factor this in?

Eisler: Well, I showed you that last slide with these migratory birds, a sort of a generic type of slide. So you have to know where it's been and what it has eaten. That may not be as simple as it sounds, so as an indicator for a particular regional area, the **sessile** organisms are good indicators. But when you get a highly migratory fish, let's say along the East Coast, a bluefish, it could pick up a slug of contaminants as it travels up the coast and then works its way into a thermal plume and dies because its defenses are low. So one more stress might do it. Sometimes organisms die from causes other than what you are looking for and they can accumulate. A dead organism can accumulate **toxicants** from the medium that a live organism can detoxify quite rapidly. It is a good case with cadmium. I was dosing fish with cadmium, very high levels of cadmium, radio-cadmium, as well as stable cadmium, and in the first three hours there was essentially no uptake because its slime layer was completing the cadmium and it was being sloughed. But after three hours they couldn't continue the process and started accumulating cadmium, That process took a long time. A long time for them to reach equilibrium and a long time for them to die. I noticed that you mentioned yesterday that the metals came to equilibrium within three days, maybe most do, but cadmium doesn't.

Irvine: A question about the point of conversion in the food web. I've read accounts that say the major point of conversion of inorganic mercury to organic mercury is at the level of phytoplankton. I also read that in Japan it was thought to be at the level of zooplankton.

Eisler: Apparently it can take place almost anywhere. **Jernelov** was one of the first investigators in that area. But this strengthens my conviction and statement that any form of mercury discharged into the environment is capable of being transformed into **methylmercury**. Which is why we shouldn't dismiss the fact that the pinnipeds have very high levels of inorganic mercury bound to inorganic selenium and doesn't seem to be biologically available. Maybe that is what the evidence seems to indicate now. But I don't know at what rate it is capable of being converted to **methylmercury**, which is the most hazardous of the chemical species. It can occur on the outside layer of fish in the slime. Inorganic mercury can be adsorbed; in fact, most of the uptake studies on **phytoplankton** and zooplankton are really adsorption types of studies. It's very difficult to find out what has been absorbed. There may be some transformation and then absorption because it can be taken up through the skin surface, at least in higher animals, probably through the outside membrane of whatever species. That is why it is so confusing. It is a naturally occurring element. All you have to do is **translocate** the process a little bit and we have a **Minamata** Bay. You can live with mercury, you can't legislate it out of existence.

Eisler: Questions and Discussion

Irvine: What about synergistic effects of dredging activities and mercury, where you are talking absorption or adsorption, you mentioned earlier about effects of siltation on gills.

Eisler: Mostly the effect of mercury and its various species with other elements are unknown. What you are trying to do is pick out one component and **fix** the blame on that in terms of the entire operation of Norton Sound dredging. You may be right. But I don't know the levels of lead or other potential contaminants. This is a high volcanic area and many species of marine mammals have high Hg levels in their bodies. Dr. Ronald from Canada did a number of studies that showed that many whales that beach had unusually high levels of mercury in the inner ear. This might affect their equilibrium patterns, but it may not have. He has published a number of papers on why the whales beach, how they became disoriented and the possible role of mercury.

Irvine: Parasites are implicated in some strandings.

Eisler: Parasites in most, but mercury in some.

Emerson: Is the methylation primarily bacterium mediated?

Eisler: Primarily, but it can happen through other processes.

Emerson: Could a host organism through its own indigenous microbiota initiate that process?

Eisler: Yes. Dr. **Rita Colwell** at the **University** of Maryland has done a lot of work on mercury-transforming bacteria. Apparently almost any strain can acquire the ability to transform mercury into **methylmercury**. In Chesapeake Bay she found at least 223 different strains of bacteria that were capable of doing that. And the number that initially, strains that couldn't, did in a few generations.

Emerson: That were in the digestive tract of organisms?

Eisler: No, it is in the sediments.

Emerson: I am saying within the micro flora of that digestive tract.

Eisler: I don't know.

Hansen, David: Yes, there have been few studies with Escherichia coli. Experiments in vitro, in vivo with rats.

Emerson: So could a seal generate its own methylmercury problem and cause some erratic behavioral problems?

Eisler: Good question, I don't know.

Emerson: It would mostly show up as a behavioral problem, right? Before we see any toxicity because isn't it neurological?

Marsh: There are some reports of bacterial action in the gut causing methylation. But it seems to me that the important part of the seal story is that if a seal has a total mercury concentration in the liver of as much as 100 ppm, that 3 or 2 ppm would be methyl. There is the question you are probing. What about the inorganic part of that? is it possible for a small part of the inorganic to be methylated in the gut? I can't answer that. Theoretically some seal might be. We know that maybe 3 or 4 ppm in seal liver, that is very high. I don't know how much the people in Nome eat. What is a meal? When you eat seal liver, how much would you eat? Would you eat a pound, at a meal? How much would one person eat? One pound or 100 pounds? If you compare that to eating any species of fish, 3 or 4 ppm is very high for any fish that they are likely to eat. All this fuss about king crab, they have got 0.0 something ppm, so for every pound of king crab that they eat, you compare that with 1/2 pound of seal liver or 3 or 4 pounds per

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month, this is the harvest which concerns me. *It* is of theoretical interest as to what happens to the inorganic, the other 90 something percent. Could some part of that be **methylated**? But I'd be very concerned about the methyl part. Everybody says don't worry about it, because it is mostly inorganic, but the methyl part is the same concentration as, for example, a big shark might have or some of the highest levels around the world in swordfish, 3 or 4 ppm.

Armstrong: Not only do they eat a lot of it, but they eat it often. Not a lot of liver at once, but seals are a regular staple in their diet.

Hansen, David: I'm just commenting on some of the work done by Ronald on harp seals indicates that even though the levels found in seal muscle are low, the percentage of **methylmercury** there is very high.

Eisler: In any area up to about 4 ppm it is almost all **methylmercury** and I think the highest levels that I know of are in some black marlin off Hawaii where you might have 7 or 8 ppm, about 2/3 of that is **methylmercury**.

Hansen, David: Also, in the seal flesh, other than the liver, the percentage of mercury in the seal muscle is almost all **methylmercury** rather than inorganic mercury. So if they are eating just the seal muscle...

Eisler: Depending upon the level, I would say up to the first 4 ppm, certainly the first 2 ppm is almost all **methylmercury**. But again in most species of fish you rarely find anything exceeding 2 ppm. In seals probably the same pattern holds true, but I don't know, I haven't looked at the seal flesh.

Hansen, David: The studies by Ronald show that what was in the seal muscle was almost 100% **methylmercury**. The natives may be getting it from the muscle as well as from the liver.

Emerson: Do you think the method of preparation **would** affect that **methylmercury** level? Like you had your seal liver medium well or well done?

Eisler: No, it won't make any difference. Cooking will not destroy the **methylmercury**.

Emerson: Well, it seems to be kind of a hard species to keep in place, the **methylmercury**. It seems to be readily moved through the cells?

Eisler: Well, let me put it this way, if you like **sashimi**, raw fish, or if you are mercury deficient, then you may want to eat tuna; it doesn't matter, you'll get the same amount of **methylmercury** whether it is raw or whether you cook it. It is not destroyed by cooking. In fact, cooking probably concentrates Hg, because you've driven the moisture from it.

Emerson: So it is probably attached to somewhere in the cell. *It* is probably associated with some protein complex and it stays as opposed to being just within the **cell** fluids.

Eisler: Yes, it forms a thiol complex with the cell.

Emerson: So preparation *isn't* going to help you basically. *In* terms of the seal liver, you probably aren't going to have that raw.

Eisler: It is very difficult to get people to change their dietary habits. On the Nile River in Egypt, for example, where the Nile was capable of supporting 54 pounds of fish per person per year, the average person around that area only ate 18 pounds. Instead they had dietary supplements of very low nutritive value of cereal grains, and they were suffering from malnutrition. It didn't matter that you told them that they could become healthier by eating more fish. It is almost impossible to change dietary preferences of people.

Prentki: Ron, as far as parts go, if we went into a monitoring program, would we need to monitor both for **methylmercury** and total mercury in these organisms?

Eisler: Questions and Discussion

Eisler: As I have indicated total mercury, any part of total mercury, is capable of becoming methylmercury. You'll find that when the residues are low, probably at least in a biological organism, it is going to be almost all methylmercury. But you have to know what the total is going to be.

Prentki: You need to have bet% of them?

Eisler: if you had to do one, you'd do total methyl. It is always preferable to do both, but as you look for methyl, you may miss the dimethyl; you may not analyze for that too.

Prentki: Is that separate, when they do analysis for methylmercury do they just pick up monomethylmercury?

Eisler: I suspect they transform all of the organomercurial to methylmercury. I'm not sure.

Prentki: Do you have any idea how more expensive it is to analyze for methylmercury than just total mercury?

Eisler: No. But if the contract is large enough, some accommodation will be made.

Wright: I keep coming back to the basic premise that I think what we want to know is what is going to happen, and not why it is happening.

Eisler: I agree with you 100%. I am trying to say that you can't say what is an effective residue until you know all modifying variables for that species.

Wright: The question comes up, will lead interact synergistically with mercury and selenium may offset it and so on and so forth. But be careful with correlations because they do not imply cause and effect. I just had a good one today. Dave Hansen was on the East Coast last week, they had an earthquake; now he is here and we have an earthquake. I hope he doesn't stop in Memphis, because if the New Madrid fault turns loose, then Vicksburg is going down the river. I think when you get into situations like you have here, where you're in the laboratory under controlled conditions, where you can add a single contaminant and establish a cause and effect relationship, the only way to approach it is to take the whole ball of wax and throw it at the critters and say: 'what does it mean, what's it going to do to you?' Don't worry about whether it is mercury or lead or cadmium or "bolognium", you will probably never ever be able to find out in a natural situation, unless there is something there that is just totally overwhelming, like PCBs in the upper Hudson. Which takes me back again to what prompted this, was the question on monitoring. You've got to establish what is going on now in order to determine what changes you are monitoring. What are you going to compare it against? If you don't have anything now, if you don't have an effect now, if you are going to monitor you are going to have to define what your effect level is, just as Narragansett did with New Bedford. They said this is where we break the line, and when we get above it we are going to do something; stop the dredging. I don't know where you are going to set that line, but I think you absolutely have to determine if what you predict is going to happen.

_: Is there a level where the deputation and the uptake balance off and you have an equilibrium or the concentration doesn't increase?

Eisler: No, as you get older you just tend to accumulate it, it is always on the plus side. This is true for a large number of metals, including lead. But lead doesn't accumulate in the liver, it accumulates in the bony tissues. It is true for selenium, which seems to follow mercury very closely. It is true for iron, which again is also in the bony tissues. But sooner or later, this brings in the whole process of aging, which is why I started this project a long time ago, why do animals age and why do they die and does this correlate with metal concentrations? It may be that as certain metal levels reach a critical threshold, there are changes in action potential or the cellular membrane. The point is that may be part of the normal aging process. Mercury accumulation is true for all marine vertebrates regardless of where they are located.

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Rusanowski: Just to expand on that, your last slide showed a bird population in which in less than six months you lost more than 90% of the supposedly accumulated mercury. Does that mean that birds are different than the marine vertebrates?

Eisler: No. The function of that slide was to show that these three species of *Calidris* picked up the mercury from eating fish in the western European estuaries where they were unable to fly because they were molting. They did deplete in six months. You are right, I hadn't thought about that, maybe it is because it wasn't bound, or maybe it's because the species doesn't live more than three years.

Rusanowski: Well, it doesn't seem to indicate that it is a one way accumulation over the lifetime.

Eisler: You have species of seals that might have 30 to 40 ppm of mercury in the livers and that same species in that same age in a different geographic location would have 3 to 4 ppm. So it is quite possible that there will be depletion.

Wright: Most birds molt twice a year, maybe they got rid of it in their feathers,

Eisler: Their feathers or their eggs, that is possible also. That probably is a more reasonable explanation.

Hansen, David: What Kim's data on brook trout said is that most of the depletion that he saw when he transferred the brook trout to clean water was a result of growth dilution rather than the fish actually ridding itself of its body burden.

Eisler: Well, they weren't actually ridding themselves, the same residues stayed in milligrams/total fish, it "is just that the fish doubled in weight and milligrams per kg body weight halved.

Newbury: There is another factor that might affect uptake of mercury by seals for about six months of the year during the ice-covered period, their movements are very localized by the ice cover. They will stay in a particular area, even though they are capable of migrating great distances; the ice cover kind of localizes them.

Eisler: So if they are localized then you would want to see what the significance of dredging in Norton Sound would be on their food items. What are there, are there clams in Norton Sound? It is a very shallow bay, 10-30 m deep?

THE ACCUMULATION AND EFFECTS OF ORGANOMERCURIALS IN WILDLIFE

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INTRODUCTION

[n addition to causing a concern for human health affects, environmental mercury (Hg) contamination can create risks to the health and reproductive success of numerous wildlife species. The widespread treatment of agricultural seed with organomercurial fungicides during 1940-1970 resulted in the poisoning of significant numbers of seed-eating birds and their predators (Borg *et al.* 1969). The recognition of such outbreaks stimulated considerable research regarding the toxicology of short chain alkyl mercurial, especially methylmercury (MeHg), in birds and other wildlife. The present manuscript reviews these, and more recent, investigations.

PHARMACOKINETICS

Exposure to MeHg by wildlife takes place almost exclusively via ingestion of food. Whereas the absorption of inorganic Hg from the gut is at most only a few percent of the administered dose, absorption of MeHg approaches 100%. The kidney is the only major reservoir of Hg in birds and mammals following exposure to inorganic Hg, but MeHg distributes to many tissues (Backstrom 1969). Typically, the relative concentrations of Hg accumulated during dietary MeHg exposure are: growing feather/fur > kidney ≥ liver > brain ≥ blood > muscle. The biological half-life of Hg after MeHg exposure is two to three months in a variety of bird species (Swensson and Ulfvarson 1968; Odsjo and Edelstam 1975; Stickel *et al.* 1977), which agrees well with that measured for humans (WHO 1976).

TOXICITY

Simply stated, the three major toxic effects of MeHg ingestion in birds and mammals are death, neurological impairment, and reproductive dysfunction. A review of the published literature indicates that, for birds, the tissue Hg concentrations which are associated with these effects are frequently similar despite differences in species, body size, dietary Hg concentration, or length of time required to produce the effect (Bhatnagar *et al.* 1982; Fimreite 1971; Finley *et al.* 1979; Gardiner 1972; Heinz 1976; Scheuhammer 1988; Stoewsand *et al.* 1974). Neurological signs (weakness, difficulty flying or walking, incoordination) are typically associated with Hg concentrations of 15 µg/g (wet wt.) or greater in brain, and at least 30 µg/g in liver or kidney in otherwise unstressed adult birds. Death can occur without further increases in brain-Hg levels, although hepatic and renal concentrations tend to be higher (>50 µg/g) in association with outright mortality. Reproductive effects occur at very much lower tissue-Hg concentrations (2-20 µg/g in liver) in the absence of observed toxicity in adult birds. Table 1 summarizes the nature of the reproductive effects of chronic, dietary MeHg exposure in birds, and indicates the dietary Hg concentrations at which these effects have been observed. Overall reproductive success can decline by 50% at MeHg concentrations of 2-5 µg Hg/g (dry wt.) in the diet. As a general rule, the dietary concentrations of MeHg which are required to produce significant reproductive impairment are about 1/5 those required to produce overt toxicity in adult birds.

The susceptibility of mammals to the various toxic affects of MeHg is similar to that of birds, and the toxicity of MeHg in wild mammals has been reviewed (Wren 1966).

Ecologically, the feeding habits of the species will determine its relative risk to MeHg exposure, Carnivores accumulate more Hg than omnivores, which in turn accumulate more Hg than herbivores. Moreover, predatory species associated with aquatic food chains accumulate more Hg than those linked primarily to terrestrial food chains, and fish eaters accumulate more than species feeding mainly on insects or other invertebrates (Braune 1987; Doi *et al.* 1964; Hesse *et al.*, 1975; Lindberg and Odsjo 1963). Clearly, those

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wildlife species which are potentially at greatest risk from environmental Hg contamination are top predators associated with marine or other aquatic food chains. These species include eagles, ospreys, a variety of carnivorous seabirds, and mammals such as dolphins, otters, seals, and polar bears,

FACTORS MODULATING MeHg TOXICITY

Three important factors which affect the toxicity of dietary MeHg are: age, demethylation ability, and dietary selenium (Se) concentration.

Younger birds and mammals are more susceptible to the toxic effects of MeHg than are adults. In birds, 3-7 $\mu\text{g/g}$ Hg in brain can be lethal to hatchlings (Finley and Stendell 1978; Heinz and Locke 1976), whereas concentrations approximately five times as high are required to produce neurological impairment and death in adults. In quail, the oral LD50 of MeHg was lower for hatchlings than for two-week old birds (Hill and Soares 1987). Fetal and neonatal mammals are similarly more sensitive than adults of the same species (Chang and Annau 1964). The reproductive effects of MeHg exposure are largely accounted for by this greater sensitivity of the developing avian or mammalian organism.

Demethylation of MeHg in tissues of birds and mammals has been demonstrated (Komsta-Szumaska *et al.* 1983; Norheimn and Frosli 1978), and it is generally assumed that this represents a protective response to MeHg toxicity since inorganic Hg is much more readily excreted than MeHg. However, the relative ability of different species of birds and mammals to demethylate MeHg has not been adequately studied.

Toxicologically, an antagonistic relationship exists between dietary MeHg and Se. A diet containing 20 $\mu\text{g/g}$ Hg as MeHg caused 90% mortality in quail, yet no mortality resulted when the same diet was supplemented with 5 $\mu\text{g/g}$ Se (Stoewsand *et al.* 1974). In experimental mice, maternal Se deficiency enhanced the fetolethality of MeHg (Nishikido *et al.* 1987). The highly correlated deposition of Hg with Se documented in livers of carnivorous marine mammals (Itano *et al.* 1964; Norstrom *et al.* 1986; Smith and Armstrong 1978) has not been convincingly demonstrated for birds, but in view of the known antagonistic relationship between these two elements, the monitoring of tissue-Hg concentrations in free-living birds and mammals should be accompanied by Se measurements in the same tissues,

INDICATORS OF MeHg EXPOSURE

In order to assess the degree of dietary MeHg exposure in wildlife, convenient, dose-responsive indicators are needed. Feathers and eggs of birds, and the fur of mammals are good integrators of exposure; the collection of which does not require the death of the animals being sampled.

Figure 1 illustrates the pathways of uptake and loss of metals in feathers. In the case of MeHg, dietary exposure results in a dose-dependent deposition of Hg into growing feathers, and the resulting concentrations exceed those in other tissues by a factor of at least 4 (Heinz 1976, 1980; Finley and Stendell 1978; Stickle *et al.* 1977). Exogenous contamination and leaching are typically insignificant. A similar tendency for Hg to accumulate and remain stable in the fur of mammals has been noted (Wren 1966),

Hg accumulates in eggs in a dose-dependent fashion (March *et al.* 1983, Heinz 1976). Scheuhammer (1987) reported a biomagnification factor of 5-6 when comparing the Hg concentration in egg albumen with that in the food supply of birds experimentally exposed to a range of dietary MeHg. Thus the Hg content of eggs is a useful indirect measure of the average dietary Hg concentration.

Table 1. Reproductive effects of methylmercury.

Study	Species	*Hg in Food	Effects
Scheuhammer (1987)	ring dove	4.6	egg fertility hatchling mortality
Heinz (1974)	mallard	3	egg laying hatched hatchling mortality
Fimreite (1971)	pheasant	2-3	egg fertility embryo mortality
Barr (1986)	loon	1-2	egg laying territory use

*Content ratios are $\mu\text{g/g}$ dry wt.

Scheuhammer: *The Accumulation and Effects of Organomercurials in Wildlife*

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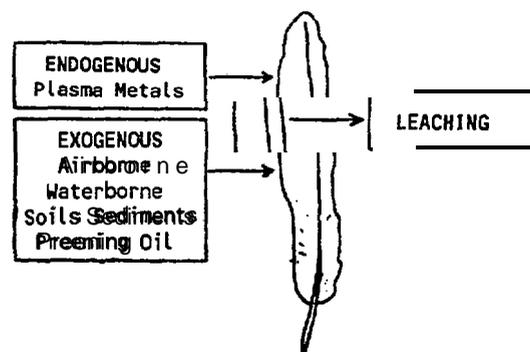


Figure 1. Pathways of uptake and loss of metals in feathers.

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THE ACCUMULATION AND EFFECTS OF ORGANOMERCURIALS IN WILDLIFE

Anton M. Scheuhammer
Questions and Discussion

Prentki: On your slide where you showed the loon concentration of 1 to 2 ppm, in terms of wet weight, would the food source concentration be about 0.2 ppm?

Scheuhammer: You can generally divide by 4, if you want a rough estimate; dry weight to wet weight.

Tornfeldt: How do you analyze the feathers, do you cut them up?

Scheuhammer: What we normally do is wash them very thoroughly with a nonionic detergent, and several rinses of distilled water to remove any surface contamination. That doesn't affect the mercury, mercury is very stable in the feathers; it doesn't leach out during the washing process. The feathers are then dried, cut up, and digested in nitric acid. You can buy nitric acid that is super pure, low in mercury, and the feathers digest quite readily in concentrated nitric acid. Once they are digested they are simply run through a mercury vapor generating atomic absorption spectrophotometer. There are standard methodologies.

: Did you analyze for methylmercury?

Scheuhammer: No, just total mercury, on the assumption that it is methylmercury in the diet that is the problem.

Irvine: When you were looking at the relationship between mercury and selenium, I think you were looking at all the major tissues so that you could look at something like a budget or total amount of selenium versus the total amount of mercury?

Scheuhammer: In the experiment that I described we weren't doing that. The main reason for doing that experiment was to see what would happen to the normal distribution of selenium in the body, if mercury was being ingested in the diet. Other experiments have been done in which the diets were supplemented with both mercury and selenium at the same time, which show that mercury and selenium co-accumulate in the tissues. In fact, mercury levels can increase to quite high levels without causing any apparent toxicity. I wasn't interested in this particular experiment to look at what happens if you have exposure to both. I wanted to see what would happen to selenium levels in various tissues if you just had the normal level of dietary selenium and you were then exposed to methylmercury in the diet. I think that is maybe what is happening in a vast majority of cases where there is an increased exposure to methylmercury. I don't think it will typically be a situation where there would also be an increase in exposure to selenium. In some cases, it may be that there is increased selenium. We were talking about the liver tissue of seals, for example. If liver tissue has very high levels of selenium then one might say "wouldn't that protect a person against the mercury that is present?" The problem is, in these livers, the selenium is almost totally complexed with inorganic mercury. So from my point of view, I would say that there is still a potential problem. You are not going to be protected against methylmercury simply because there happens to be high levels of selenium in the same tissue. Because that selenium, I think, is pretty much bound up with other inorganic mercury.

Irvine: Does it bind preferentially to inorganic mercury versus organic mercury?

Scheuhammer: The selenium that is in liver tissue, to the best of my knowledge, tends to be associated with inorganic mercury. There is probably some kind of mercury-selenium protein complex that occurs. This has not been very well studied at all in terms of the actual biochemical mechanisms that are occurring. But my guess would be that what occurs first is a demethylation. It is in those tissues that show demethylation of mercury that you get this association of mercury and selenium. I think that if it is a good guess that what's happening is that the liver and the kidney are demethylating mercury and that the inorganic mercury then becomes associated with selenium, approximately in a one to one molar ratio. That mercury tends not to be toxic to the organism in which it is found. But there will still be some percentage of methylmercury left in that tissue. It won't all be inorganic. Some methylmercury is still there and able to affect anything that

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happens to eat that tissue.

Emerson: *Do you think then that once the selenium mercury bond is made that is more or less the end of the story for that organism?*

Scheuhammer: One can't say that for sure. I can only tell you what I would guess, because I haven't done the work and no one else has done it either. But the affinity of mercury for selenium is higher than the affinity of mercury for just about anything else, it's higher than the affinity of mercury for **sulfhydryl** groups. The mercury-selenium bond is very stable, I would say. In those studies that actually have supplemented the diet with both mercury and selenium, you don't get toxicity of mercury showing up. That suggests that once it binds with selenium, the mercury is more or less rendered non-available.

Emerson: *Do you think then that demethylation can occur in the absence of selenium as well, or is that a cofactor in the exchange?*

Scheuhammer: Again, I have to say that we don't really know the exact biochemical mechanism that occurs when **methylmercury** is **demethylated**. There are ideas, I don't want to get into all of them now, because they are speculative. Suffice it to say that there are certain tissues like liver that do actively **demethylate** mercury. Once that mercury has been **converted** into an inorganic form it tends to associate with selenium and tends to be relatively non-toxic.

Eisler: *Selenium poisoning in birds is a very serious problem as you probably know. In Kesterson National Wildlife Refuge in California, agricultural drain water, heavily laden with selenium, is pouring into ponds of several hundred acres. We have death and reproductive effects and one of the mitigating measures that was proposed, but which has since been shelved, is to feed mercury to these birds. Just to confound the issue.*

Emerson: *How did they do?*

Eisler: *They didn't,*

Scheuhammer: I don't know what would happen if people intending to consume mercury-bearing foods would supplement their diets with selenium, but you can do that. Selenium is an essential trace element, you can get selenium supplements. The problem is selenium is also toxic. The range in which it is good is fairly narrow, **dietarily**. You can easily take in too much selenium and start getting symptoms of **selenosis**.

Emerson: *It is neurological?*

Scheuhammer: As to selenium toxicity in birds and mammals, we know that there is a lot of embryo toxicity, but it can also be toxic to the adult organism as well.

Eisler: *Insufficient selenium produces symptoms or signs that are probably more drastic than selenosis. It is something that is starting to be worked on now. Selenium deficiency is probably more of a problem world-wide than selenium poisoning. But as someone pointed out there is a very narrow range separating deficiency from maintenance from selenosis. Mercury, on the other hand, has no good useful purpose.*

Emerson: *What is selenosis, what are we talking about?*

Eisler: *Selenium poisoning.*

Emerson: *Do you think it is neurological like mercury?*

Scheuhammer: One of the hallmarks of excess selenium intake actually is that your breath starts to smell like garlic. Toxic effects are not primarily neurological.

Wright: *I don't know whether you can pick up selenium through your skin or not but the active ingredients*

Scheuhammer: Questions and Discussion

of **Selsun** blue shampoo is selenium sulfide. Maybe if you wash your **hair** frequently

Scheuhammer: I think selenium sulfide is not **bioavailable** through the skin.

Tornfeldt: Selenium has a positive valence, right?

Scheuhammer: It has all kinds of valences.

Eisler: It can also be negative. It ranges from -2 to +6.

Tornfeldt: And that is how it **can** associate with mercury which is also positive,

Scheuhammer: Yes

Hubbard: In the earlier part of your **talk** you were talking about your zebra **finch** work in neurological impairment. I was wondering **how** you detected this? How refined, or how much confidence did you have in detecting various subtle neurological things versus the obvious?

Scheuhammer: I don't have any confidence at all in detecting subtle neurological damage in that particular experiment. We detected rather gross neurological problems, problems that were obvious. That brings up an interesting point. There are central nervous system **dysfunctions** that may occur that are pretty subtle and may go undetected, unless you have the proper neuro-behavioral assays. In humans it is **fairly** easy, you can do a battery of **neuro-behavioral** tests; in zebra finches, it is not so easy. We settled on the classical symptoms of mercury intoxication when we put them in the category of **neurologically** impaired. It could be that they were slightly **neurologically** impaired before. Undoubtedly they were, but I couldn't have detected it.

Hubbard: I was wondering if you used some sort of assay like classical conditioning?

Scheuhammer: No we didn't.

Hubbard: That might have some application if one were to undertake a monitoring program out in the environment, though, whether or not you could **actually** detect **whether** to get **worried** and do some more serious testing.

Scheuhammer: I could see people out there watching seabirds and how efficiently they catch fish, for example, and relating it to **methylmercury** intoxication.

Hubbard: Whether they are **able** to effectively copulate would be a good assay.

Rusanowski: You mentioned the use of a feather as an indicator. I have two questions relative to the others. One, the high numbers of mercury that you showed in feathers, do you have any indication of what percent of the **total** body burden that represents; and two, if you switch the birds over to an uncontaminated food source, do you continue to get elevated **mercury** levels in the feathers as a deputation mechanism?

Scheuhammer: You certainly don't in the feathers that are already grown, obviously. The feathers that are grown are fixed in terms of their mercury content. But, yea, studies have been done to try and determine what percentage of mercury may be bound up in the plumage, it goes as high as 60 to 90%. It is almost certainly true that birds actively excrete mercury into their feathers as the feathers are growing. That this is a mechanism that birds use to get rid of mercury isn't an absolute fact, but it certainly seems to be the case.

Hubbard: On that same note, do you know of any studies where they looked into the possibility of the salt gland in **marine** birds as being particularly effective in excreting mercury?

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Scheuhammer: Salt glands, no. I do know some work that was done to investigate the levels of mercury in preening oil. It was found not to be particularly significant. But salt glands, no, I don't know anything about that.

Wright: Is it conceivable that large aggregations of molting birds, especially water fowl, might be a significant source of mercury to uncontaminated areas and maybe you should do something about these birds?

Eisler: That is not as far fetched as it may seem.

Wright: That is what happened to your cormorants, they got rid of the stuff in eggs and in the feathers.

Eisler: Seals excrete a large amount of mercury, and along the California coast there is an unusually high accumulation in mussels associated with seal droppings.

Irvine: There are seabirds at those same colonies, seabirds and seals.

Scheuhammer: I don't know what happens to feathers once they are molted and reabsorbed, shall we say, into the environment.

Irvine: Have you looked at selenium in feathers?

Scheuhammer: In feathers, not in association with mercury. I wouldn't know what the relationship is, if there is one.

MERCURY EFFECTS ON HUMAN HEALTH

METHYLMERCURY POISONING IN IRAQ

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Methylmercury (MeHg) poisoning was initially considered to be an occupational hazard (Hunter *et al.* 1940), but the Japanese outbreaks in Minamata during the 1950s and Niigata in the 1960s affected members of the general population who consumed MeHg contaminated fish (Tsubaki and Irukayama 1977). Most of the data on human MeHg intoxication has come from Japan and Iraq.

Historically, Iraq was a wheat exporter. Its early agriculture and civilization developed because of the fertility of land around the Euphrates and Tigris rivers. Poor harvests in the 1960s resulted in a governmental decision to import a large quantity of high grade seed grain. During October 1971, over 73,000 metric tons of seed were imported through the seaport of Basra and then distributed to all rural areas of the country. The wheat had been treated with a MeHg fungicide and was not meant for consumption, but some was ground into flour and used in the daily baking of homemade bread. The mean MeHg concentration of the flour was 9.1 ppm. A typical loaf of bread weighed 200 grams and contained 1.4 mg MeHg (Bakir *et al.* 1973).

Alkylmercury poisoning was first suspected in late December 1971 and Iraqi hospitals were inundated with cases in January 1972. Studies were organized by faculty of the University of Baghdad College of Medicine and the University of Rochester School of Medicine. These included an extensive program of hair collection and segmental analysis of the hair samples. Methylmercury is incorporated into hair during its active phase and provides a good index of exposure. The mean hair to blood ratio of mercury concentration is 250. Head hair grows at an average rate of 1.1 cm per month and its segmental analysis gives a retrospective calendar of exposure. Iraqi women usually had very long hair so that segmental analysis of a sample collected as late as 1974 showed the baseline mercury concentration in 1971 before exposure began; the period of consumption ending in the peak concentration, and then a decline to the baseline level. Blood mercury analysis was a less useful index because it only indicated the current level and few could be sampled at the time of peak concentration or serially. In some cases the half-time of 65 days could be used to calculate the peak concentration. Urine mercury levels were not used because most MeHg is excreted in the feces, and the blood to urine relationship is not consistent.

Post-natal exposure (subacute) resulted in an asymptomatic latent period of a few weeks followed by dose dependent symptoms and signs of the Hunter-Russell syndrome: paresthesia (subjective sensory symptoms) of the extremities, sometimes extending over the trunk and/or around the mouth; constricted visual fields; sensory deficits; ataxia and dysarthria; more diffuse central nervous system signs; coma, and death in the most severe cases. In the serious cases that survived the most disabling feature was usually the ataxia. Minor effects resolved. Rustam and Hamdi (1974) described 53 severely affected patients. Bakir *et al.* (1973) provided an extensive account of the outbreak and established a dose-response relationship. They reported blood mercury levels determined, or corrected to, 65 days after expected peak concentrations. The half-time for MeHg excretion is approximately 65 days so the reported blind values may be doubled to give estimated peak concentrations. Their data then suggests that the lowest effect level was a peak blood mercury concentration of 460 ppb equivalent to a hair concentration of 120 ppm. This conclusion was supported by the results of a separate survey of several hundred patients reported by Shahrastani *et al.* 1973. Reviews of Japanese data from Niigata and Minamata (Berglund *et al.* 1971, WHO 1976) concluded that the lowest effect level was a maximum hair mercury concentration of 50-60 ppm or blood level of 200 ppb. The hair sample that, according to the dithizone method had a mercury level of 50 ppm, was preserved and later analyzed by atomic absorption. This more accurate method determined a concentration of 96 ppm, and it was estimated that the maximum concentration for that individual had been approximately 200 ppm (Tsubaki *et al.* 1978). No other patient among those reviewed had a documented maximum hair-level below 100 ppm. There remains some uncertainty about 'delayed onset' or "chronic" Minamata disease. It may be

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that long-term exposure to lower levels may result in adverse effects, but this has not yet been well substantiated. Any controversy about the lowest level for post-natal effect has **lessened in** importance because the fetal brain is vulnerable at considerably lower levels.

Pre-natal exposure resulted in psychomotor retardation that was dose-related. A search for infant-mother pairs who had been exposed during pregnancy and had provided appropriate maternal hair samples identified 84 pairs. The index of fetal exposure was the maximum maternal hair mercury concentration during pregnancy. There were few pertinent **covariables**: the mothers did not smoke or drink alcohol; they had similar occupations, diet and education; there was no evidence of malnutrition; breast feeding was routine; no mother received ante-natal or maternity care. Field examinations of the infants were performed by experienced neurologists. Planned psychological testing had to be deferred because of the Gulf War. When peak maternal hair mercury concentration was related to frequency of effects (**e.g.** retarded walking, central nervous system signs), a dose-response relationship was demonstrated. The most seriously affected children had signs of cerebral palsy (**Amin-Zaki et al.** 1974, Marsh *et al.* 1980), and the lowest effect level (threshold effect) was calculated to be a maximum maternal hair index of approximately 15 ppm (Marsh *et al.* 1987). Although this result was supported by the conclusions of Canadian (**McKeown-Eyssen et al.** 1983) and New Zealand (**Kjellstrom et al.** 1986, and in press) studies, it should be regarded as a preliminary and tentative conclusion that requires further investigation, A much larger study is currently being conducted in a fish eating population,

The Iraq studies confirmed the observation in Minamata (**Harada** 1968, 1977) that the fetal brain is much more susceptible to adverse effects of MeHg than the **expectant** mother. In an exposed population the target organ is the fetal brain. Whereas post-natal exposure can cause areas of focal brain atrophy, the fetal brain can suffer impaired migration of cortical neurons with retarded brain maturation and development (**Choi et al.** 1977),.

It is not clear whether the effects of a MeHg fungicide or of extreme contamination of fish with MeHg from industrial effluent can be extrapolated to a population that consumes seafood with natural concentrations of **methylmercury**. Animal studies have suggested that selenium in fish may counteract the toxicological effects of **MeHg**; no human data exists. Any risk to a seafood consuming population is greatest to the fetus, That risk could be monitored by a survey of mercury concentrations in the head hair of women of child-bearing age. Long-term fish consumption would result in a hair mercury level of 15 ppm with daily intake of only about 6 1/2 ounces of fish at 0.5 ppm.

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METHYLMERCURY POISONING IN IRAQ

David O. Marsh
Questions and Discussion

Armstrong: Dr. Marsh, is hair sampling very difficult? Are there lots of labs that can do that, and is it expensive? Are there places in Alaska that can process hair samples or do they have to be sent out? I am wondering because I was telling how they do the hair sampling in Nome and had heard concerns that there are many labs that don't do a good quality of hair analysis.

Marsh: I think one does have to be concerned about what lab does trace metal analysis. We've heard a lot in this meeting about very low levels in the ocean, the necessity of a clean lab, etc. There is something to it; however, I know nothing about what facilities you have. There are a number of labs. Ottawa does a huge number of analyses on their native populations. Rochester does a lot. You need to have a lab that has some quality assurance, where they exchange samples with other labs.

Armstrong: Isn't it also cheaper than doing blood analysis?

Marsh: I don't know.

Emerson: In the sampling process, it's indicated with the bird's feathers that the mercury is endogenous and any exogenous mercury could be cleaned off. One of our big problems in this kind of stuff is the sample gets more contaminated than the content of the tissue or whatever we are looking for, so it looks like we have something here that is bound up pretty well and approaching major significance and labs can digest it?

Marsh: It seems to be recently there has been a rather fascinating technical development. There used to be a lot of concern about external contamination. If you cut through the hair shaft, there were certain techniques that would tell you if the mercury was around the outside. We used to fear that was external contamination. In fact, mercury that is laid down from the blood is deposited in the external part of the hair, not all the way through. That's only been known in a very few months. So, in general, and I am not an analyst, there are analysts who believe that the hair should be washed; there are other analysts who say that it need not be washed. But it is interesting that some external mercury in the outer part of the hair shaft is, in fact, incorporated, not external contamination,

Wright: I might inject a minor word of caution before we start giving all the ladies crewcuts. We do know that mercury, lead, copper and cadmium, etc. are released through the combustion of fossil fuels, lead in particular, from automobiles. As you saw this morning, there is a possibility of exogenous contamination even of feathers from the atmosphere. I am aware of one study in New York, 4, 5, or 6 years ago, with regard to lead in ghetto inhabitants. Hair samples were taken. The study was totally confounded by exogenous depositions. People were out in traffic, and so on and so forth. They did get around this by using pubic hair rather than head hair which is not exposed to the atmosphere. So that might be an alternative. I know it was done in one study.

Marsh: Mercury has been measured in pubic hair. If you want to do segmental analysis to get that retrospective calendar, you have a problem. For example, some of our samples have been from negroid hair, Negroid hair tends to curl up. For the technician to actually measure that and chop off a few millimeter segments, it is difficult. I wonder if pubic hair might have the same characteristic,

McCrea: I might hazard a guess that Nome probably doesn't have that much mercury in the air, like urban dwellers might have lead in the air, before lead reduction in gasoline.

Scheuhammer: I've read at least one paper where anomalously high mercury levels have been found in hair, in certain hair samples and was tracked down to mercury in shampoo.

Wright: As I mentioned this morning, selenium sulfide is an ingredient in Selsun Blue shampoo.

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Marsh: It is possible to have populations where hair dressings can be of difficulty. Luckily this Iraq rural population had no shops, there were no stores in these villages. One patient told me he had this terrible pain, All I had with me was a bottle of aspirin. I gave him two and I was about to give him the rest of the bottle, and then all the hands were open. They ail wanted an aspirin. There is no place to buy anything. So they couldn't buy any hair dressings. There were no shampoos, they were lucky to have a bar of soap. But this can be confounding, things put on the hair artificially. External contamination is a consideration from the environmental exposure. In Seychelles, we've found some hair with a lot of bromine, That seems to come from some shampoo or hair preparation that contains bromine.

Emerson: When you say that the earliest sign in the fetus that can be affected from mercury contamination was some slight amount of retardation, to measure that would be tough. Are we talking about some behavioral scale or when you say slight amount, I am wondering how that translates?

Marsh: I should have stressed, when I had those slides up there, the horizontal line and then the other slope, and where they meet is the lowest effect level. It is the statisticians who produce slopes, I did not want to give the impression that a doctor can go out and identify a child as abnormal when that child was exposed to mother's hair concentration of 15 or 20 ppm. That is a statistical extrapolation. Those children who had severe cerebral palsy, their mothers' hair was above 150, mostly above 200 ppm. Once you get down to threshold effects, nobody, the best pediatrician in the world would not be able to look at that child with threshold effects and say "Ah, you've got mercury poisoning". This is a statistician's ability to extrapolate down from observed data to what is calculated to be threshold. I am not a statistician. But anyway, this is a statistical exercise using the data. It is not that some pediatrician looks and says that kid was exposed to 15 or 20 ppm of mother's hair and is abnormal, You couldn't do that.

Emerson: The statement that you made that there would be a slight amount of retardation in the fetus, that didn't sound statistical, that sounded like something that you expected to happen.

Marsh: Well, when we are talking about threshold effects, we are talking about an effect that is so small that it just appears above the background noise, above the frequency for that effect in the general population.

Emerson: But we don't have the data for that threshold difference, we have to go to the high end of the spectrum, then draw our lines.

Marsh: Well, we do, Of course all the examinations were blind, When I examined a child I did not know what the mother's hair level was. In the same village, even in the same household, these are big extended families. You'd think they would all have the same sort of level in the hair, but not at all. Some of them would hardly eat any of that bread, others would eat a lot. So, in the same household, you would have women with quite low levels and quite high. So there were no clues to which child had been exposed and which had not. Within the study group were controls, We had, as I said, children of mothers with hair levels right down to normal, just 2-3 ppm, in that same population.

Emerson: Do you think another factor that is not measurable is the mental stability? Since we are talking about neurological condition, you can't measure it at that level. Let's say that as a synergistic concept of the stresses of the environment and so on, that there maybe a reduced tolerance for stress factors, based on a lower level of exposure?

Marsh: I am not quite sure what you are getting at,

Irvine: You mean like pre-adaptive?

Emerson: There's a kind of a buffer, let's say, in our behavioral patterns which we can tolerate stressful conditions. For example, right now there is a high incidence of suicide in these villages along the coast. Would a body burden of some contaminant make the individual more susceptible or less capable of coping with some of his changes that are going on in his normal everyday living?

Marsh: Well, what I started talking about originally, the post-natal, the Hunter-Russell syndrome, certainly

Marsh: Questions and Discussion

does include some psychological effects. Studies by Baghdad psychiatrists concluded that the adult exposure caused depression. I never saw how they were able to separate that from just being depressed about the physical aspects of their disease. If you are talking about psychological status of **fetally** exposed children, what we planned was to have Arabic speaking psychiatrists/psychologists do a battery of psychological tests. And we are still hoping to get that done even though now these children are seventeen years old. Many people believe the psychological testing is a more sensitive test than the type of clinical testing we did. So, it's possible that if one had included psychological testing, that might have been more sensitive and produced an even lower threshold.

Emerson: When you said that your sensitivity level, which was reported in the Iraq study, was twice as high as reported in the EIS, what were you comparing?

Marsh: Well, I wasn't sure if you wanted to get in to all of that. But you see, in the EIS, what they give you is part of the gospel of mercury. They say that the lowest effect level, this is for adult exposure, is a blood level of 200 ppb, which is equivalent to a hair level of 50 ppm. Those levels can be achieved after long-term consumption of 300 μg of **methylmercury daily**. Now all of that came from Japanese data. This antedates the Iraq data. Back in 1971, there was a very interesting Swedish publication called *Methylmercury in Fish* (Berglund *et al.* 1971) and it applies to any consideration in the Nome area, and it is still worth looking at. It was put together by a group of Swedish toxicologists (the Swedish Expert Group). I put the reference down in my abstract I handed in. They went to Japan and they got all the Japanese data they could from **Minamata** and **Niigata**. Then they did a very good job of analyzing that. There was one man in **Niigata** who had a hair level of 50 ppm. He had signs, and he was **ataxic**. That was the **basis** for this 50 ppm in the hair or 200 ppb in the blood as the lowest effect level. But there was no one else in that study close to that effect level. That data came from Professor **Tsubaki** in **Niigata**, who died last year. In 1978, he came to a meeting in Toronto, Canada, and he quietly dropped this small bombshell. They had preserved the hair samples from that individual. Originally the hair sample had been analyzed by the **dithizone** method. They preserved the hair and reanalyzed using atomic absorption (AA) and he **quietly** revised that previous result from 50 to **96** ppm. Then he went on to say that the estimated peak value in that hair was 200. There was no one else below 100; in fact, there was no one else below 150. So I don't think the basis for that magic number exists. Then other groups picked up on that. The American **Food** and Drug Administration used that in their calculation. Basically, what they said was that the lowest effect level was 50 in the hair, adding a safety factor of 10, one shouldn't have a hair level of above 5. You can achieve the level of 50 after long-term intake of 300 μg of **methylmercury** a day. The safety factor of 10; therefore, you should not consume over 30 μg **methylmercury** per day. I don't see any evidence for myself, from Japan or Iraq, that there was effect in the post-natal group, below a hair level of 100,

Emerson: Was there a publication on the new basis?

Marsh: Those last two slides are from a statistical account which goes into this but we have not yet published it. There is going to be a meeting in December this year, in Rochester, NY, a World Health Organization (WHO) meeting at which they are planning to rewrite the WHO document on **methylmercury**. The other good source of data is the 1976 WHO criteria document on mercury. Maybe a year from now there will be some updated document from WHO on **methylmercury**.

Emerson: So do you think we should leave the number until that conference is over?

Marsh: Well as I said, I did not want to push that number. I think it is preliminary and I think it needs further study. I am hoping that we will get a lot more data from the Seychelles study. I think at the moment the basis for any level, the fetal effect is quite insecure. But I am sure it is much lower than it is for adults.

*Emerson: In both the **Minamata** and Iraq cases would those be considered in a general sense as a dose response as opposed to what you will be answering in the Seychelles study, in this island population where you have more of a chronic low level exposure? Now you are going to have a lot of variables in that type of study and with the range of mercury you are seeing in the **hair samples**. I hope that doesn't create too many problems. Anyway, it seems like our issue here is as a population consuming a **low** threshold level of mercury over a long period of time, maybe as a normal part of their diet throughout their lifetime, the*

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sensitivity in terms of the cumulative sense here, what this material may, or may not be doing, we are talking about a different level of sensitivity?

Marsh: It could be. We don't know the answer to that. Of course this doesn't apply to the fetus, because the fetus has a limited nine months at the most, limited duration. The Japanese are talking about what some of them call the chronic Minamata disease or delayed effect Minamata disease, What we used in Iraq as the index of exposure was the maximum concentration. So I showed you the peak level, that peak concentration is what we used as the index. Now it is quite possible that what matters to the individual exposed is not just the maximum level of exposure but also the duration. This question "is it possible that long periods of exposure to a slightly lower peak; could that cause damage or even just as much damage as one brief exposure to this high peak?" we don't know. There is some experimental data to suggest, what some people say is common sense, that duration has to be important. But it is not well worked out. The trouble with the Japanese data is I've not seen any cases that stand up to scrutiny. Because for human exposure, you need an index of that long-term exposure. I have not seen it in any case. I've heard Japanese investigators express their firm belief that has to happen. When Tsubaki retracted that one case, he reintroduced the level of 50 ppm as a possible level for chronic Minamata disease. He showed data on four patients, but it was not complete data. There were long gaps, 18 month gaps with no hair level or blood level and further exposure could have happened in those 18 months. So it is a possibility and I don't think anyone has good human data.

Emerson: Your upcoming study may not answer that either?

Marsh: I think in a way it becomes less crucial. Now that there really is good evidence to believe that the fetus is more vulnerable at lower levels. There used to be a lot of dispute about what is the lowest effect level and I think that really we have gone beyond that. If there is an exposed population, whether it is Canadian, Cree, or North Quebec, Inuit or people around Nome, in any exposed population, the greatest concern must be to the fetal brain. The fetus is exposed for a maximum of 9 months or so and we don't know yet if some part of gestation is crucial. We have evidence from Iraq that it is possible to have severe adverse effects in the maximum exposure in either of three trimesters. We don't know if there is one part of gestation in which the fetus might be more susceptible than other parts. We don't know if there is some critical maximum concentration for a certain minimum duration, we don't know that yet. But this to me is much more important than worrying too much about the adult. Ron Eisler had some nice phrase about "if you care for the brood". If you take care of the fetus, in effect you take care of the population. I think this is true. If one safeguards the fetal exposure, then all the other ages are taken care of automatically.

Emerson: I think that in invertebrates it has been pretty well shown that in the early developmental stages, at least it is measurable, that gastrulation is sometimes stopped, I don't know in human development, if that's something that you can measure anyway.

Armstrong: Would you even venture to give us a number of what you think the fetal exposure should be?

Marsh: Well, as I mentioned, traditionally, when you deal with the human data you work out the lowest effect level, and then you add a safety factor, traditionally a 10. If it should be true that the mother's maximum hair level during gestation is somewhere around 15 or 20 ppm plus or minus quite a bit, you cannot use a safety factor of 10. So say you choose 20. You can't say then we will have a safety factor of 10 and no pregnant woman can have a level of above 2, you just can't do it. You can't find many people in Tokyo with levels below 2. You won't find pregnant women in Nome with levels below 2. So we have to give up any notion of the traditional safety factor of 10. So my comments were not including any safety factor. It could be that the Nome population already includes women of child-bearing age who have hair levels around about the area of suspicion. Could be 15, 20, 25. As I said, in the Seychelles, which is another fish eating population, without any dredging, way out in the Indian Ocean, 1000 miles from any industry, 1000 miles from Africa, more than 1000 miles south of Arabia, more than 1000 miles west of Ceylon and India, the fish diet, oceanic fish, from non-polluted areas results in fish causing hair mercury levels up to 40 to 45 ppm. I wouldn't be at all surprised to find that seafood diet in Nome causes women of child bearing age to have maximum levels of 30 to 35 ppm, who knows?

Marsh: Questions and Discussion

*Hansen, Don: You mentioned at the beginning that the first symptoms of **methylmercury** poisoning are impaired speech. You mentioned that there were others. I was wondering if whether there has been any correlation between studies relating alcoholism with high natural levels of **mercury**?*

Marsh: I don't know of any relationship for **methylmercury**; for elemental mercury, there is some effect. Elemental mercury is inhaled and alcohol does have some effect on the absorption in the lungs. But for **methylmercury**, I don't know of any either positive or negative relationship.

Armstrong: I guess this was just pure speculation. We were wondering because there are countries with high rates of alcoholism, Scandinavian countries, the arctic peoples all have problems with alcoholism and also they are in areas where they have high levels of mercury too.

Marsh: You are suggesting that too much mercury would make you more likely to drink?

Armstrong: Be an alcoholic. There are differences in ways that people deal with alcohol. Some people can drink alcohol and not become alcoholics and others can 't.

Marsh: I don't know of anybody looking at that specifically for **methylmercury**. As I said, people have looked at the effects of mercury vapor.

*Hansen, Don: Could you **clarify** to me, your horizontal grid on those figures that you showed with the hair concentration, was that always, in the case of both adults and the fetal data, the high concentration in the 1 cm segment, or what is that number really?*

Marsh: All of them were segmental analyses. initially we used 1 cm segments analyzed by atomic absorption. Then Tom Clarkson got this clever x-ray fluorescence machine that would analyze single strands in very small segments, So the last two slides I showed you were on single strand **analysis** from 2 mm segments. But around the world, and in this country in general, you'll find that most labs will use atomic absorption. And then it depends on the concentration of mercury in the hair. That the higher the concentration then the smaller the segment you can work with. But for most of these studies, a good technician likes to have a centimeter of hair.

*Hansen, Don: But didn 't they go back to the peak exposure period in **all** cases, where you comparing the same time span?*

Marsh: Yes.

*Hansen, Don: What is the variance associated with a couple of millimeters versus a centimeter, is there much **difference**, does it give you anything more?*

Marsh: Well, yes. If 1 cm represents a month's growth, in a subacute exposure, like Iraq, an awful lot can happen in that month. In fact, you can go in that month up to a peak. So the shorter the segment, the better delineated is the profile of exposure, both for the time of take up and the actual peak level. But for practical purposes it is going to be difficult for many labs to do single strand analysis, Although I am told that there is a commercial company that is probably going to bring out x-ray fluorescence equipment; if is not going to be cheap, it is going to cost \$100,000 per machine. So atomic absorption is likely to be the main methodology for some time.

Yoesting: I have a couple of related questions. One is, I understand that mercury just accumulates in the body, it doesn't go anywhere from there. And yet if it is being extruded into the hair, you are losing some, or is it just an indicator?

Marsh: If you think of a population eating seafood, like a native population, there may be in something close to a steady state, By a steady state, one means that their intake equals their output. So the **methylmercury** that is taken in doesn't just sit there in a passive way. There is a mobile system of intake and eventually excretion. **But** if you swallow an amount that equals the amount you put out in the feces, in the urine, a

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little bit in the hair and little bit in sweat and so on, then you are in a relative steady state.

Yoesting: What I was thinking of is that if you are going to measure the amount of mercury in the hair of women of child-bearing age, and say you came up with high enough numbers that you would want to warn them not to get pregnant, and I assume that would be what you would want to do?

Armstrong: No.

Hansen, Don: Not to eat fish or marine mammals when they are pregnant...

Marsh: I don't think we have quite reached the point. I tried to stress when I was talking about lowest effect levels, that those are our best estimates but they are not totally supported by adequate evidence. This is why we are doing a much bigger study. I think we might be at a point when, although we don't know with certainty what the lowest effect level is, we have some concern about relatively high levels in pregnancy. For example, in Canada, I know of one Cree community in that situation, where they have had rather high levels. Their advisors know perfectly well that the **data about the lowest effect level is not really hard, final data, but they felt obliged to start an educational program.** So "in that community they have all sorts of posters in the native language advising them about avoiding high consumption of known high concentration fish. I gather there is going to be some discussion a bit later about what monitoring should be done. Some obvious things would be to have a program of analyzing the various types of seafood, sea mammals, seal muscle, seal liver, the various fish species, to get a good idea of what the concentrations are in the food and a survey of the hair mercury concentration, especially in the women. I can't anticipate what those are going to show, It seems very likely that some women, some small proportion of women in the native population may well have rather high levels, even prior to any dredging, So I don't think we are at the point of saying that we know that this level is so high that you should not continue with the pregnancy, we just don't have that data. We are talking about risk. When we talk about lowest effect levels, we are talking about the small risk of a small effect. But we might well be, after some preliminary survey, in the position to want to educate so that seafood with known high mercury concentration might be substituted to some extent by seafood with known low mercury. For example, this king crab industry has very, very low levels from what I read, extremely low. If they were doubled or tripled they would still be very low, Whereas seal liver has very much higher levels, several orders higher than the king crab. But I don't think that survey is being done. I presume that this is one of the things that we want to talk about and seems logical to have such a survey.

Yoesting: It seemed to me from this hair analysis that you can lower the levels in your body. If you could correlate the hair sample with other body . . .

Marsh: In that slide I showed you of Iraq, I tried to get across that they had fairly acute or subacute, short-term exposure. They ate the contaminated bread everyday for roughly two months. Then as soon as it was recognized to be a problem, sometime in January 1972, the government issued a very stern directive that people must stop consuming that bread. Now that is not analogous to a society that has a fish diet. It was a period of consumption leading to a peak and then word got around to stop eating that bread. Some families were confused because they mixed the contaminated grain with good grain. They didn't know which was which, but in general, they stopped eating that bread by nearly every case the end of February. And then you had the decline and the methylmercury was excreted over that half time of about 65 days. So eventually it got down. But if you are in a community that eats fish all the time, you are not going to be like that. You are going to have an intake of methylmercury which is close to the amount excreted, which is a steady state. There will be some seasonal fluctuations within that. But it is not the same as Iraq. But if there is a seasonal intake, supposing that there is a greater intake of methylmercury in certain months of the year, and then a lower intake of methylmercury for a few months, then the body burden will become less. Then the seasonal increase will pick up again. That could be shown by segmental hair analysis in which you would get a profile for that community, including seasonal profile for a 12-month period, for example. I think, in terms of any monitoring, it would need to be a 12-month monitoring in order to make quite sure you were picking up seasonal differences.

McCrea: I think having a steady state makes intuitive sense to me. However, if methylmercury does accumulate and if you are eating a steady amount year-round and it excretes at a half rate of what it

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accretes, would you ever reach a steady state or would you always just be slightly accumulating more and more?

Marsh: You can reach something at least very close to a steady state. Now the earlier talk today, we were told about the age relationship. In many different animals and birds, the older the bird, the greater the level. Certainly in fish, the older the fish, the longer the fish, the higher the concentration for that species of fish. Again thinking in terms of studies done in Canada, that there is in general an age relationship for both the Cree Indians and the Inuit with higher levels in older people. It may be that when there is a seasonal fluctuation and you have a seasonal increase and then a drop. You might not get right down to baseline, you might gradually creep up each year. But there are societies where there is very close to a steady state with not much seasonal difference. And then the intake equals output, There are many unknowns. So it seems so obvious that there has to be a program of monitoring both concentrations of mercury in seafood and hair levels to cover a 12-month period, enough to get a good profile of the population.

*Hansen, Don: One thing in your Iraq study, you covered some of it, I was concerned about the individual variation from one person to another as far as sensitivity to **methylmercury** poisoning or symptoms. Is there quite a bit of variation?*

Marsh: There is and you know we often talk in terms of average. We talk about the half time for excretion of about 65 days, that is an average. The shortest for **methylmercury** is probably around 40 and the longest may be close to 100.

*Hansen, Don: A/so depends on what tissue as far as **the** half life.*

Marsh: Well, I don't think it really does for **methylmercury**, but many of the Japanese authors firmly believe that the brain half-time is much longer.

*Hansen, Don: It has been suggested that if it gets to the brain, **it** takes longer,*

Marsh: 200 days. They don't have adequate data for that. There is good data that the main part of individual difference is the difference in half time, So that if you hang on to it much longer, you obviously have a different problem than if you get rid of it quickly. That varies by a factor of at least two, from 40 days to close to 100 days. That author, **Al-Shahristani**, I mentioned, did some studies. His data suggest that the half life varied between about 40 days **and 120 days. He had**, in fact, a two **phase** distribution, but nobody else has ever confirmed that. I think that it is probably a single phase distribution from 40 to 90 or maybe 100 days. But that accounts for individual differences. So that in the same household you can have a person eating the common dishes and one person being much worse off **than another, just because of that difference** in excretion rate.

*Irvine: The slide you showed with **the** peak and then that drop off in the hair **analysis**, you talked about the smaller **curve** being the 50 **hairs**, would those be from different individuals?*

Marsh: No. The lower half of that slide, was that single curve up to a peak, that was analysis of a single strand. The top half showed also analysis from the same individual of about 50 strands, It is not nearly as relevant for a chronic state or seasonal fluctuation situation. It makes a big difference if you are trying to investigate acute exposure, Because the single strand analysis gives you much better definition of the duration of exposure and of the level of the peak concentration. But for **fish** eating population with little change, maybe seasonally doubling the amount that wouldn't be a big factor. Routine hair analysis using the collection of 30 to 50 strands and analyzing in a conventional fashion would be quite adequate for that.

*Irvine: What you are saying then is that there is variation among the hairs in that what you are looking for is the peak, the extremes, right? Even in a chronic **case**?*

Marsh: No, there is no variation from hair to hair. We have demonstrated that there is no variation from hair to hair but there are some **artifactual** features. When you collect a sample of say 30 or 40 strands, you identify a cluster of strands, hold them between finger and thumb and then cut them off as close to the

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scalp as possible. But they are not the same length. It is almost impossible to get them quite the same length, so that introduces an error. But if you analyze any one of those strands, in small enough segments, then you get better definition of the duration of exposure and peak.

McCrea: *Kristine isn't here anymore but I was talking with her about her question. One of her concerns of relevance is there is a great deal of concern with the fish eating population in Nome and the marine mammal eating population, but there are tailings from a lot of gold operations in the past. Evidently as a Superfund site, it has the highest mercury content of any site in the United States. So maybe your facetious comment about being contaminated by what is in the air is not facetious at all. Maybe it is of concern. How should we also be factoring that in, should it be factored in or would washing hair take care of it?*

Fitzgerald: *I was going to comment on this a little earlier. Absorbed mercury can be a problem in terms of analysis. It has appeared in studies of meteorites which have been laying on the ground and then when you analyze them you find that there is an absorbed mercury component that is not associated with the meteorite. It has been picked up because it has been sitting there. The way they addressed that, which I don't know if that would be applicable here, is to warm it. If you get up to about 100°C, absorbed mercury can be removed. Something like that perhaps can be used?*

Wright: *I don't think that is what she is saying. There are two problems here. One is exogenous input on the surface of the hair, the other is these people are sitting on a mercury dump, they may be inhaling mercury vapors, mercury dust, etc. which is then going to convert into endogenous mercury. So it is not going to be related to diet.*

Fitzgerald: *No, no, I was addressing the question on analytical artifacts which I thought was part of the question.*

McCrea: *That is half of the question.*

Fitzgerald: *The analytical part I think you can address and handle in the laboratory. The other part is the sources of the mercury and how it is affecting the population, that is another question entirely.*

Marsh: *The other part of that question, and I don't think you will see this discussed in the literature, but it looks to our group in Rochester that hair is not an indicator of absorbed elemental mercury.*

Wright: *You might have them wear tight fitting caps year-round or alternate/y take hair from someplace not exposed to the atmosphere all the time.*

Marsh: *I'm just trying to clarify the analytical problem. We are talking about an area that has gold mining and mercury is found in the same strata as gold is found, Plus that gold mining, the old fashioned way, from 1898 to World War 1, and later, the DEIS tells us, that there is 140 metric tons of elemental mercury distributed around that area. Plus you have natural deposits of cinnabar and this river going into that area. The background level of possible mercury contamination, heaven knows how much of that gets methylated and ends up in local seafood. We are talking about dredging in an area that is enormously high background, plus the native people with this extraordinary intake of seafood. It is a remarkable combination of factors to find all together in one place.*

Newbury: *Your comment about analyzing the hair for getting the history interests me. I think it would be a good idea to analyze hair in other organisms as well. Up here we have been analyzing bowhead baleen, not for mercury, but for carbon isotopes. We can get the history of ingestion in different places. I think it would be possible to analyze hair in other animals. Examples might be seal whiskers, walrus whiskers, to get the seasonal pattern of exposure to mercury. The hair isn't eaten, it is not interesting for that reason. And it might not concentrate mercury more than say the liver, but it would give you a different part of the picture. That is, the seasonal exposure. I think there is a good chance that the seasonal exposure will vary. I mentioned earlier that during the winter, especially for the seals, their movement is localized by the ice cover. The ice cover affects it in another way. It removes the wind in the water, the driving force from the water. Earlier Tom Wright mentioned that he had a lot of resuspension. Well, in the winter, that resuspension*

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*drops to very low levels. There are certainly tides in Norton Sound but there are **no** wind-driven currents. For that reason the highest uptake may occur during the time when there isn't dredging. It may **occur** in the winter. I think it would be interesting if mercury is analyzed in **seals** to analyze the mercury level in their whiskers.*

Marsh: I am not aware of any report of that being done. But I am sure you are right, it could be done. It's been done in rat vibrissae segmental analysis and what Tony **Scheuhammer** was telling us about, feathers. For birds, the feather is much the same as hair. It is possible to do segmental analysis of feathers. There are so many things that could be done. This marvelous mural all around the ballroom that shows us all the wildlife. You know that there is research to last a **1000 Ph. D.s**, a life time, in all the aspects of what happens to the walrus and the seals and the **beluga** whales, and all the rest. So I think it would be interesting. It depends whether one's real aim is monitoring the **local** human population or for some people here employed specifically to look after wildlife. You could do endless work on the ocean concentrations, on sediment concentrations. The short cut is to go to the human diet and the human biological indicators. Then everything else, if it is people's work or there is money for it, would be interesting.

*Hansen, Don: To comment further on this, wouldn't you have to know the rate of growth, just as you do for human hair, in order to accomplish what he is suggesting. And that is to learn the **seasonality** of uptake with walruses or seals ?*

***Rellar:** For your information there is **pre-existing** data on the **blood** levels and urine levels of mercury for the people in Nome in conjunction with the Superfund site. Also, private citizens are concerned about it. They have gone to the expense of having their dogs' hair analyzed, even to the extent of having their deceased spouses hair analyzed from lockets that they have kept. **In** addition to the **mercury** though, if you look at this compliance order, there is a problem with the other **metals** too, copper, arsenic. Nome not only has the highest levels of mercury contamination in the U.S. but has the highest levels of arsenic contamination in the center of town. And arsenic is a carcinogen and there is a whole raft of different exposure levels there too.*

Marsh: Could you tell us what the maximum levels were?

***Rellar:** 450 to 1000 ppm mercury within three blocks of the hospital that children played on with their **three-wheelers** and brought home in their hands and played with **at** home.*

Marsh: You just mentioned that there is some data on blood?

***Rellar:** Right, I don't have that with me.*

Armstrong: Was that the study done by the state?

***Rellar:** Right,*

Armstrong: I think they only did urinalysis.

***Rellar:** Yes. And it was also done after the children had not played in the playground for approximate/y a month.*

*Armstrong: I don't think they did any blood, at least the **study** I know of.*

***Rellar:** It was not a well controlled study, but it is something.*

*Hansen, Don: The urinalysis is not a very good test for **methylmercury**.*

Marsh: It is not good for methyl, but you've got all this elemental or inorganic mercury lying around.

***Rellar:** It was measured, **there** were levels there, it wasn't like everything was a trace or non-existent.*

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Prentki: That wasn't an inorganic mercury problem though.

*Rellar: Yes, it probably wasn't but the arsenic definitely was not only **arsenopyrite**, but had oxidized to forms which are used as rat poison in other countries. So there is this **biogeochemical** transformation going on.*

*Prentki: It was assumed to be inorganic mercury. The didn't actualy **analyze** the chemical form.*

Rellar: Right, but mercury was analyzed in the air at low levels in the town.

*Yoesting: In humans, does mercury accumulate mostly in the brain, is that why you get so many neurological effects ? Or does it **also** accumulate in say the liver **like** in marine mammals?*

Marsh: The concentrations tend to be higher in the kidney and liver than they do in the brain. But we don't think with our kidneys and livers, our higher conscience is in the brain, but it is not preferentially deposited in the brain. This blood-brain barrier is supposed to protect us from bad things. The levels are higher in other organs.

*McCrea: Another naive question based on ha/f-understood **article**, I have understood that any neurological damage or impairment as a result of **mercury** poisoning was essentially with you for the rest of your life. I'm hearing that you can get rid of the **methylmercury** from your system but the effects left behind remain always or do they also decay?*

Marsh: I think that is really more or less true for fetal effect. If you are born with severe cerebral palsy due to high exposure *in utero* to **methylmercury**, that is not really going to improve. You go through some stages where it looks like there might be a bit of improvement, but essentially there is a fixed deficit. For post-natal effects, adults and children, the data from both Iraq and from Japan shows **very** clearly that there can be improvement. So in Iraq, if you suffered a moderate degree of exposure, and you had paresthesia, constricted visual fields, and some **ataxia**, the chances were good that those would improve and disappear, I was shown a video tape in the hospital of a girl who was so unsteady that she couldn't walk. When I examined the girl her walking was perfect. This was only a couple of months later. Children, whose exposure has been after birth, have an extraordinary ability to improve from **all** sorts of insults to the nervous system. Those that were severely affected and survived tended not to improve. But if they had anything from mild to moderate effects, the tendency was for improvement, sometimes quite remarkable improvement, especially in children, This also happened in Japan.

*Emerson: Have you been involved in any study, I guess this maybe applies to your present Seychelles study area, where you have laid out what you think are the parameters and the frequency of testing as well as size sample and all of that for an adequate database for decision-making; is that pretty **well** established now or are we still just guessing at what needs to be done?*

Marsh: Well, we've given a lot of thought to the study that we are doing in the Seychelles. We are trying to use reasonable measures of outcome. We don't know at this point whether that big study is going to confirm the hypothesis from Iraq, that the effect level is somewhere around 15 or 20 ppm in mother's hair, We keep an open mind. I didn't really want to mention selenium, **it** is a very confusing area. In a fish-eating population you are studying much more than just the possible effects of **methylmercury**. You are studying the effects of the fish diet, that includes **methylmercury** and selenium and maybe other factors. There is no human data to tell us whether the selenium in seafood helps to protect against adverse toxicological effects of **methylmercury**. We don't know at the present time whether it is fair to extrapolate the data from Iraq to a fish-eating population. The Iraq exposure was to a **methylmercury** fungicide. Methylmercury produced in a laboratory and sprayed onto seed grain to prevent fungus diseases, We don't know if it is really fair to extrapolate the results from Japan to an ordinary fish-eating population, Where in **Minamata** a factory that produced **acetaldehyde** had a big drain pipe directly into **Minamata** Bay and the fish were contaminated enormously by this chemical **methylmercury**. The same in **Niigata**, discharging into a river, No one knows if the experience from Japan and from Iraq should be extrapolated to a fish-eating population. We do know that for inorganic mercury in animals there is **very** good evidence that selenium counteracts the toxicological effects of inorganic mercury. There are various reports on the possible ameliorating effects of selenium to

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organic mercury, including **methylmercury**. But those are not in total agreement. The **Kjellstrom** fetal study was on the consumption of marine fish which would have selenium, It claims to find a positive effect at maximum level in mother's hair during pregnancy of 25 ppm. That was a study that did include selenium in natural ocean fish. But **it** is a study that can be criticized. So we have an open mind. I don't know whether it is going to confirm the Iraq hypothesis. There are other factors in fish that people have suggested apart from selenium, vitamins and so on. We just don't have the data yet.

Emerson: When is your study going to be initiated and when do you expect some preliminary results?

Marsh: Well, we have completed what we call the pilot study on about 500 pregnancies and are hoping to get funded to do a further study. In the main study, we hope to get data on 600 new pregnancies and measure the outcome by different methods, including psychological tests.

*Emerson: Are the results of **the** pilot study available?*

Marsh: No. We haven't got around to writing a manuscript for publication. I think we might get some useful data even out of the first one year, and probably then write a manuscript. But you are talking about at least a couple of years before anything is going to come out of the main study.

Emerson: If you get funding does that mean then you can make available the pilot study?

Marsh: That doesn't depend on funding. We have to get together and write it up.

*Emerson: **In a localized situation like the Nome area, are we talking about a megabuck study and tremendous effort or do you foresee it as maybe even coordinating it with something you are doing now? Maybe to improve the database on some other questions that you can't answer with the Seychelles study?***

Marsh: I think you can gear from the expense point of view in any one of a dozen different ways. It depends on what your main goal is. if you want to look at the cheapest way of seeing what the human situation is, it would be a matter of getting hair samples from the women of child-bearing age in that population, with special interest in the native people. It is a small population, so we are not talking about a large number of hair samples. The cheapest way to get some idea would be to get hair samples from women of child-bearing age in the native population and measure 1 cm closest to the scalp. If those were all very low, then that is one thing. They won't be, chances are. You almost certainly want to go into segmental analysis, Depending on the length of the hair, you probably need to have a further hair sampling program a little bit later on. Then eventually get enough segments to cover 12 **months**.

*Emerson: When you make the calculations to get your concentrations, are we assuming that **all hair** is a critical weight to make your calculation or do you need a **large sample** then to do your mathematics on that?*

Marsh: I was asked this question as to what weight of hair do the technicians like to have, and I recall that they like to have **10** mg of hair. The required weight depends on the mercury concentration. Now my expectation would be that I think you are going to find relatively high levels. I don't think you are going to be talking about 1 or 2 ppm. My guess is you will find a few like that and others at 10, some at 20, maybe even some at 30 ppm, or higher. So then you need a smaller weight of hair when the concentration is higher.

Emerson: There is a great variance in the weight of hair between individuals?

Marsh: Yes, What the technician likes to have for ordinary atomic absorption is a rather generous sample of at least 30 strands. Do the women tend to have **longish** hair? Twelve months is only about 12 cm, only a few inches, So many of the native women are likely at a single time to give you one sample that goes back 12 months and will indicate the seasonal fluctuations.

Wright: It all sounds to me like again we are attempting to embark on establishment of a cause and effect

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*relationship in an uncontrolled experiment which by definition is bound to failure. I am sure if someone came around to my wife and said I want a **little** hair sample, well what for, well to see if you keep eating seafood if it is going to fry your retina or deform your baby. I think that person would cutback on seafood, right there. **It is** one thing to put it in the newspapers. But when someone comes around and starts taking hair samples and says well go ahead and try to get pregnant because we want to see if 'we can get a relationship here with what you eat and whether your child has three legs or something like this. You are automatically introducing **all** matter of uncontrollable bias. If you are trying to establish cause and effect relationship between the dredge doing something which is reflected in the animals which is subsequently reflected at yet another step removed in the people, it is not going to work. It is not going to work in a convincing fashion.*

Marsh: You are not going to be able to measure effect in this small population. The reason we went to the Seychelles is we have a suitable range of exposure and they average 1600 pregnancies per year, We went around to various Inuit communities that had high exposure in northern Canada. They were all small. It would have been very, very difficult to even add together several communities to get a big enough number for a reasonable estimate of risk. So, I don't see any possibility that one could study the Nome population to get the answer to any questions about the fetal risk. You have to get that information from some other place. What you could do here is collect hair samples, monitor the population and see what the levels are. Then you would have to apply data from elsewhere as to what levels of exposure carry a, certain risk of adverse effect.

Wright: What are you going to use as a control? You have got to have a control.

Marsh: Why do you have to have a control?

*Wright: Well, let's say the dredging starts and the mercury levels in the hair go up. **It** may have gone up whether the dredge started or not, you have got to have a control somewhere.*

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Wright: You aren't talking about a phenomenon, you are talking about perhaps some degree of augmentation of an existing phenomenon.

Irvine: I view this as several questions. One, does the dredging have a particular effect, and is there a potential for risk? Which is like getting baseline information.

Wright: But again as I said this morning, if you want to demonstrate cause and effect, you don't do it by correlation.

Emerson: What are you suggesting then?

Wright: I am suggesting that one needs to think about this more fully. Let's put it a different way. What hypothesis are you trying to test? When you monitor, number one, you state the problem. Number two, you have to be able to gather quantitative data regarding that problem which you then use to test, accept or reject some hypothesis. I have not heard the hypothesis; in fact, I haven't heard a statement of the problem, which is the very first step in monitoring. A lot of people look at monitoring as collecting baseball cards. It's gathering a great bunch of data and see if we can make sense out of it. To monitor you have to state the problem, you have to have some objectives, you have to test the hypothesis.

Emerson: Here is one hypothesis that Gail has stated: 'How sensitive is this population to a 'potential' effect?'

Wright: You might find that out by giving various people various dosages of mercury and you'll find out. They might get irritated at you doing that. That becomes an untestable hypothesis then. I have not heard a testable hypothesis.

Newbury: The hypothesis being that the "dredging will not elevate mercury levels in natural organisms."

Wright: That is a good first hypothesis. Now **what** do we measure to accept or reject that hypothesis?

Armstrong: If the water quality is already exceeding EPA standards or criterion, then do we have to have a hypothesis, don't we have to **monitor**?

Irvine: You want to have a directed program so that you are not just going to measure things, You want to have some criteria against which we can work, directing the research or setting up levels for which we can accept or reject the evidence that we get.

Wright: It's called the scientific method,

Prentki: But you see most of your effect at the higher trophic levels, that is where you get the most biomagnification. People are at the top.

Hansen, Don: We use correlations all the time to forewarn people of potential dangers of carcinogens; it is being used all the time.

Hansen, David: So you can't always go with direct cause and effect.

Hansen, Don: But, I think all Dr. Marsh is calling for, and it seems reasonable to me, is some assessment of what the background condition is on a reasonable sample of the population, on a seasonal basis. With that baseline information, one can form a hypothesis that there will not be an increase or that there will be in that population and test it.

Marsh: ...and on seafood?

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Hansen, David: And on seafood, absolutely.

Marsh: Ideally, it would be nice to have done prior to the initial dredging. I gather there has not been very much dredging done, since it was not monitored prior to the initiation of the dredging, it seems to me that this is something that should be done. Then compared with future levels, if the dredging is going to be allowed, supposing you find that the levels in some women of child bearing age are already rather high? Then it raises the question as to whether the dredging should be done. There are so many different angles, political angles, obvious economic angles. It is not just scientific, there are many different issues that come into it.

Hansen, Don: The problem is that it is pretty hard to keep something on just a scientific level when it has to do with potential human effects; there is no way.

Newbury: I think the second part of that hypothesis could be if there is an elevation, does the elevation present a health risk to the human population? Rather than trying to wrap all of it into separate things, I agree with Gail and Dave, and Tom partly, I think it is good to set out some hypotheses that are going to be tested so that there is a focus to the study.

Hansen, Don: I think the hypothesis that dredging activities are not going to increase the mercury levels in the ecosystem or certain tissues would be a valid hypothesis with which to begin. Then we can see whether there is or there isn't.

Eisler: You are putting the cart before the horse.

Hansen, Don: We know whether there is going to be a change..., and we decide on, yes, this situation is monitored. What do you want to monitor in the first place? What is a good representative baseline level? From there you can start with your hypotheses.

Eisler: Why dredge if the baseline levels are so high as to present a potential hazard to representative fish and wildlife or other trophic levels? Dredging should not really be a consideration if the levels are sufficiently high. If they are not sufficiently high, then you can work in a hypothesis that dredging will not elevate,

Wright: But, wait you are putting the cart before the horse again, because we do not have now really any evidence that I have seen that the dredging will indeed increase the levels of mercury in the biota. There is absolutely no evidence of that, because the people haven't done ~~the~~ the right test to show that.

Eisler: Well, there is no baseline.

Wright: You don't have to do baseline, You can go out and get some of the sediment and expose some animals to it and see what it does to them, You haven't done that yet, that is the first step.

Newbury: ...looking at that first hypothesis, will the dredging lead to elevated levels? Earlier we were talking about animals. I think the comment came up that crustaceans were not good, that they shed their mercury, that caged bivalves were good. I'd like to see it involve those organisms.

Irvine: I still have some questions about the crustaceans. Don't some lobsters have high levels of mercury in them? I attributed that to long life because they are long lived. **Part** of the concern for king crab is that the potential would exist even if they don't appear to be **bioaccumulators**.

Eisler: Take a look at Eisler (1987) in the background section. Are lobsters listed there?

Irvine: I have a paper some place where it is listed.

Eisler: I don't recall elevated levels in crustacean muscle.

Marsh: King crab levels are some of the lowest for all seafood,

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Wright: King crabs levels are low, lobster tail is generally low. Lobster **hepatopancreas** is where all these things come to reside, **PCBs, dioxins**, you name it. I guess it depends on what part of the animal you are looking at. I don't think you eat anything on king crab except the legs, do you?

Eisler: You can make a lobster bisque which involves adding the shell of the lobster to give a red color to the soup and what you are doing now is imparting a cadmium hazard...

Newbury: I want to go back to the hypothesis I mentioned earlier. I'd be interested in seeing an analysis of seal whiskers, maybe other parts of the seal too, the liver. But among other things, I'd like to see the whiskers analyzed. I think there are ways of getting the growth rate of the whiskers. We've done that with bowhead baleen with carbon isotope analysis. I heard a comment earlier, too, there is reason to look at both total mercury and **methylmercury**.

Wright: Is the ice cover sufficient to walk on or snowmobile out to the dredging areas? Does it get sufficient ice cover?

Hansen, Don: Part of it, part of the state dredging area

Wright: I don't think it would be an overwhelmingly expensive or logistically difficult exercise to get some mussels or clams even if you have to ship them in, and chop a hole in the ice and put them on the bottom in a cage for a month, then pull them up and analyze them. It might cost you a couple of thousand dollars, but it might give you a wealth of information, unless it is so cold that they just sit in the dark and don't do anything. They have got to breathe from time to time.

Hansen, Don: Oh, yes, but you may end up with a species that you introduce from somewhere else to that environment.

Wright: Well, if they are all dirty out here anyway to begin with, **taking** a dirty animal and moving him a mile isn't going to show you anything,

Hansen, Don: No, I'm just saying you were saying about bringing in some mussels, I don't know where you were planning on bringing them from.

Wright: Don't mussels occur here? No?

Hansen, Don: Well, I wasn't sure where you were, where you meant

Wright: I don't know, go 50 miles down the coast where it is not as dirty as it is here and get some clean animals. At least **get** animals that have lower levels than the animals here and stick them out there or alternately try the EPA's **bioassays**. Take them to the lab and put them in a suspension and see what happens to them there. But, it is probably just as easy to stick them out in the dredging site and see what they pick up from the water column. That would be useful information. It wouldn't be prohibitively expensive. What if they don't pick anything up?

Prentki: You have a lot of trouble doing **bioassays** in cold water. The organisms don't always behave very well. Sometimes they just close up and a lot of your typical test organisms will just not survive in that sort of climate.

Wright: Well, you would want to use an indigenous organism. I wouldn't get something from southern California and bring it up here. Use indigenous organisms,

Newbury: There are bivalves there, that is what walrus eat.

Prentki: But, not right in the sale area.

Newbury: I think there are bivalves in Norton Sound...

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Prentki: Why aren't they in the sale area?

Newbury: It doesn't matter. I agree with Tom's comment, you get some bivalves, cage them and put them in the area where the dredging has occurred.

Prentki: And you are going to put them in the dredge plume?

Wright: **No**. Put them out there before you even dredge and see what they do. I am just saying do it this winter rather than wait another year or two, Or, if you want to see what they'll do to suspended solids, you are going to have to get some material and take the critters back to a lab somewhere and subject them to the suspended solids. I don't know if you have labs that do that up here or not, I know that **Battelle-Sequim** does it. That might be the closest place, not that I am endorsing them, but I just happen to know that they are down there.

Emerson: That is a static system.

Wright: I don't know what they have down there, it could be a static system.

Emerson: We know that there are certain shortcomings to that test.

Wright: Well, a static system is absolutely the worst case, Because what is going to happen there is that you are going to maintain essentially a constant concentration. What is going to happen in nature is that immediately after release you've got a log of the concentration...

Emerson: I don't think you maintain a constant concentration even in the static system, it is actually decreased by wall effect...

Wright: It might decrease a few percent as opposed to the real situation where if **will** go to ambient, I dare say within 10 to 15 minutes.

Emerson: Well, surely we have preliminary base case "analysis on the **bioassays** to see just how much of a wall effect you have sitting there in the lab. Is that still a **96-hr**?

Wright: Depends on the animal. If you are using something like oyster larvae, yes, it is 96 hours of **Acartia**, **copepods**. If you are using **mysids** or what have you, it is ten days.

Emerson: Didn't we say yesterday that in order to make that test effective you have to do your test in the first hour, isn't that what you said?

Hansen, David: I don't think it was in the context of this that I mentioned it. I'm not sure we are addressing it right yet. It seems to me that what we have to do is establish the main critical questions that we want to answer in the monitoring program first. Once you've identified those key questions, then you design a monitoring plan specifically to answer them, I think we were started on a good track with the hair analyses, I think we touched on, just briefly, the associated analyses that must be done in order to characterize potential increases in **methylmercury** concentrations in **biota** that are consumed by man. I think that we have to maybe have some early warning signals, these would be indigenous species. I think then we need some early warning signals of potential **methylmercury** accumulation that is associated with the **nearfield** of the dredge and make sure that we have the appropriate. background accumulation data on caged mussels or clams or whatever to allow us to be able to answer the question, "**was** there really an increase associated with dredging? The studies would have to be designed to obtain critical seasonal information, If one was concerned with immediate releases of contaminants, mercury or otherwise, then there are a series of tests that could be applied to that. If the focal point is really only mercury, not the total process, I'm not sure that it should be; someone else would have to answer that. One could conduct a series of generic assays with organisms that focused on what was the normal survival, growth and reproduction of the species in the water and sediment from Norton Sound. Then, what is that condition following the dredging operation? There needs to be a statement of the major questions of concern prior to the development of the monitoring plan.

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These must come from the individuals responsible for regulating dredging and those most likely affected by it.

Prentki: Do we know what the species are, much less what the growth rates are?

Irvine: There are a lot of things that we don't know for the federal areas. Based on information we've got from the monitoring studies associated with dredging in state waters, we are learning a lot about **types** of things we didn't know before. We are assuming a homogeneous environment, actually a lot more rock, boulders, things like that associated with organisms. We don't know about the extent of those types of habitats in federal waters that determine what species might be there or in what numbers.

Hansen, Don: There are factors other than just looking at mercury.

Irvine: There are habitat alterations that would be of concern; in this workshop we are mainly addressing mercury.

Hansen, Don: That is just one aspect. Say you want to monitor other habitat-type effects. There are concerns in Nome with crab fishermen on changes in king crab distribution. Other crab fishermen suggest that in the area where they dredge, you won't find these king crab. There is no hard data on it, **but it** may be a concern that you want to address.

Prentki: Question for Dave on this. How do you feel about the **fact** that data we have to date indicates that the background mercury concentrations in the water are not on the order of 0.3 to 0.6 ppb?

Hansen, David: Well, when I look at that and I compare that to the tissue concentrations, I don't see a particular concern.

Prentki: Even though that is tenfold of the water quality criteria?

Hansen, David: Absolutely.

Wright: Are we sure that those were dissolved values, that material went through a 0.45 micron filter?

Prentki: That is not dissolved, but the 1986 **criteria** require you to use the total recoverable.

Hansen, David: And then if you exceed the number, what it requires you to do is to monitor local populations, and if **methylmercury** in **biota** exceeds the FDA action level, then you've got a problem. My understanding of the monitoring data on local **biota** is that you could conclude from that there is not.

Prentki: Not for king crab, but there would be for seals.

Armstrong: What do you do when the FDA action level is designed for a population that does not consume seafood the way these people do? I don't know how you can apply the FDA action level of 1 ppm to people who are eating higher amounts of seafood?

Hansen, David: That is a separate issue. That issue is most **readily** addressed by the approach Dr. Marsh suggests. The concern relative to the dredging permit is the increase that is associated with dredging or other activities, it would be helpful to have a discussion on exactly what has gone on to date from you or other Alaskan officials. How you would actually summarize the data, its meaning, its magnitude and range. It is helpful in designing a monitoring plan to have more detail from the people that developed existing databases. This would have helped us to aid you in designing the monitoring plan.

Emerson: I am sure some successful monitoring programs **with** some specific local problems have been designed, and I am sure that EPA has helped design those and even monitored those. That is all we are looking for here. We are not trying to reinvent the wheel and I think that you could probably give us the guidelines to approach that monitoring effort.

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Irvine: Are you just wanting more of a sense of where the problems lie?

Hansen, David: From your perspectives, as the people that are closest to the data, rather than somebody that just glanced at it.

Emerson: It **would** be like maybe you had a localized PCB spill and you want to see what the effect is because people are consuming certain food resources, **it** is just like a lot of things that probably are already being monitored to date.

Hansen, David: What I was looking for was a synthesis of the tabular information that is associated with the materials that you gave us and your assessment of the relative importance of the various kinds of information there, not just that associated with mercury but other concerns as well.

Emerson: The **primary** concern is based on water quality criteria and especially since the background case already exceeds one of those criteria, but you say that doesn't concern you, Then why do we have that criteria, I am not quite sure?

Hansen, David: This is an important point. The criterion for mercury is unique, The criteria document specifies that if the criteria continuous concentration is exceeded, **methylmercury** concentrations in organisms need to be monitored. Only if the FDA action level is exceeded is the criterion exceeded. You've done that and concentrations do not exceed FDA limits. Therefore, the **criterion** is not violated. The question that remains is has your monitoring of indigenous species been sufficiently rigorous. This concern has been mentioned previously.

Emerson: And that is in the base case?

Wright: The criteria are not magic or foolproof, they are to guide you. You've got a case where the criteria are exceeded, so that throws up a flag and says you may have contaminated **organisms**. Now go look at the organisms. It doesn't say you will have, it says you may have. So now you've gone and looked and you don't have.

Hansen, David: Have we looked at sufficient fish and **benthic** organisms? That is an important question to answer... and you think we have?

Armstrong: I think they've only looked at two seals.

Hansen, Don: Well, if you have only looked at three seals, we don't feel that they have looked at sufficient organisms to say whether there is or is not a problem.

Hansen, David: Then that is something that needs to be incorporated in the monitoring plan you develop.

Hansen, Don: So we have this red flag out there and the mercury levels that they are finding in the water and so forth, there is a question if these are real numbers or contamination.

Wright: They told *you*, go do something else...

Hansen, Don: That's right. In the situation right now, we have no control over what **NORTEC** has done, this is state water, we don't have jurisdiction,

Wright: What are we using for criteria for the seals?

Hansen, Don: What do you mean criteria for the seals?

Wright: If you go out and look at...

Hansen, Don: We haven't set, we don't know what the present level is.

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Irvine: Isn't it an EPA criteria? FDA?

Anderson: Isn't it Minerals Management Service's responsibility to go between that three and nine miles? Isn't that your responsibility to go do the research and come up with the recommended numbers, come up with a baseline? Then when you have your lease sales, say this is our monitoring plan, this is our base and you play by our rules, this is the way we set it up. And then if you have your rules set up which are realistic then you have companies coming in who will want to buy your program. If your program isn't realistic, if you don't have that scientific stuff backing it up, then nobody will want to buy into your system.

Hansen, Don: I am not sure whether that is necessarily true.

Prentki: We have not committed to monitoring as MMS.

Anderson: Why monitor if you don't have the base rules?

Prentki: That is a good point. Technically we've not committed to an MMS monitoring program. We might prefer to have the EPA doing it perhaps.

McCrea: If there is no FDA action level for a species, and your water quality criteria are based only on FDA action levels, what do you do in those instances when seals are consumed, when there are other indicator species that might be telling?

Mawson: I can answer that. There was an incidence where Fish and Wildlife Service measured high cadmium concentrations in walrus kidneys. They then sent that information to the FDA for an opinion from them as to what these concentrations meant as far as the diet of people who were eating those walrus. The FDA decided that since they were not a commercial food species, they would then defer it to the EPA, who although they were unwilling, wrote a letter to the community there that said that they should immediately cease eating walrus kidneys.

Wright: That is a good standby approach,

Mawson: Then the epidemiology department here in Alaska did some urine sampling with old people on St. Lawrence Island, which is an island where a lot of this food is consumed. Based on the results of this urinalysis, they determined that there was no cadmium problem in the population. And that is how that happened. So basically there is now, as far as I can see, no mechanism for people to deal with this type of thing,

McCrea: Perhaps the monitoring program, that would be an indicator...

Eisler: As I understand your monitoring program, you've monitored crustaceans and seals for mercury levels. One group is always going to be negligible and one group is always going to exceed. Neither of these two groups are appropriate indicators to monitor mercury, in my opinion...

Irvine: Why aren't seals appropriate if the liver is consumed?

Eisler: Seals are an unusual group of animals. They have unusually high levels of mercury but it doesn't seem to represent a hazard to them. I don't know if it represents a hazard to consumers but they are not appropriate indicators.

Newbury: Could you use bivalves?

Eisler: I would use bivalves, not necessarily mussels, they are not as good accumulators as, let's say, clams.

Newbury: Get ones that are clean from some other part of Norton Sound. Put some in, some near, some outside of the area and compare them after a period of time.

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Eisler: That is one approach. Another is to see what is actually here **or what** the levels are today, You have supplemental data, you'll have levels in sediments, you have levels in water and based on those two criteria, you would expect levels to be above the 1.0 ppm FDA action level, in appropriate indicator organisms, I would think that a bivalve mollusk is an appropriate indicator. I do not consider crustaceans or pinnipeds in this geographic area as appropriate.

Hansen, Don: The problem with pinnipeds is the point source pollution. They are a migratory species up there and where do they get it from? So there is that real problem with monitoring seals,

Beelman: I was just going to say, I'm with the Department of Environmental Conservation (DEC) and we've spent four years with WestGold working on the permits that are about to expire, They are expired now. We get together in January to review the data that has **come** in since our last meeting in October. Doug Mister was indicating that you need a synthesis, you need to go back and ask or **re-review** what the questions were in 1985 and see if they are still appropriate questions. I think it's been helpful for the DEC and WestGold people to sit here and listen to what you have said because we are worried about the human population but we didn't look at it from that aspect. We thought that if we monitored the crabs and we monitored the prey organisms that the crabs subsisted on, and at that time, three years ago we didn't even know what they ate, we knew that they were omnivorous but we didn't know what their main diet source was. We are beginning to get a picture of **that**. We do see the higher elevations of mercury in the water. We don't see it in the critters that the crabs eat, or in the crabs either so we are not too worried at this point. I think it would be appropriate for some human population studies to be done. However, I think WestGold certainly would agree that you can't point the blame on the dredge operation, especially if the population eats seals, walrus, whales, animals that are all through Norton Sound, I think there could be independent studies going on. Another thing I should throw in here is that the mercury issue is the issue of today and yesterday, but the overall picture includes the turbidity factor and how much of the bottom you disturb, We are more concerned if the crabs will come back to an area that is disturbed. We have data that show that the recolonization of disturbed areas is not happening as fast as we would have hoped. Maybe it is going to take another two years in those areas. We are **really** trying to do the monitoring while the dredging is going on. That is **difficult** because you can't sit back and **say**: "Okay, we'll study ail this area and then if it looks good we will do the dredging." That is not what we really want to do. I think we have done a reasonable effort so far and now it is time for refinement. If any of you want to come to that meeting in January, we would appreciate it.

McCrea: We are given no FDA action levels, what was the EPA looking at as water, as an indicator that although ambient exceeds criteria,..

Hansen, David: Your focus is mercury, right?

McCrea: At this point, it is mercury.

Hansen, David: I don't think it is bad to monitor mercury concentration in organisms to establish what the baseline is right now. Then, in the vicinity of the dredging operation, during the same time of year as the background monitoring, monitor to see if there is an increase in mercury concentrations in the **biota** in the **nearfield** of the dredging. One concern is that dredging would increase the aeration of the sediments or cause a change in state or availability of mercury, which would result in an increased concentration in organisms that might be consumed. The question in my mind should be, has there been a significant change? Now how you want to define significant is something that this group has to decide, We did that in New Bedford Harbor. We decided that significant was **a** statistical increase. That may not be appropriate here. Maybe significant is a twofold or some other increase. That is how I would approach it. In New Bedford, we are just looking at the number one contaminant of concern, in that instance it was **PCBs**, and at metals. This multiple approach probably needs to be done here. But we may be concerned because of the complex of contaminants that are associated with the sediments and the implications of dredging. Chemical monitoring may not be sufficient to allow us to detect increases in contaminants we don't know about or haven't measured. By testing organisms in New Bedford Harbor before and during the dredging operation, or the dike construction and all the other phases of the operations, we hope to reveal a spatial and a temporal gradient of response, not only in accumulation or release of contaminants but in biological

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responses as a function of the dredging operation. That is how we in Narragansett are handling that one particular situation, which is really a worst case kind of dredging operation. I would say that you can do the same here. That you can establish what background is from a chemical concentration standpoint in water and biota, not probably just mercury, although that may be very important. One could, because you might want to get more control over the situation, hang mussels or clams or something in a grid out from the dredging operation to see if you can see an increase. But not only an increase, an increase that is spatial, that is up-plume and down-plume, so you can say, yes, we really do believe it is associated with the dredging operation.

Eisler: That doesn't always work. Sometimes you can have bivalves in close proximity to a plume, they will just close up, due to too much turbidity. Then you'll actually have lower levels than those that are further away, because they haven't been filtering during the turbidity.

Hansen, David: Yes, you have to concern yourselves with things like that. **But** that is just a detail associated with how you select your spatial grid. We felt very strongly with New Bedford though that there needed to be biological tests that could detect an immediate problem. These tests detect toxicity being released from a dredging operation, We wanted to check that toxicity right away, not in seven days, so we can determine if dredging should be stopped, silt curtains added, dredge heads changed or time of dredging to confined just to the flood tide. Some of the tests can be conducted in a laboratory to see if there is likely to be rapid biological responses in lethality, in growth or in reproduction. If those **laboratory** studies say that is probably not going to be an issue, they become secondarily important in a monitoring plan. Monitoring plans are very expensive and so we want to put the effort of where your key important questions are. That is why I say you really have to identify the questions important in Norton Sound as we did with New Bedford, Individuals close to the project have the best insight as to what those questions should be.

Prentki: Part of the problem is that we are talking about a sale area of about 200,000 acres

Hansen, David: That's huge.

Irvine: And distributions of organisms that are not very well known. So we can't write it off. There may be critical king crab habitat in proposed areas, so there are reasons we can't **write** it off.

Hansen, David: So that becomes very important **to** incorporate in the monitoring plan, To see how quickly recovery will occur and how quickly populations that are desirable will return then. But again as with all monitoring plans, one has to have decided ahead of time when the **insult** is too much and you need to take some action.

Armstrong: It is so easy when you can just say you're **exceeding** FDA action levels, then you cut off the dredging. But in this case, if these mothers have elevated levels of mercury that are of concern, I mean, obviously it is only of concern to women when they are pregnant, if they are just **slightly** elevated, say there is just a small increase, how much of an increase is too much of an increase? I don't know how anybody is going to come up with that.

Marsh: It seems to me that there are two rather separate types of questions. One question is all about the dredging and the monitoring toxic effects on the **biota**. Quite separate is this very unusual circumstance of this high background level of mercury in this area and the question of is there currently, without dredging, some small risk to the fetus in the limited number of native peoples. These are two separate things in a sense. Now the latter question, about the human risk, it is possible that might exist to a small extent right now, It is **also** possible that the dredging might have no adverse **effect**, in terms of elevating the **methylmercury** levels in seal liver. If that happened, that first risk, the human one, would still be there. If the dredging did result in increased levels in seafood consumption then any risk to the human population would be greater. In a sense they're two separate things. I could see someone might argue that the two are separate and the pros and cons about allowing dredging should be considered separately, because the remedy to the possible human risk could be quite apart from dredging. It could be a matter of education about what to eat and what not to eat. So, personally, **I** feel that it is two separate problems. There are certain interrelationships, obviously, but **I** would think the discussion of the two for practical purposes might

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be separated even though they interconnect.

Emerson: ...is being proposed without what has been at one time an operational procedure to do some process of separating the gold on the dredge with mercury. In a couple of instances dredges have been subjected to storms and crashed or sunk, The fate of the mercury, sometimes it is still contained, sometimes it's not. Dick Prentki has the details on all that. Down the road the economic factor always comes into play, as to what is the basis for preventing or allowing some smaller operators that may come into the area to process their samples on the dredge. We have gotten into those arguments already as to the cost effectiveness of that, Right now because of this uncertainty, probably we will require, I am guessing here, they are not going to be allowed to process onboard ship, to prevent such an accident, to minimize any more insult. If you had another population where there was not a critical background level, just looking down the road, there may not be as much basis for preventing it. We are going right now on no data as to what more mercury in the environment is going to mean, We don't know the sensitivity level of people in Nome or in the food chain, for example. There mayor may not be a good basis for preventing processing onboard ship. But right now to be sure, to take a more conservative position at this time, this sale will probably be posed with that restriction or mitigative measure. Then often times with the success of a sale, like we have had in our seasonal drilling restrictions, we gain more information, we loosen up a little bit and we probably don't have to shut down drilling because of potential oil spills at such and such a time because the whales aren't there "at that time. Well, in this case maybe we don't have quite such a worry about mercury in the environment, We may be coming to the point that the effects of recolonization and so on are more the issues, but we still don't know how important this question is until we kind of know the status of the local folk, do we?

Marsh: I don't think so.

Scheuhammer: If I was going to design a monitoring program, I would be very concerned that **part** of that program address those species that are at greatest risk for increased exposure, and that includes humans, because they are top predators essentially in an aquatic food **chain**, it includes other mammalian and avian species. Those are the groups of animals that are going to be at greatest risk of increasing their exposure to **methylmercury** in the end should there be an effect of this dredging, Now, if you institute a monitoring program to look at baseline levels, and you establish what those baseline levels are, then you have a platform to **start** from. So I think really the issue is to work out the nuts and bolts of that monitoring program. What exactly are you going to measure, how much money are you willing to spend to do these measurements, how many different species are you going to look at? With the human situation, I think it is pretty simple to get some basic baseline data. You have to then decide whether you want to extend that out into wildlife species, for example, that might be at risk of higher exposure, These are all things that have to be considered in the light of monetary concerns.

Armstrong: One thing I kind of hope personally comes out tomorrow at the Coordination Team meeting is that we can have you, all the experts, tell these people at the meeting that human monitoring should occur, because there is some reluctance on the part of everyone to do that. I know that MMS doesn't feel that they should, it is not in their jurisdiction. I would just like it to be known that is probably something that they should do.

Marsh: Did you get any feeling for why they did not want to have...?

McCrea: It's not on leases, is one of the problems,

Armstrong: The comment was made something like: "Oh, we are not concerned with that because all we are concerned with is everything on the lease", which isn't true because National Environmental Protection Act expresses you have to be concerned with the environment and that includes the human environment,

Prentki: We can't require them to give us blood samples or hair samples,

Armstrong: The other comment that was made was that we can't take samples, you would have to rip the people apart,

Hansen, Don: The problem is jurisdiction too, who has the authority to say we will monitor this. You have several different government agencies involved. Right now the present monitoring system is going on in state waters by a private company, NORTEC. We are looking at what they are doing, seeing how can we improve that. We are looking at the mistakes perhaps that they have made at Nome. Like Dr. Wright was saying: "Well, they should be doing this and you should be doing that." So right now we are looking at what the federal program should be doing. We ourselves initially have not, do not have a monitoring program. We are looking at what the state is doing. I don't know if anybody is aware of that or not, that's the perspective of where we are coming right now. Dr. Hansen mentioned having specific levels of concern or levels of effect. The EPA staff can do that with the state, with **critters**, water column, acceptable levels. But I guess with people it is pretty difficult to know what you are going to accept even in situations with dredging out there, how much habitat is displaced, etc. I guess it is really hard to come up with an acceptable level of effect that you can tolerate, When you get into the values of what is more **important**, the money that is being brought in from this gold operation versus the king crab fishery in **certain** areas, it is pretty hard to come up with an acceptable level.

Wright: It is a political decision.

Hansen, Don: Yes.

Rusanowski: Just a comment on extending this to human health monitoring. Generally, when you start looking at an application in monitoring, you want to monitor things that have a potential for being affected by the project, So far, what we've identified is that the mercury problem in Nome exists in marine mammals, which are wide ranging and have no relationship to the dredging project that presently goes on, or to any potential dredging occurring in the proposed lease sale area. So to extend monitoring to human health effects requires some sort of relationship to be established that generates a potential risk, not a theoretical risk. You have got to have some tangible risk that you need to assess. I don't see the link at this point between the present set of data and an offshore sale that would require human monitoring.

Irvine: Since you are going through several **trophic** levels, I guess it is pretty hard to show a relationship, unless you can identify the specific mercury that would be stirred up by the dredge or whatever, and say this mercury is showing up in these marine mammals, you have that problem with point source. I think you always have that problem with any kind of pollution when you are dealing with higher trophic levels..

Rusanowski: Mercury is in the marine mammals before the dredging occurs, We have approximately ten animals, six of which were collected prior to any dredging activity offshore. They are all collected from areas anywhere from 5 to **30** miles away from **Nome**, which is where the seal hunting occurs,

Hansen, David: What were the levels? I think I've seen it was 2.3 ppm in the liver.

Rusanowski: Oh, yes, they are significant in terms of the concentrations, but they come from Norton Sound. They are not coming from the area even close to **Nome**.

Irvine: I think again you are going to want to **look** at the potential for that, If you pre-examined human health and found that it was borderline, that mercury might be an issue that needs to be scrutinized, that the actions that we take, whether it is an acceptable risk to allow some operation, that could cause a problem.

Rusanowski: But, it **has** to be tied to the project. Find a link to the dredging project, there **has** to be some way of tying the two together.

Hansen, Don: Are you saying that the marine mammals do not migrate through the dredging area, that they can't be exposed?

Rusanowski: Oh, they could be exposed for a short period of time, we have seen them around there. But I am saying that in order to make any monitoring requirement of the project, you have got to establish a relationship. I am not disputing the baseline position and wanting to get that information, but to make human monitoring a part of your monitoring program for that project, for that lease sale, requires one to

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make a relationship established that the dredging itself can cause that effect, I don't think we see anything that remotely approaches that.

McCrea: The monitoring program is to establish that possibly that doesn't occur. I don't think one way or the other has been really established at this point and to just cut off the question because you can't prove that linkage, is cutting your research.

Hansen, Don: You can approach it from the standpoint that the dredging is not causing an effect too. You know it's a null hypothesis to say what dredging is not having an effect on. Marine mammals tend to be the top as far as a consumer, not human consumer, of food.

Irvine: I think birds may be a more realistic measure because there is a number of colonies of birds that are very wide ranging, that are foraging in the dredging areas,

Hansen, Don: But from a standpoint of human use, I am not sure how much use there is in the seabirds.

Irvine: It depends really on what you are asking, whether you are looking for indicator species or whether you are looking for transfer in the food webs.

Prentki: If I could switch this back to water quality for a second, I can give you a problem I've got with the water quality data we got. We have some data indicating that if we believe the existing numbers for mercury, there are in the order of 0.3 to **0.6** ppb, sometimes up to over 2 ppb. If that data are correct, and we use EPA methods, and we've several numbers by a couple of different labs now, then it looks like high levels of mercury in the water, at least, are not causing problems with king crab. If you are putting in a little more mercury for dredging, compared to 2 ppb or 0.3 ppb, the dredge will probably be putting in just a little bit. Then you probably don't have a problem. But, if those numbers are wrong and if you went to, say, gold foil technique for analyzing mercury in the water, and it turns out that the concentrations really are 5 parts per trillion and the dredge is putting in enough just to get over the 0,025, then we have probably an entirely different situation.

Hansen, David: Yes, and the way you would tell you have an entirely different situation is to monitor the contaminant concentrations in organisms.

Prentki: Yes, that is one way, but we are going to have the sale before we probably do that,

Eisler: You are going to have the sale before you do that?!!!

Prentki: Quite possibly, it is scheduled for July.

Eisler: I thought that was what this was all about here?

Hansen, Don: There is another point, while making a cause and effect relationship with the dredging activity, that should be brought out is that we are responsible also, in a sense, for looking at the cumulative effects of these **toxics**, the potential toxics such as mercury. Looking at present levels of mercury are a concern to us as well, even though dredging may be a minute threat, I think we are also concerned with existing levels, all of the mercury, both man-made and natural mercury in the Nome area. Of course, natural you can't do anything about, it's there, A lot of human activities have increased mercury levels in the area. And we are concerned about that as well, so it is making this direct connection, where we have to add a little slop to it because we are looking at existing effects as well.

Prentki: To go back to water quality for a second, with the Corps of Engineers approach where you use **elutriate** testing, the next step would be to use the **elutriate** test if you thought you had a problem. We are talking about an area of about 200,000 acres. We know that gold is in pockets in this area and you'd expect that mercury would also be in pockets. We have suspected contamination from gold mining on the shoreline of Nome. USGS thought they saw a signal in their sediment data for mercury. We know we have cinnabar deposits in the area, We expect to have a very patchy distribution of mercury and possibly different sorts

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of mercury from the different sources, and you are talking about dredging operations that can go anywhere in this area, go down 10 m. We don't have any **elutriate** data for our sale here at this point. How much do we need to characterize that?

Wright: Well, there is an empirical way to find out and that is, assuming you know almost nothing, go in, and depending on your budget, take some samples and do an analysis of variance. If all the samples are almost identical, then you have taken more samples than you needed to. If the variance is all over the place, there is a simple formula that will tell you how many you need to take to get to some confidence interval. It might tell you you need to take 2,860 samples more than the gross national product,...

Prentki: Data that has been done for Norton Sound by USGS indicated that maybe 10% of the samples may be tenfold higher than the rest of them. And the data we got from Tom Gosink the other day, his numbers are a factor of 3 higher than any USGS found in their Norton Sound survey.

Marsh: Have you done any core borings?

Prentki: USGS did two offshore of Nome, where they went down several meters.

Marsh: Did they try mercury in a particular stratum?

Prentki: No. The data I've seen indicates it is highly variable. There wasn't any correlation with depth. WestGold may have some information which is proprietary in terms of where the gold, where the mercury is. I know one company has come in, just prospected for gold. We don't have any specific data on depth or distribution or really anything worked out.

Wright: Let me try to answer your question. You go out there and take some samples and you can get mercury numbers but then you don't know what the numbers mean in the sediment. I'd forget numbers. I would go out there and take some samples and do some acute toxicity tests, do some **bioaccumulation**. If things across the board are not acutely toxic and there isn't any **bioaccumulation**, I wouldn't restrict it to the mercury. If you are going to look at mercury, you might as well look at everything else, then who cares what the numbers are. You can play the numbers game forever and ever and you can get worried about the samples that are three times more than that sample. What you may indeed find out is the stuff in that sample over there might be more toxic or more **bioaccumulative** than the one in the sample that is three times.

Prentki: Would you start out with the **elutriate** test first, though, and if it doesn't show anything, just stop there?

Wright: Well, you can start out with the **elutriate** test and if you do not observe any release, I think that is a pretty good indication that you are probably not going to have an effect. Wouldn't you agree with that, David?

Hansen, David: I think a **biogeochemist** needs to tell us what the rates would be for the processes that we are concerned about; that is, the processes that would lead to an increase in the available mercury concentrations or in the forms that are most toxic. If that was compatible with the duration of an **elutriate** test, then that would be appropriate.

Wright: ...**operating** on the assumption that at least in the upper layers of the sediment, I don't know about the deeper layers, since you do have crabs running around, and since there are obviously prey organisms for the crabs, that some upper portion is not toxic, and things are not **bioaccumulating** from it.

Prentki: There are a lot of distributions of **benthic** organisms in Norton Sound which are patchy and we don't know the reason why they are patchy. Whether it could be chemical toxicity or just different terrain or what.

Wright: Could be grain size, organic carbon, particle configuration..

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Hansen, David: But, if I heard right, the oxygenated layer is not very deep.

Prentki: It gets thinner as you go farther offshore.

Hansen, David: But the dredging operation is going to go very, very deep. So from a mass standpoint the concern probably needs to be focused on the deeper sediments that you are going to disturb rather than those **surficial** sediments...

Prentki. Unfortunately, we've only been able to sample the **surficial** sediments.

Hansen, David: But that is where if the mercury concentrations are highest. That is where the greatest problem is located. Metals will be sulfur bound in **anoxic** sediments and dredging may change that and release metals.

Hansen, Don: Yes, I think they said 60 m is what they are dredging at.

Prentki: No, it is only going to take about 10 cm of sediment out.

Hansen, Don: How deep does the dredge go?

Prentki: We are assuming it is taking out 7 m of sediment.

Hansen, David: 25 m is what you've got in core samples, no, 25 cm **vs. 7 m**.

Emerson: Didn't we say yesterday that the **elutriate** test and all the tons of material that have been processed with that bioassay basically show no effects?

Wright: We are talking about the water column bioassay, yes, **that** is correct.

Emerson: Well then, we are not going to show anything either.

Wright: I doubt it. If it would, you would be seeing it now. In other words, the storms resuspend the material, and if it is toxic or **bioaccumulative**, we should be seeing that now, And I don't think you are.

Hansen, David: I think what you must determine is the potential magnitude of release of mercury rather than biological effects.

Emerson: Well, do you think the fact that all of these reams of data that have accumulated to show no effect with that test are a tribute to the fact that there are no effects from dredging by the Corps of Engineers or that the test isn't any good?

Wright: Well, if the test isn't any good, the EPA probably shares the blame because it is a jointly developed and approved test which has been in use for 12 years now.

Hansen, David: Well, it is a good test, it answers the question. The question is: "IS water from a shake test toxic?" And the answer at the time it was derived was we didn't know, Now we know. Should that test be applied here?

Emerson: We also know that if you pour a toxic solution into this **borosilica** glass container and let it sit and monitor it for a 96-hour or 4.5-day period, that the concentration of, let's say, the most toxic species in there could be the **divalent** cations, decreases exponentially . . .

Hansen, David: You've said **that** about a half a dozen times, and I haven't argued, but I think I will now. We have examined the difference between **LC50s** derived from flow through tests with measured concentrations and static nominal tests. On the average, the difference is a **factor** of 2. For some chemical substances it is very important to have flow-through methodologies. There are processes that do cause the chemical

concentration to go down. For those kinds of materials you do flow-through testing if you want to do a reasonable environmental assessment. But a castigation of the static testing methodology is really not called for, because they provide important information at low cost. Most often I would rather have more information about a lot of species and their sensitivity than really **good** data from one or two. Because it is the range of species sensitivity that is typically important than defining very accurately the sensitivity of one or two species. For example, for mercury the range is two to three orders of magnitude. That is very important to know,

Emerson: Well then, we are talking about mercury in this case, does that mean a flow-through system?

Eisler: I've conducted a series of static **bioassays** where the contaminant including mercury was in solution for 96 hours before the test organisms were added and another series was run at the same time as the contaminant was added, the difference in **LC50s** was less than four. Among 75 different **chemicals** tested, it's never been more than an order of magnitude, and that was with **heptachlor**, but with mercury it was less than two. So the 96-hour static test where you add the compound to the solution 96 hours before the organism and another where organisms are added shortly before the test chemical, shows negligible differences. In terms of a divalent cation, there was no exponential loss. It may be with something that is extremely volatile. **With** a large series of **divalent** cations, it is usually less than a factor of two.

Emerson: Some of Ken Shin's work at USC has shown that you could actually clean the test solution or your **elutriate** by just the scavenging effect of particulate material for those divalent cations...

Wright: We see that happening all the time.. when we go out and dispose of material and it strips the metals and phosphorous out and potassium **out** of the water column...

Emerson: Well, I guess what I am saying, it seems to me then that the results are a little more complex, In that case, you don't even need to run the test but it depends on the organism, its life cycle. Let's say it's feeding strategy primarily. **If** we are chelating these things on **organics** and if the critter you are testing likes these organics, then we've got maybe a toxicity problem.

GENERAL DISCUSSION
THURSDAY MORNING, DECEMBER 1, 1988

Holder: We would just like to say a few things to the speakers about this afternoon's session where you will be giving a summary of what you said before and a little bit about the Coordination Team.

The Coordination Team was established last winter in response to a request from the State of Alaska. Basically it was established so that they could share their experience in the permitting and monitoring processes that they have gained over the last four years with the offshore dredging in state waters. The Coordination Team consists of 27 members outside of MMS. They represent federal, state and local agencies and special interest groups. Many of the members from the state and federal agencies have strong backgrounds in biology. As far as I know I don't think there are any chemists. We don't have quite as many people with advanced degrees. I know it is difficult to condense all that you know about mercury in the environment in the time that you were provided the past two days; however, we now are expecting an even briefer version, The format for the afternoon will be 5-10 minutes for each of the speakers, followed by questions and answers.

Marsh: There will be people here this afternoon that have not been here the previous two days?

Holder: That is right. There will be some overlap, there will be many new people,

Emerson: Well, I was asked to continue the discussions that we were into last night and see what relevant questions have been generated after a "good night's sleep" that we need to address while we have these experts with us today. I was going to finish up on the odds and ends of questions this morning and then ask some of our representatives here from the agencies to speak. George Valiulus is here from Washington, D.C. I might ask him to address the importance of a monitoring program as it presently applies to this document, this EIS. Maybe one of our Studies people, either Jim Cimato who is here from the Washington office, or our Studies Chief, Jerry Imm, could address the question of monitoring and what our responsibilities are. There is also an unclear issue of whether our responsibility stops with organisms that are consumed, or does it extend to the human population with the present background and historical situation that exists in Nome. If we were in academia, it would probably be a great opportunity that graduate students would be "jumping on" for grants. When the problem looks too complex or there is not a clear line of responsibility, we tend to look around for who needs to pick up the responsibility, This is kind of a new question... is it the EPA? Is it MMS? Maybe it is no one. Sometimes because of the complexity and uncertainties, no clear mandate, insufficient funding, etc., agencies may want to pull back and state: "Hey, I don't think it is my problem". Maybe we don't need to take that stance; maybe this is an opportunity to take a more "academic" look at the problem. Just because the lines of responsibility aren't clear cut, I don't think it should deter this group of experts from making recommendations.

Armstrong: I had a couple of more questions for David Marsh. This is just a technical question. When you are doing that hair sampling, how many months did you say you could get from one strand of hair'?

Marsh: It depends how long the hair is. It grows just over 1 cm per month.

Armstrong: So you would need 12 cm for a year?

Marsh: Yes.

Armstrong: So if you have long enough hair you could conceivably only have to do it once per person?

Marsh: Well, if you have hair that is just about 12 cm in length and you analyze it in segments, then that will give you the history of exposure during the previous 12 months. It will give you any seasonal variation.

Armstrong: So you would only have to do it once?

Marsh: Well I think in many women the hair is likely to be at least that long. You would get a lot of information out of just one sample.

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Wright: But once you do it, it stops at that point in time. If you want to know what happens next you'll have to do it again.

Armstrong: Of course. The other thing I was wondering would you expect that the **Apgar**¹ scores to be lower on fetuses that were exposed to **methylmercury**?

Marsh: No. No, I would not.

Armstrong: How about birth weight? Would those be lower?

Marsh: I don't think one can do a study in this population of fetal exposure. But one of the co-variables, if one did do a study, would be other medical events that caused mental retardation. One of those would be a very low Apgar score. But the methylmercury would not be expected to cause the low Apgar score.

Armstrong: Would it cause lower birth weights?

Marsh: No, although birth weight may be associated with adverse Apgar scores, The biggest reason why it would be a difficult task, would be many co-variables, especially the alcohol consumption. Alcohol consumption causes Fetal Alcohol Syndrome, which mimics the effects of **methylmercury**. The partial syndrome (where you don't have all the facial features) includes psychomotor retardation which would be difficult to distinguish from **methylmercury** effect,

Armstrong: I was wondering why you couldn't do a 100% sample? I mean you could in a space of a year, do all the children born in Nome and why that wouldn't.,.

Marsh: You might get some data, but what you need is a big enough group of babies for a statistician to calculate an estimate of risk, We are not talking about a huge **effect**. We are talking **about** a risk at some low level of exposure of perhaps 5% of babies with effects because of **methylmercury**. That would be an important event in the population, This potential problem is not unique to Nome. Probably it affects all the coastal Eskimo groups as well as some other groups. The mechanics of a study in small communities without roads, hopping by plane is expensive and very difficult, and complicated by alcohol consumption. To combine enough communities to allow enough numbers for a statistical estimate of risk would be very **difficult**. That is why I indicated the study has to be done somewhere else, but one needs to do some surveys and monitoring. But to do the primary investigation here would be difficult. If there is interest, that could be discussed.

Emerson: But don't we have a unique situation here, an inland community maybe afflicted with the same level of alcohol addiction, except that the diet is almost solely terrestrial animals and migratory fish. Where the coastal community may have a similar level, maybe some key variables, in this case, alcoholism, and you would have there a comparable group situation with the coastal communities,

Wright: But you are going to run into **intragroup** variance because you don't know that the diets of these people are the same. Even though they all may eat seals, body burden of seals may not be the same. One community may eat a lot of seal this year, and not eat so many next year, So you've got an uncontrolled variable. You've got subgroups within your experimental group.

_: He is referring to an inland community that does not eat seal or marine fish.

Wright: I am referring to a number of marine communities separated geographically, That is your

¹A numerical expression of the condition of a newborn infant usually determined at 60 seconds after birth and being the sum of points gained on assessment of heart rate, **respiratory** effort, muscle tone, reflex irritability and color.

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experimental group. And these people are not being fed controlled diets. They are eating, I dare say, somewhat different diets, and the animals' body burdens are different,

Marsh: As I said it would be very difficult to do. But the index of exposure can simply be the mother's hair mercury level. Then I wouldn't care where it came from, whether it came from seal or walrus or fish or some whale passing by. If you have the hair, you can measure both the maximum exposure and the mean. Your idea of comparing the coastal group and the inland group I think is good. We did that in this study in Peru, not a fetal study. We got blood and hair from coastal fishing community and then an inland group, in the foothills of the Andes, where they had no fish. And of course the hair methylmercury was enormously different in the two populations.

Emerson: Was that a major study? Are we talking a lot of sampling effort?

Marsh: Here you would be talking about a major study, with a lot of difficulties. But when you talk about surveying: hair sampling, sampling seafood and analyzing it, that is not a big thing to do. That is relatively minor. I can envisage that might be done. But to do the basic research, the clinical research, in this area, I think would have a lot of problems. I don't want to give the impression that I am totally negative, I am just stating the obvious. It would be a difficult project. It would be quite expensive.

Holder: If you wanted to sample pregnant women in the villages of the region as well as Nome, I don't know a statistic on this, but I am pretty sure that most of the women in the villages come into Nome to have their babies a few weeks before they are due. So that they have the advantage of the hospital. So you do have that, they are in Nome, in one spot. So if you were going to do some hair sampling or whatever, at least you would cut out a lot of travel expense to the villages.

Armstrong: There are also a fair number of women that come to Anchorage to have their babies. You could even sample them in Anchorage and get distribution from all over the state.

Holder: That is right. A lot of women from Nome come into Anchorage to have their babies.

: What would your sample size be?

Holder: I was trying to think what it might be. Actually, yesterday afternoon there was a doctor here from the hospital, I don't see him now. I just don't know a number, population around 4,000 in Nome, 7,000 in the region around there.

Armstrong: There are not 4,000 natives there.

Holder: Yes, total population, say 60% native, 2,400 natives, I think it is probably on the order of 100 to 150 births.

Wright: I would like to have some time to tie up some loose ends? Many of you have got copies of this viewgraph (see Figure 2, page 46 this document). I want to caution you again, if I didn't before, about this number, this 50%. This number says that if the toxicity of the material you are looking at is greater than 50% over the reference, you have restrictions, etc. This 50% came about by assembling a group of experts in Seattle, dealing with Puget Sound and Commencement Bay, and saying what is your opinion of what number we should have before we really start getting concerned. Ocean Dumping regulations specify 10%. Ten percent plus statistical significance, you get concerned. That is not a pass/fail, it is a concern level. The various experts kicked it around, considering the animals they were using and came up with 50%. I have no quarrel with that. Remember that the number you sat here is going to determine the protection level. So if you set it at say 10%, you are going to be very protective, very conservative; if you were to go up to 75 or 80%, you would be very liberal, very non-conservative. So don't think there is any magic in this number, this number is not a part of the Corps of Engineers regulations or the process. You've got to have something here and that is what the experts came up with.

Just a word of caution. I've found part of the reason here for some of our discussions, where we differ in

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evaluating dredged material in the water column. We take a four to one sediment water mix, we shake it up, and then let it settle for an hour. If it is clear enough that you can see the organisms in it, we decant it. There will still be some little particles in here. We decant it, put it in another container, put our animals in and do our bioassay. If it is still so turbid you can't see the animals, because you need to be able to see the animals to see what is happening to them, we will centrifuge it or perhaps let it settle for a while longer, to get it down to the point where you can see the animals. If we are going for the chemical analysis, we decant after it has settled, that is to allow a reasonable exposure time after an hour of shaking, another hour or so of standing. Then we filter it, .045 micron filter and do our chemical analysis. Now this is where we part company with, I think, what you are doing. Because you are not using a filtered sample and that has been baffling me, Well, I finally found out the reason. The reason is that in the regulations, both Ocean Dumping and 404, Clean Water Act, dredged material is specifically treated differently from sewage sludge, industrial waste, and all such associated things. I think there are legitimate technical reasons for this, because dredged material doesn't behave like sewage sludge or industrial waste or acid waste or alkaline waste, etc. This procedure is in EPA's regulations and we are just the implementors. They are EPA's regulations, to filter the material and do a dissolved analysis. We compare the dissolved analysis to the water quality criteria, Now why is it that here you are doing a total recoverable analysis? In other words you are shaking it up and letting it settle for some period of time, and you do not go through this filtration step, That is because this operation is covered by National Pollutant Discharge Elimination System (NPDES), even though it is basically a dredging operation dealing with marine sediments. I've made some inquiries and it is because powers higher than any of us here, have, I guess, legislatively, administratively, declared this not to be dredged material. It is processed industrial waste. As processed industrial waste it falls under NPDES. The EPA calls the shots on NPDES and it is the EPA's call at present, Although I understand there is some flexibility in the regions, I don't know if David Hansen can comment on this? But under NPDES, apparently most of the time, one does not go through this filtration step. So I hope that clears up some of the confusion as to why we go through the filtration step.

Now I asked another question, I haven't had an answer to this question. I guess the processing that goes onboard is that the material goes through a riffle separator, is that 'correct? That is the processing? That is what makes it processed industrial waste, I have asked the question of certain individuals, what would happen if the dredge were merely removing overburden? I got some equivocal answers. They said we'd rather not answer that. Again, it has been declared by administrative fiat to be processed industrial waste which, administratively, takes it out of the realm of dredged material. I guess you will have to settle in your own minds as to whether or not dredged material procedures are applicable to this or whether you should, and you may not have any choice, be following NPDES procedures which are designed for sewage sludge and sewage outfalls and industrial outfalls and industrial dumping.

Another thing to get across, is when we do the **bioassays**, we do three of them, We do a control, a reference, which is the disposal site, and **the material itself**, **The control** is for the purpose of looking at the general health of the organisms, If the air supply **went off** last night and you come in the morning and these animals are dead, you run and look at your controls, If your controls are alive that tells you something is happening over here. If the controls are dead, that tells you they might have died from old age, the pesticide man might have come through your lab despite the fact that he is supposed to be barred from the building, the power went off or who knows? In our comparison then, this control does not factor into the comparison. It is a control to make sure that everything is running properly. The comparison, the evaluation is made between the dredged material **and a reference disposal site**. Our standard procedure is to use five replicates because we have to treat it statistically, with approximately 20 animals in each replicate; unless you are using something like oyster larvae, you don't put 20 of those in there, you put thousands of them in there.

Emerson: **Is** that bioassay aerated?

Wright: Is it aerated? It may or may not be aerated. If the material is such that you are going to have a dissolved oxygen (DO) sag; yes, it has to be aerated. If the DO will maintain itself, what we usually do is check this out in advance to see if we have to aerate it.

Emerson: Do you think you lose much in volatilization in **the** aeration process?

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Wright: Not detectably. We check that. Because with such materials as the lighter molecular weight PAHs and PCBs, by the time they get into the water from the atmosphere or from a source, get attached to sediments, transported perhaps 10s or 100s of miles, and finally deposited, you've lost all your **volatiles** before it gets there. We rarely find things like **naphthalene** in detectable limits. It is always the higher molecular weight materials. One can contrast that with the other circumstance which is the **benthic** bioassay, where we simply take the sediment. This is a total evaluation, we may or may not subject it to a chemical analysis. If we use very weak acid, because you don't want to strip the material out of the clay matrix or out of a mineral matrix, when the material in there is not available for sure, and that is not relevant. So we use a weak acid analysis. Some people say we shouldn't even use that, we should **just** use a water extraction, but this gives you a little more of a worse case. If we are going to do a bioassay, we simply take the material and put a layer on the bottom of an appropriate aquarium and let it settle. We put our animals in and we like to use animals that are in intimate contact with the sediment. We don't use water column animals. We use animals that will actually creep or crawl around and preferably animals that eat the sediment, such as deposit feeding bivalves or burrowing deposit feeding **polychaetes**, marine worms. And again, as with the water column, we have control, a reference, and then the material itself and we do **five** replicates with approximately 20 animals each. I hope that **clarifies** that.

The other clarification point I would like to return to is monitoring and give you a quick example. You've got to have a statement of a problem. To give you an example of a statement is that "**the** action that may result is the smothering, let's say, of bivalves". How do you determine that? You have to have something that you can measure. It has to be quantifiable. So you can say, if we have 3 cm or more of sediment deposited over a 30 day time period, if it is going to smother the bivalves, that you can measure. You can go out and poke a stick in the sediment and see if you've got 3 cm or more of accumulation. Now you are going to get some variability, So you have to formulate your action criteria which would be if it is greater than 3, that is a no, **no**. If it is under 3, you don't worry. You can set up a hypothesis, if you have to, you wouldn't in this simple example, to verify whether indeed it is over 3 or not, If it is over 3, you still haven't done anything unless you have some sort of management or remedial action planned in advance, Because it becomes a "so **what**" otherwise. And what sort of action could you have? Well, in our own operations, we can manage to diffuse the material more. We can manage to **confine** it to a more restricted area. We can space it out so that we don't exceed the criteria. But we do **an** awful lot of monitoring, and I review an awful lot of monitoring things that come into our offices. These are basically the first four, there are other screens or criteria or questions we ask anytime we look at monitoring: 1) have they stated a problem; 2) is it a real problem or is it an imagined or perceived problem? Sometimes perceived problems are real. They may not be in the real world, but if they are real in people's minds, they can become real; 3) is if something that can be measured, if you can't measure, how will you ever know; 4) can we develop some criteria or some sort of hypothesis to test? Finally, if we get into trouble "can we do something?". So once you get into monitoring, and I hope you keep this sort of thing in mind, because otherwise if you don't when you get done, you wind up with a great huge mass of data and neither you nor the world's best statisticians or anybody else can do anything with it whatsoever. Ok, point is clarified. Any questions on this?

: When the Corps of Engineers conducts their dredging operations, are there any beach nourishment or replenishment projects?

Wright: Lots of them. That is a beneficial use and we do lots of them. In fact, there is some evidence, and we don't know why, that at least in Florida, turtles seem to like material that we have placed on the beach better than natural beach material. It may not be an actual preference, **it** may be that where the beaches haven't been nourished, they are practically gone or they have become so compacted that the turtles don't like it. When they get one of our beaches, they really like it.

: When you are cleaning out channels, for instance, a lot of material, and that mixture material is in sediment, do you do any processing in order to get the sand for the beach?

Wright: No, that is an operational constraint or pre-operational consideration. If we are going to use it for beach nourishment, you don't want it to be high in silt, clay, or have lots of **organics**, tar or anything of this nature in it. It has to be suitable material. This isn't to say that it can't be processed, and in some instances it is. But we (Corps) can't do that. The local sponsor (people that want the beach nourished), if

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they want to process it through a conventional sand and gravel separator onshore, and if they pay for the cost of it, fine. But we do not do that. We dredge on the Mississippi River, and there are sandbars there, When high water goes down in the spring, these sandbars are all covered with a couple of centimeters of mud, The Corps goes in early spring before navigation really gets started and cleans up the channel and gets everything ready. We just pump the material, it's sand, on these sandbars. A couple of years back, mainly because we had some dredge breakdowns and we had some problems way up river. Down in the middle part, in Iowa, they worked dredging on schedule, We slatted getting irate letters and phone calls from people who wanted to know "just when in the hell we were going to get on the stick and clean up the beaches?" Apparently, the public thought that it was part of our job to go in every year and pump clean sand on the beaches.

Emerson: Maybe this might be a time for George **Valiulus** to give us a short statement as to how monitoring may or may not fit into the present proposed action.

Valiulus: Based on some of the comments that were **made** by Tom Wright yesterday when we were talking about the monitoring program, I thought it might be useful to give a perspective of how this monitoring program fits into this Draft EIS and into the proposed sale. What I am going to say is explained in the EIS in depth, but obviously not everybody can read it, so let me just briefly summarize,

In the Draft EIS, when analyzing the proposed action, what we call "Alternative 1" (which does not presume a monitoring program being in place), the analysts came up with major impacts in the areas of commercial fishing, subsistence and **socio-cultural** systems. This is summarized in Table S-1 in the EIS, and the **impact** level definitions follow that table. This is primarily due to the **bioaccumulation** of mercury potential and the elevated levels of mercury in the ambient waters at present. From Minerals Management Service's viewpoint, our obligation, under such circumstances, is to try to get mitigative measures, For this particular case, we have what we call "Stipulation 1." A stipulation is an obligation the Secretary of the Interior can choose as part of this sale. Within Stipulation 1 is the monitoring program. Stipulation 1 is titled "Environmental Survey and Monitoring Program and Operations Management", and the monitoring program is only one of three aspects, It states that: 1) there will be a baseline survey, 2) there will be a monitoring program, 3) and then there will be a control whereby if as a result of our monitoring we find that the environmental situation is unacceptable, showing a trend, the Regional **Director** can then curtail the dredging operation. So this has both the monitoring and the control aspect to it, When we take into account this proposal stipulation, an analysis is also made of this EIS as to how the impact levels are different. The impact levels for the categories mentioned are considerably reduced, The reasons for that are, as a result of monitoring and baseline, we would be getting **some** specific data of what is really out there, We also have a mechanism to do something about the operations, if we are getting into a situation that is unacceptable. What we were doing here yesterday and what we are doing here, is that one aspect, that is we are looking at what kind of a monitoring program should we have that would be effective and this is how it sort of **fits** into the bigger picture, if you will.

Emerson: Any questions?

McCrea: 1 would also like to point out that the stipulation goes on to a lease, therefore if is the lessee's responsibility to do the survey and monitoring, It comes back to MMS to do the control part.

_: Who actually designs the monitoring plan, MMS or the lessee, or both?

McCrea: It would be the lessee coming in with a plan that Field Operations, which is a branch within MMS, would review and has to pass on before it would be considered adequate.

Eisler: What happens if the baseline survey indicates that the appropriate indicator organisms have mercury levels in excess of the FDA action level?

McCrea: I couldn't answer that one. I would probably cause a great deal of difficulty,

Emerson: Have you any ideas of what those might be?

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Eisler: I don't have any data.

McCrea: For this area, FDA action levels really apply only to the crab, that is the only species and the fish...

Armstrong: But the problem with that and I've said it many times, is that I don't think the FDA action level should be applied because these people eat so much seafood.

Holder: What is the FDA action level, the one that they have been using, 1 ppm?

Emerson: But the Nome community is estimated to eat about 15 times more seafood than what the FDA action level is based on. That is a rough estimate.

Wright: Knowing the procedure by which the FDA action level was calculated, all you have to do, I would guess, is plug in a consumption factor to account for local population. Then set whatever number you want as the state standard. Indeed a number of states have set their own levels. The Great Lakes states folks eat an awful lot of seafood. They have had some pretty severe problems with mercury and PCBs. Their levels are considerably more rigorous than the FDA levels.

Armstrong: Do you happen to know what they are?

: What states are involved?

Wright: I think for sure Wisconsin and Michigan have set their own levels. They may have removed them, this has been 6-8 years ago, when everything was up in the air over PCBs.

: I think they used 1 ppm in Wisconsin.

Armstrong: I thought, I may be mistaken, but I think what they actually did was tell people not to eat too much of it in a week.

Wright: Right, "you should not consume, and pregnant women, etc., fish from the following area at all and should only eat 3 oz of fish or 6 oz, and you should broil the fish to cook out the PCBs." But I don't think there is any reason that you couldn't go through the FDA procedure and set your own state criteria. Of course, you might have to go out and handcuff these people to keep them from eating seal liver, but, well you are protecting them after all from themselves.

Emerson: Were they setting an action level based on some activity occurring in federal waters? State action level, federal activity, there is kind of a gap there as to who can tell whom what to do or even suggest it.

Armstrong: But FDA is a federal action level, so I don't know why...

Wright: Most of the Great Lakes levels were aimed at recreational fishermen because there isn't or there wasn't that much commercial fisheries anyway.

Marsh: It seems to me that everything we've just heard about the stipulations and the baseline screening and monitoring program, etc., all those things tie in together very well and would be very appropriate for some other place. But, unfortunately for this dredging procedure, I get the impression it is going to go ahead. It sounds as if, the way everybody is talking, is that this is a *fait accompli*. But the background levels are so high I think one really has to keep that in mind. I don't know whose responsibility it is to consider human health surveys; this may be something completely different from the proposed dredging program, but the idea that the lessee is doing all right if he doesn't increase the level of contamination very much, a few percent or so. There are quite separate reasons why that should be surveyed, why there should be hair sampling, sampling of the seafood diet, quite separate from the dredging procedure, I don't know what that would show, It might show some small risk at the present time. So still, in my own mind, I look at this as two rather distinct questions. First of all, is there a health problem, a risk to the fetus along these coastal

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communities? And secondly, what would be the impact of the dredging procedures, would that increase the residue of **methylmercury** in seafood? Would that cause some additional risk? I know nothing about these agencies and all these complicated regulations as to who should be responsible, but it seems to me that the public health authorities, state health; and when it was said just now that the lessees would be responsible for the monitoring, I could see that they might have a responsibility for monitoring even human health or dietary changes the dredging would result in. It is difficult for me to see why the lessee should do what is required in terms of immediate, or in the near future, surveys prior to any initiation of new dredging operations, So I can't answer the question as to who should have this responsibility, but I think one needs to look at it as two separate things. I don't think the DEIS takes into account the high background levels, the high seafood intake and the probability that the body burdens of **methylmercury** are relatively high in the Eskimo population.

Armstrong: My problem, as the analyst with all that, is that I sit there and I look at this, because we are dealing with human health issues, to me those things aren't things you can just discount, It is just not as easy as it might be with other organisms. So I get a lot of flack from some of the people higher up, because the risk is so small, it is **not going to make any difference**. But I ask the question when do a few children who are going to be affected, I mean, there may be just a couple more children with this dredging project who might be slightly less developed, when does that become important? When does that become a major impact in our EIS? That is what my difficulty **is**. Because so often when we are doing these **EISs**, we have to talk about the most likely case, what is most likely to happen. It is likely that there just might be a couple of kids, but when does that number become **important** when you are talking about a lease sale?

: It is pretty hard, when you are dealing on a human population level, you have to look at **individual-person** levels as far as effects, You can't say, well, the **majority** of the Nome population isn't going to be affected, therefore the effects are negligible, I mean you can't do that.

Marsh: In a broad sense if you have a huge document labeled "environmental impact", you really can't discuss the possible environmental impact without knowing what the current situation is. And that includes knowing in quite a bit of detail what the diet is, what are the maximum amounts of **methylmercury** consumed, and what is the current status of the exposed population. I don't see how you can just concentrate on water levels and effects on wildlife and so on without doing preliminary status surveys, Otherwise you won't know if there has been or is going to be any impact on the human aspect of the environment.

Armstrong: I had a long discussion last night with one of our **people** who can see about that, because we have to identify in the **EIS** what have significant data gaps. If **they** are significant, to the point where we really can't draw our conclusions, we have to be able **to** say that. Generally what we do is try to make assumptions and we've asked that question, do we need to do a worst case analysis, do we not know enough? Actually what I did, was I based what we knew from the Yukon-Kuskokwim area, I assume that probably the levels will be comparable in **Nome**, because they are coastal people and they have similar diets. That may be a false assumption, it may be higher, it may be lower. I don't know, maybe I can't do that, maybe I need to say that we really don't have sufficient information to draw any conclusions.

Marsh: Well, you have a 1.5 inch thick document, and I don't see any pertinent data in there about the human health of the Nome area. You have one reference to this other area, where now maybe you can amplify that brief statement from the article which I have not seen. But you have this very cryptic comment that the mean concentration in mother's blood is 33,5 or something, and whatever it is in the infant. You don't say how many, whether it was a single blood analysis, it doesn't tell you very much. So if that is all there is, I would say that is completely inadequate, It gives you just about no data relevant to Nome. All it tells you is what one already would suspect. Chances are that some Eskimo people living in the Nome area have extraordinary high levels of **methylmercury**. Which is a very good reason why that should be defined. So I think that at a minimum, you can take into account coats and everything else, the minimum would be collection of hair from the women of child bearing age. And preferably analyzing that in segments. So you then will know the maximum level and the maximum seasonal level. In addition, the minimum would be a

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survey of a good enough sample of all the relevant seafood which is consumed in order that you might have a basis for giving advice on how to change that intake. We know just by talking that there is a lot of seal consumed. You have to keep in mind that to do a comprehensive dietary survey, it is extremely difficult and a very expensive project. I don't suggest you need that. But you need to at least have some data on the amount of various seafood consumed in order that then you would have a basis for advising people on what they should cut down on and what they could increase in the way of **seafoods**. You obviously can't get some political organization to ban seal consumption, what else are they going to eat? In my view, that would be a minimum, sensible requirement. I think one has to accept at the moment, the DEIS has an enormous number of pages on everything except the human aspect. There is just about nothing done at the present time. So there is this big gap, I don't see how that could be **left** until after the operation begins. You need to know, Already there's been a little dredging, you need to know prior to any new dredging what the situation is as far as human health goes and the human diet. Then you would need to continue to monitor that after, if the dredging takes place.

Scheuhammer: I think something else that maybe should be made clear is that we as scientists cannot really tell you what levels of risk you should accept or not accept. Scientists cannot tell you that your community should or should not accept this level of risk. All we can tell you is what the risk may or may not be. Then it is up to decision-makers, the policy makers to look at social aspects, etc. to come up with a decision as to whether that risk is acceptable or not, I have no idea what level of risk is acceptable to the people in this community,

Emerson: Well, what about, say on a basis of your **specialty**; for example, peregrine falcons?

Scheuhammer: Well, yes, now there you get into a different kind of thing. If something is going to threaten an endangered species, well, there may be **regulatory** powers that can be called upon to say, "okay, quit that".

Emerson: Maybe this would be a time to have the speakers give us their ideas with each of their respective disciplines as to what the monitoring program might include. I think Dr. Marsh kind of laid out what he thinks. What would you suggest at this point? Some things that you might think are important or not important to do with the present proposed action from your own viewpoint of the marine birds, Dr. **Scheuhammer**?

Scheuhammer: Well, I do agree **first** of all with Dr. Marsh that there should be some level of concern for the human health effects and monitoring of that aspect. If we want to extend beyond that into, shall we say environmental quality, generally, and extend that into the wildlife arena, we should be picking some species that are indigenous to the area, that don't range over a vast area. Something that comes to mind would be a colonial **seabird**. Some top predator in the marine food chain that you could monitor for levels of mercury, trends of levels of mercury in eggs or feathers, which would give you some kind of indication as to whether or not this dredging operation is increasing the mercury exposure in the aquatic food chains.

: I guess the situation is with a lot of the higher **trophic** level organisms, we do have that problem with mobility. I think that seabirds could be monitored, but again point source causes of pollution could be a problem, I think that to give an overall level of what is happening in the environment, I think is worthwhile, particularly important is to know what the baseline levels are in these critters, So the question comes up whether mercury levels are a problem in seabirds, for example. There are no data right now, what in the seabird colonies in Norton Sound area, the mercury bird level or any toxic level **is**. And the colonies actually near the dredging activities have declined in the past 20 years. There is speculation that may have to do with changes in food availability on the winter range or something. Again, there is an unknown there, Somebody may turn around and blame this on dredging or say that there is no effect, or whatever. We really don't know what the levels are, from a baseline standpoint. I think you can find out what is available on these animals, but again there are cause and effect problems.

Scheuhammer: You will always have problems with cause and effect...

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_: But we are dealing with mobile species, particularly in Alaska, because of the **seasonality** of breeding season, migration elements, it is something to keep in mind. I agree with what you are saying, but there are some problems.

: Well, I just wanted to add one thing about the peregrine falcon. As far as the top predator, it is usually associated with seabird colonies, We are in a biological consultation with Fish and Wildlife people now as far as the Endangered Species Act, and we anticipate that we will be required to do a monitoring program as far as the peregrine falcons go. First of all," we need to do a baseline as far as mercury is concerned. Also, I understand that the adult peregrine falcons replace a couple of their primaries in the summer when they are here during the summer nesting. So there would be an opportunity to trap adult birds which the Fish and Wildlife Service has been doing up here for quite a few years and banding. But they can trap the birds and take these particular primaries, which I think would show the mercury uptake in the summer period that they are here, And also they would be taking some fledgling feathers too.

_: So we anticipate that will be a requirement for monitoring on the peregrine, so we will have that species covered.

Emerson: Is the analysis of the feathers probably one of the better recommended indicators at this time?

Scheuhammer: I would say for methylmercury, yes. For many metals, no. Methylmercury is one of the metals for which feather analysis is very **good. It is very** stable in feathers, as it is in hair. The level in the feathers does very well reflect the dietary consumption at the time that the feather is grown. So if you can identify those primaries that are specifically grown here, that would be good. The other convenient thing about feathers is that you don't have to kill animals,

Emerson: Anything else besides the feathers that might be of interest or of importance to the program?

Scheuhammer: Well, if the Wildlife Monitoring Program is going to essentially center around the peregrine that are associated with the marine food chain, it might still be worthwhile to do some monitoring of those prey organisms that they are actually feeding on.

: Its prey species: **murres, kittiwakes**, have declined in the last 20 years, so you are looking at a population **perturbated** by something.

Scheuhammer: What I would do there **probably** would be to sample eggs,

: Not fledglings either?

Scheuhammer: Well perhaps, but the eggs are good integrators of mercury, dietary **methylmercury**.

: Also you can look at other contaminants with eggs, right?

Scheuhammer: Right.

McCrea: Like arsenic?

Scheuhammer: I am not too familiar with arsenic, in terms of its metabolism and so on.

Eisler: Arsenic doesn't seem to be much of a problem to marine life. The high levels that you find in seafood is in a relatively innocuous form, **arsenobetaine**. Arsenic has the added virtue of mitigating the effects of mercury, much like selenium or lead,

Emerson: Tom, can I put you on the spot here? I know you are primarily concerned with the cause and effect problem, that is going to be a tough question, any specifics?

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Wright: Yes, I understand where we all are coming from on the people and the wildlife. I think that is a rather large piece of land up there. I am not sure how in the world you will ever, ever manage to relate that back to the dredging operation. I suppose you could rationalize it and say well the only thing that has changed up here, over the past two or three years, is that we've got the dredge running where the dredge wasn't running before. And maybe if your environment is so stable and consistent that there has been absolutely no change you could make a circumstantial case. It would be expensive, it would be tedious. I would worry about the variation in such things as the peregrine falcon, because they are flying all over the place, eating here today and there tomorrow, Seals are doing the same thing. That notwithstanding, my experience has been that if anything is really going to **start** showing up, I think probably it is going to show up in the **benthic** organisms. These are the things that are in complete intimate contact with the sediments. We've already discussed the problem with arthropods, is that they shed their exoskeletons. I would look around for a marine **polychaete**, a deposit feeding **bivalve** if you have some of those. Lay out some sort of a grid. There are models which can predict this. You can go in and get baseline data which I think you should do. But more importantly, find out where the plume is going to go and where the material is going to settle during operations. There are models that will tell you this. You are going to have to pick a reference population that is not affected by the material from the operation. I would suggest gradient. In other words, if the predominant deposition of material following discharge is over a 1 km stretch to the southeast, then that is where I would align my sampling transect, southeast or west to get any gradients that would hopefully give you an indication of cause and effect. You should have higher concentrations of whatever you are worried about near the dredge than away from the dredge, unless the guys just clam up. They may clam up for a while in the immediate area, but they will open, and they will get exposed. You compare this to animals that are not being exposed or only moderately **exposed** and go from there. Of course then there is the matter of the criteria, how much is too much, or when have you had enough? In the shellfish, and I don't have the answer to that, that is a local, I guess, societal decision as to whether the animals go to two times the level of background or four times or 1.5 or wherever, you get concerned. Then, as follow up after the dredge has gone through, because time-concentration relationships are important, you don't stop there. You ought to continue to look at them, assuming the animals pick something up. But if they pick something up, keep looking at them and see how long it takes for them to get rid of it. It is one thing if they pick it up and they stay at an elevated level for five years, where animals will be eating them for the next five years. It is something else if they pick it up in the **course** of the passage of the plume of the dredge and lose it in ten days where because of all the hammering and banging and disturbance, no animals are apt to be out there to eat them. So if they pick it up and get rid of it, and nobody is going to eat them while they have got it, again you don't have a problem.

Emerson: Probably some of those are your thoughts too, Dave?

Hansen, David: A variety of thoughts.

Emerson: We might not be seeing immediately some real significant effects here. One of the concerns, probably the most difficult thing to determine, is long-term trends, and possible degradation. I think that the key in our discussion of monitoring concepts is always what kind of trends may be occurring here in the environment. And, unfortunately, that takes some time, so you **probably** would be streamlining the program, try to measure that based on time and money. Has that been a problem or concern in previous monitoring exercises?

Hansen, David: It has to be a concern in an operation that is going to be occurring over a long period of time. If the operation is short, then maybe long-term problems aren't as an **important** issue as they are for this dredging operation or discharges from a pipe. It is important to understand a long-term risk. Particularly we know with mercury, the risks are long-term exposure and reproductive effects. So the long-term issues are important in this particular case.

: I think so. I think in the **EIS** we assume that dredging would take place over a 15-year period.

Wright: You've got a moving target, it is not a point source that will sit here and keep doing its thing. I don't know how fast it will move. Obviously it is not clipping along at 15 or 20 kn. It is creeping along, but as it creeps, whatever it is doing will advance with it. And whatever it was doing will recover behind it, because

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the influence, as it vanishes over the horizon or into the sunset, the influence will become further removed. So you will have a localized effect.

_: **Well**, a different type of effect. It may not just because it has left the area, You have had the disturbance in sediments but that doesn't mean that there is no longer an effect, In this situation, we are looking at an increase in oxidation of mercury, **whatever**; if you stir up sediments that are down to 7 m, just because the dredging took place two months earlier doesn't mean that there are no longer any residual effects.

_: They will revert back to their original physical condition.

Wright: But if is the physical-chemical things that control the **bioaccumulation** and they will revert back in terms of hours to days, back to the physical condition and chemical condition. We saw that in the Field Verification Program where we dumped contaminated material and...

_: ...**eventually**, if you have **methylmercury**, it is going to be picked up by some critters within that time frame...

Wright: Yes, but it is picked up but the signal immediately goes back down because where **it** is coming from has reverted back to the original physical,..., what we will get, we'll get rapid oxidation...

: Are you talking about a signal in the sediments or...

Wright: No, in the animals, the signal in the animals, You get a quick pulse and then that is it.

_: Didn't the dredge stay in about the same 60 acre area for an entire summer or maybe moved once or twice a summer. They are not moving very much. It is within one season.

_: I guess the thing is you have a signal in the **critters**, but you are dealing with a mobile population, so it is not like you have something that picks it up initially and that is all the further it goes,

Wright: No, I am more concerned with a **sessile** population than a mobile population.

_. No, but like you were saying, you have the signal going up and then it goes back down...

Wright: Those were in caged animals, right by...

_: So you are not having something eating that in the process. In the real environment you are having a signal going down in one organism, that may be, but if that organism is picked up by another higher **trophic** level organism, the signal doesn't end. When you are looking at the ecosystem, you don't have just this dip and that is it, the mercury is gone from the system, it is not,

Emerson: In other words, that burdened organism gets consumed before it gets a chance to **depurate**.

Wright: That is a possibility.

_: And so you can't necessarily say that it is no longer having an effect after it's peaked and gone down.

Wright: You just might want to condition your monitoring a little **bit** by doing a radical operation here, going out there and getting some sediment, and bring them back and see if anything **bioaccumulates**.

_: That is our main concern, I think with mercury.

Wright: With mercury. Bring it back to the lab and do some **bioassays** and we already have evidence that it is not in the animals out there, but remember they are living up near the surface, get a 7 m core or several

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and composite them or do whatever you want. Expose it to some animals and if it doesn't bioaccumulate...

Eisler: We don't have any evidence that sessile organisms living there bioaccumulate...

Wright: Yes we do. There is evidence in here that they do not.

Irvine: Most evidence is for king crab and not nearly enough sampling of other organisms and possibly, also, not sampling of some organisms that you might expect to bioaccumulate here, I agree that is still a gap...

Eisler: I agree with you that we should be looking at the sediment dwelling marine polychaetes and perhaps a deposit feeding clam, but I also would like to see the filter feeding bivalve mollusk, if this area is naturally contaminated, not only by anthropogenic sources, then it should be reflected in Hg concentrations in sessile organisms.

Hansen, David: If marine mammals have high levels, they have to be picking it up somewhere from natural sources.

Eisler: That is right. From natural sources. I don't know what we can do in a situation like that. But if the organism is the ultimate arbiter, and there are a number of factors that might be exacerbating or mitigating mercury accumulation, then the organism should reflect it. So I think that you have to separate baseline from monitoring. If you find, based on what is in the water column, elevated levels of mercury in let's say filter feeding bivalve mollusks, that is the baseline. If that level is sufficiently high where it might pose a risk to sensitive species of waterfowl or furbearers, non-pinnipeds that consume it, that is something that has to be taken into consideration. And then you might want to find out the impact of the dredging operation on top of this total initial burden. You may find that the organism has relatively low levels of mercury, in which case you could probably proceed with a dredging operation and monitoring. But if it has elevated levels aside from consternation, well what does one do? This is a decision that has to be made by the policy makers, we can only advise, not necessarily consent.

Hansen, David: There are two separate items that we need to address. First, are inadequacies associated with some of your background characterization of organisms, water, etc. Dr. Marsh has talked about one component, the human health monitoring, and recommended hair concentration monitoring more than human epidemiology studies. Tony Scheuhammer recommended monitoring of bird feathers. Contaminant concentrations in indigenous fauna, particularly focusing on the benthos, need more attention. All of these are very important and should be done. Whether they can be justified effectively as part of the monitoring plan for the dredging operation, I don't know, But they seem to be items that must be done before we have a sense of risks associated with mercury in Norton Sound.

Additional emphasis must be placed on the water monitoring nemesis that has led us all here today. As we heard in the first day presentation, there are great difficulties in adequately characterizing water concentrations of mercury. It would be worthwhile to spend some additional energies to confirm that background mercury concentrations in water are accurate. So those four items I think are very important in that category.

Second, there is the dredging operation itself. The concern should be is there a chemical or biological signal from the dredge that is unacceptable to us? Monitoring plans have been implemented with dredging operations to determine this which can serve as examples. Tom Wright has talked about the methodologies. Some are predictive before you dredge. Others monitor while the dredging operation occurs. That is a particularly important topic I think for this group, because the latter approach is the one that probably can be most readily justified as a requirement for the dredger. I guess I can't emphasize enough the need for a multiple-pronged approach on that. It should include chemical analyses and biological assessment as well. It should attempt to provide either positive or negative data relative to direct effects on organisms. It should attempt to address issues of increased biological availability for tissue accumulation. There should be a spatial and a temporal grid associated with it. It is not enough to do a short term testing, there needs to be some long-term monitoring as well. If the dredging operation is NPDES regulated, then the kinds of tests

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that are recognized for **biomonitoring** NPDES discharges should be utilized. There are technical support documents on how you do that, If the concerns have to do with recolonization, monitoring should examine community succession following dredging. If you are writing off the dredging site for five years or ten years, then recolonization studies are unnecessary.

Emerson: We have kind of run out of time, some of you are kind of getting the short end of the pitch here, maybe you can make it up in your summaries, Ron, do you have anything to add?

Eisler: I've said my opinions...

Emerson: Anything left over, Bill, that you want to make a quick statement on?

Fitzgerald: Yes. I wanted to say something more about dealing with **mercury** in the water. We probably don't know what the concentrations of mercury are in **Norton** Sound. They don't necessarily have to be as large as suggested in the document. They could be much lower because **mercury** is continually removed from the water column by a variety of biological and **geochemical** processes. I think, in general, monitoring water is one of the more difficult things to do in terms of assessment because of the very, **very** small changes. You have to do it on a large scale. However, you need the framework," you absolutely need the framework. So you should have reliable data on the mercury distribution and variability possible in Norton Sound. Now if the concentrations were a factor of 100 lower than **the** EIS document indicates you have, then you would have a considerably larger impact. You would want to know what that impact would **be**. It would be important to look at the relationships between concentrations in organisms and the amounts of mercury that you find in the water column, It could be that relatively "small increases of mercury in the water could result in significantly higher concentrations in organisms. Unfortunately, we know very little about that. The technology has improved as we have seen. I think water analyses can be done with high reliability at a reasonable cost. Once you have the protocols in place, the collection of seawater samples and the analyses for mercury can be done quite effectively. There are a number of laboratories that can do that. Not a great number but there are a number of laboratories. So establishing the baseline if you will and then some monitoring scheme, which would include water, I think can be developed and at a reasonable cost. I think that is important information to have. But it is the same problem, I think, as we've pointed out, maybe you have no true reference level.

Emerson: Well, we'll see what kind of questionable level we have, so probably the emphasis you are saying is not pollute the literature with pollution numbers, I guess,

Scheuhammer: Can I make one last comment about what may or may not be going on in the water, and in sediments? I think that one question that might be very well **worth** answering, with regard to the dredging operation specifically is "does the dredging" operation significantly increase the **bioavailability** of mercury?" We know that there is a lot of mercury in those sediments. The question is not whether the dredging operation is going to increase the mercury level in the sediments. It is whether it is going to increase the bioavailability of that mercury, which means does this dredging operation somehow affect the **methylation-demethylation** process in the sediments and in the water column? I think that would be a good area to address.

Wright: That is why I suggested that the first thing to do is bring some sediments back to the lab and take a look at the **bioavailability** up front, Do that right now.

Emerson: Ok, thank you for that good summary.

**COORDINATION TEAM MEETING
THURSDAY, DECEMBER 1, 19\$8**

The following is a verbatim transcript with only slight editing of presentations by and questions and answers among the six speakers,

HEALTH CONCERNS

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As Tim Holder mentioned, his request was to bring the State's perspective on this. It has been a marvelous opportunity for me to be able to work with the presenters over the last two days and to get a whole perspective of what is going on in terms of the relationship to the state and what comes under the category of an environmental health problem, and that's the way these things get categorized, within the State of Alaska, the Department of Environmental Conservation (DEC) is the lead agency for environmental concerns. It is by regulation and statute the Division of Public Health becomes involved primarily at the request of the Department of Environmental Conservation as a consultant; quite often because the DEC doesn't have medical people on staff. We may end up giving a full-blown **epidemiological** investigation. I perceive this situation as quite different from the normal environmental **health-type** activities that at least I have been involved in during the short time I have been with the State of Alaska, because primarily when we go in we are doing an acute episode similar to the sort of things Dr. Marsh was talking about in Iraq and Japan. When we have an acute situation we do a study. That's not the kind of situation we are talking about here at all; it is quite different. The other aspect of the Public Health Division and Department of Health and Human Services is that we have a major concern about the health of the population as a whole and primarily children, young children, newborns, and infants, and have a lot of our resources directed toward programs to ensure that Alaskan children are born healthy and remain so and become healthy adults. Some of the health concerns that have been raised here in the last few days definitely will **impact** on that role that Public Health has in the state. Alaska, in the real broad perspective, has one of the highest infant-mortality rates in the country. We also have relatively high rates of handicapping problems in our children, so we already have a lot of risk factors within our environment that have nothing to do with **mercury** that are contributing to some major health problems in our children, I guess that from what I've heard over the last few days, and from Dr. Marsh in particular, I would say that mercury will be added as an additional risk factor to some of the ones we are already dealing with. When we look and try to localize where those problems are within the state, the high infant mortality and other health problems in children, we generally find them more likely to occur in rural situations rather than in urban areas. This would apply to **Nome**, we are in a rural situation, so we are just adding an additional factor in here, I think. Nome is like a lot of other locations in Alaska in that it has a lot of naturally occurring mercury, and it also has a mining history that has contributed additional mercury to the environment with good and bad housekeeping,

So this is not a new situation. There's a history of mercury in this area, and we need to keep that in focus as well. What is unique about the situation in my perspective is the dredging operation. When I heard 15 years, I was quite surprised and didn't realize that was the length of time proposed. That is a lengthy process. Also, the large population of people living off subsistence so that their general diet is not what we normally would be considering. What we are talking about as far as I can determine is a chronic problem that has been going on for a long time and now potentially may be exacerbated by additional mercury brought into the environment. I don't believe that at this point in time we can predict what is going to happen, I don't think in a chronic situation we know exactly what the effects of small, incremental increases in mercury are going to be; or should there be an acute situation, exactly how that is going to turn out either.

I **totally** agree with the recommendations that have been made by Dr. Marsh and others, that without any background information on what the level of mercury is in the community, we are putting ourselves in a very **difficult** situation later on. To me, this is the most opportune time. Actually, maybe five years ago would have been an even better time, but we can't go backward, so if this kind of study is going to be done or surveyed, it needs to be done now. It appears that it could be done. It would have to be with the cooperation of the Native **Health** Corporation. Whether that also involves input from the Indian Health Service, hospitals, I'm not sure. But within the Division of Public **Health**, there are a lot of cooperative kinds of work that go on between the corporations and the Indian **Health** Service and the State Public Health

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Department. That is not an unusual working situation; in fact, it is a pretty common working situation. I think that there is the possibility of working through that kind of mechanism to get this information. I believe it is really essential to have. It's very important for the people in the community to know and to provide that framework that we have to have to go on with any monitoring program.

From what I've heard, it appears there certainly needs to be **biomonitoring** as well, and I'm not familiar enough with how those things are done and how quickly data files from **biomonitoring** are available. But it seems as though if this were done in a relatively controlled fashion, that this could even form the basis of some sort of an advisory, as far as people who were on subsistence, with respect to increased levels in certain foods that they would be consuming. There are very good data to suggest that you shouldn't mess around with people's diets too much. Telling people that they should entirely change their eating habits has not proven successful in the past. It's difficult to get people to cooperate in changing their diet. It is a very risky thing to do. So I would not recommend that we make that sort of a recommendation to people; that we monitor perhaps the mercury levels in the foods that are being consumed is much more reasonable to me.

I also agree with Dr. Marsh that at this time I don't see that a whole research project is warranted here. I think that would be not only terribly costly but would inconvenience the population. Right now that is not the information that we need to have. From the technical point of view, the analysis of mercury is nasty business that's difficult to do. There are good labs and bad labs out there even in terms of clinical work. My recommendation would be if a monitoring program was put in order, that it would be very well controlled and that the analysis be done in a **laboratory** where you would have full confidence in the information because 5 years or 10 years from now you will want to go back and look at that data, and you certainly do not want to be in the situation where we are saying "we're not so sure, this isn't right, it doesn't mean anything." That definitely shouldn't be the case. These are my remarks at this point, and I will be happy to answer any questions.

QUESTIONS AND DISCUSSION

_: You are talking about getting the breakdown of the monitoring program into a monitoring-baseline versus monitoring of the current dredging operation. Are you proposing some type of state- and native corporation-funded procedure here to evaluate the Nome community in general, which has been affected by the problem of mercury since 1898? The report would come out as a separate report that would have no connection with the current dredging operation. Is that correct?

Kelley: I haven't gotten that far down the bureaucratic trail. As a matter of fact, it was interesting to sit here for the last couple of days and see people jockey **about** where their responsibilities are; and I feel right at home with that jockeying, because that is exactly where I am too. I don't know at this point where the funding would come from. I wish I did. But I don't. I can see the mechanism of a cooperative situation. When you are talking about medical information involving people in a small community, you need to be sure that information is being properly handled. In Nome, as far as I can see, the Native Health Corporation and the Health Services in the community are the places to go to make sure that the information is being properly taken care of and archived. There are a lot of ramifications involved in medical information.

Giordano: *It is not MMS's position; we do not have a team of medical doctors, and we do not conduct medical procedures, and we are not staffed to analyze **the** procedures. I just want to make sure this is independent and has nothing to do with the E/S. The results could be incorporated into the **EIS** but have nothing to do with the **EIS** per se because we don't analyze health effects. That's what the Health and Human **Services** for the federal side and state systems are **all** about.*

Kelley: On the other hand, if you ignore this situation. . . .

Giordano: *I'm not saying to ignore this situation. I'm saying to look at it independently as a cause **and** effect. If these tests are done, and God forbid something happens **to** someone in the community, someone*

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could say, "well there is the cause, it's the Bima." This **problem** has been going on for a long time **and** should have been looked at in the past, so it's hard to relate what exists in Nome and what is happening offshore. I'm finding it very hard in my mind to say that this is because of dredging, and it may be years before this thing could be related to dredging.

Kelley: You are right when you are talking about a long-term situation.

Emerson: We covered part of that, and I'm from the same agency. I thought we had kind of a consensus, we may or may not be a part of the base case of that locality. Even though it has been ongoing for a long period of time, it may or may not be a cause and effect relationship; but we wouldn't know that unless we had a base case to work from to even make the connection of cause and effect.

Giordano: I understand that, On this base case and cause and effect, if we saw in the last few days that seals were great carriers of methylmercury, wouldn't it be more realistic to do the entire Alaskan people who depend on seals as a base case and not just the Nome community? Do it as an Alaskan study? Historically, the people on the coastlines trade resources with the people in the interior on the Yukon and Kuskokwim Rivers. The EIS mentions health situations [in relation to] mercury at the mouth of the Kuskokwim and Yukon Rivers; [that people have] high [levels of] mercury. So it might be something that people for 10,000 years have learned in their diet to live with. It might be an ethnic thing that their diet is used to consuming.

Kelley: That's a good point,

Eisler: Seals are not necessarily large carriers of methylmercury. It's true the liver is supposed to have elevated levels of total mercury, but only a very small percentage of that is methylmercury. The rest is, as far as we know, inorganic mercury bound with selenium that, as far as the seal is concerned, is biologically unavailable as a representative hazard to the seal. I don't know what happens when you eat the seal liver, whether that inorganic mercury selenium complex is broken. That's a whole area that I don't believe has been researched adequately.

Anderson: The whole thing hasn't been researched. You don't know about the seal liver. You don't know about the effect of the feathers of the thousands of birds in that area [the] breeding grounds of the birds. The whole Bethel area, thousands of acres, is a federal bird refuge. There is a huge refuge up in between Nome and Kotzebue. We are dealing with all different types of mercury and all different ways mercury gets into the system. If you are dealing with just this dredge and Nome and seal liver and mercury that were there during the high gold mining time, then you are getting too narrow as a public health issue. If you are going to look at it as a public health issue, you need to look at it as a holistic view. Somebody needs to get the base information, and somebody needs to talk about it. How is it affecting this project, how is it affecting other types of things? Maybe the zinc thing up in the Nenana region. How is it affecting the Aleut population? The Tlingit down there eat seal too.

Haynes: Dr. Kelley, at the start of your presentation, you pointed out that DEC is the leading state agency on environmental matters, and it follows that public health gets involved at DEC's request. Your presence today is actually the first involvement there has been by any health-related state agencies in this process. How do we ensure that this continues and that we get regular involvement?

Kelley: I am now on this committee, so there's one. It wasn't too difficult to get me here. I was just invited and I came,

Highsmith: You said that you thought the time was now to begin to assay the mercury content of humans in the food chain. What are the prospects in getting the study started and backed?

Kelley: I really can't tell you. Prior to the last few days I had just a reading knowledge of the draft document, and this is all pretty new information for me. I think the recommendations that are going to come out of this committee are going to have a lot of bearing on this. There are other representatives from the state here too, and they are going to be listening very carefully to the recommendations that have been made. My

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saying that the study needed to be done now should be contrasted with what I didn't say. I think it would be folly to wait five years down the road when you've got all kinds of environmental impacts that have taken place and then all of a sudden someone says, "well gee, we ought to look at the human population". I think it's too late at that point to make any kind of sense out of any information that you would get.

Highsmith: That came up at our meeting in July.

Kelley: Right now, we know more about king crabs than we do about the people in Nome. That's a little scary to me.

Highsmith: Are there other mining communities where mercury was used in the past that we might be able to use for comparison?

Kelley: Well, certainly there are mining communities in the southeast where they have used mercury in the past in the placer mine operations down there. I don't know of any mining community in Alaska that is going to have a dredge in it's vicinity or anything quite as disruptive as that. But certainly there are a lot of other communities where there were tremendous mining operations. In Fairbanks, there was dredging that was quite some time ago, as I understand it. I don't know the processing that was used for the gold, whether they used inorganic mercury in the process. They certainly did in the southeast, tons of it.

Giordano: Do you have any information on acute mercury toxic poisoning? Do you have any information breakdown from the hospitals?

Kelley: The only study I am aware of is the study that was done by the Department of Epidemiology, and this is the "playground study" that has been referred to and the urine samples that were taken there. As I understand it (I was not around at the time), it was just focused on a narrow group of children, primarily there were urine studies done, and it was regarding an exposure to mercury vapor, not methylmercury in foods. It was a rather different situation. It is not routine to do mercury analysis on a routine physical, for instance. I would be very surprised if just the regular health records that are maintained at the hospital would have much information about mercury, I don't believe that there is any occupational activity going on where the state or federal Occupational Safety and Health Administration (OSHA) people would require any monitoring. I may be wrong, but there have been extraction operations going on in Nome in the past, and I don't know if those are OSHA controlled or not. That's another place to look for health data, I think we are really in a black hole here, and we really don't know.

Giordano: I'm thinking of an incidence of death.

Emerson: Is there any reason they just looked at the urine?

Kelley: It was because of the type of exposure.

Yoesting: I was going to suggest that if it ends up that the Coordination Team, as a result of this workshop, determines that these human health studies are really important, that perhaps they write a recommendation to the Governor and Secretary of Interior stating that it's an important concern. It's almost like there are so many individual agencies and people concerned but no one knows where to go.

Kelley: That's probably a good way to go. The health care system in Alaska is a very convoluted one because of all the different players involved: the private practitioners, the state, the Native Health Corporation, and the federal presence. You're right, it's a very complicated system in which to make anything happen. It is driven very honestly by some politics. Whether that kind of a letter would have an effect or not, I don't know. I think it is important for the native population to feel that there is a need to look at this question too, I don't know if they are fully convinced at this point whether that's the case or not. I think that they need to be very much involved in this process. It's absolutely important.

Rusanowski: I'd like to make a comment on going back to what Tony brought up. If we put this in a historical perspective, what we see so far in these couple of days is a considerable concern for regional

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or localized mercury **levels that** might be above average in the population in **Nome**. What we are dealing with is an area that has had a long history of mining. If we look at the EPA data that was generated on the "playground study," we are looking **at** onshore **contamination** of several parts per million to tens and twenties and sometimes higher parts per million in existing onshore materials. These are the soils **that** people walk on and drive through. **If** we go to the beaches **of** Nome we know there's high **mercury on** the beaches, that you can take a penny and bury it in the sand and come back and find it covered with mercury. These beaches the kids play on and people drive up and down, people fish from the shore. There is a whole variety of activities that go on. When the wind blows, the dust is picked up and the dust is carried **all** around, and it has whatever associated mercury that is with it. That is the **existing** environment. When we move three miles offshore and start disturbing the natural materials that have been deposited by a runoff in glaciers or whatever that have some level of mercury in them, how are we going to make the connection between what might become available from that operation and what **the** existing population is exposed to just by physically residing in the Nome area? I think it is important in the **context** of this **EIS** and this type of an operation that that be clear. If it is not, perhaps what we have to do is pin the **tail** on a different donkey. **It's** not that it's not important, not that it shouldn't be looked at, but perhaps this vehicle is the wrong one.

Kelley: Are you suggesting that it wouldn't be worthwhile to do this kind of a baseline study?

Rusanowski: Not at all, I'm just suggesting that in the context of looking at offshore dredging projects in the E/S, it doesn't make a whole lot of sense **unless** there is some relationship to the dredging. **I** think the natural environment is going to have a far greater effect than anything you could ever possibly conceive of from offshore. So if you were looking at a mercury problem offshore, you would look at something very close to the operation as these other gentleman here **said**. Look at the **benthos**. If you don't see anything in the **benthos**, how is it ever going to get back to the people? You've got to see it somewhere, so **look** right at the source, and by looking at the human health and **relating** it to the dredging project, **I** don't see a cause and effect relationship even remotely being established unless **I** can show it first in something close at hand. What we are addressing here is an ongoing historical problem. Mercury is in the environment and put there by man and put there by nature, and people by choice are living there and raking their families there, so what we are concerned with is that population is at a greater risk than you or I in Anchorage. That's not an issue related to the dredging operation or **this EIS**. That's a different type of issue. **I'm** not saying the studies aren't needed or warranted, **I'm** just saying they ought to be done in a different context than what we are addressing here.

Kelley: I think that the baseline health study is just part of everything discussed here in terms of biological monitoring because the link is through the food chain. The fact that, I think you mentioned that the diet of the native Alaskans in that area is 13 times greater in the acceptable amounts of mercury in fish in the seafood, does create a plausible link to the **biomonitoring**. I'm not saying that you would do only this. I'm saying this is one **part** of the whole monitoring program that needs to be done. I think it's important to be done and not done after the fact, when just by happen-stance or whatever there are two children with cerebral palsy that turn up in Nome five years from now and everybody says, "what happened'?. This is an unusual situation, and they will point the finger at the dredge anyway. You won't have the background information, and everybody is going to be hanging out there to dry.

MacLean: I'm not sure **I** disagree with everything that Paul said, but a couple of items sort of concern me a little bit. The problem we are experiencing now is relatively new. Our understanding of it is relatively new. Not everyone that is living in Nome is aware of this problem; and if they were, how many of them would actually choose to continue living there? They may very well move, but there is also a segment of the population that cannot move. They just don't have the economic resources. So to put it in terms of there's a problem there, the people know what the problem is, and they choose to live there and accept that problem may not be 100 percent on target. **I'm** just a little concerned that what we are hearing is it is real difficult to pinpoint what the problem actually is. We are stumbling around in the dark trying to figure that out. **I** get real uncomfortable when I start hearing folks say, well, we are not **really** sure that there is a real problem here; and there's an historical event that has been around for a while, and if we had a few more percentage points of this it **wouldn't** be a problem. It's so difficult to measure the assumption, there isn't a problem, and we don't accept **that** very **readily**. **I** think it should be looked at in greater detail. The

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baseline information is not there from just what I've heard in the brief time I have been here at this session. We have to generate that baseline data. What I'm hearing from MMS is, it's not our problem; and I wasn't here for the other two days so I couldn't hear everyone else say it's not our problem. It seems to me the whole purpose of the EIS is to prepare a document that says this is in the best interest of the national government to have this sale, and right now we don't have the information to say that. There are spillover effects. I think the federal government owes us a responsibility to take into account what happens on federal lands and on federal waters and the people that live adjacent to them.

Haynes: I think there's an even broader concern from the state that not only do we have a case where there is a proposed offshore mining sale, there is a mining operation currently underway off the coast of Nome. Who knows how many more may get underway over time if this sale proceeds? We see the same thing on the North Slope with oil and gas lease sales. We see isolated attention focused on the individual sale, individual activity, and nobody looking at the cumulative effects over time of the series of activities that affect the environment, that have an effect on the economy of northern Alaska, and that may be having some long-term effects. But there has not been a real interest that we have found on the part of the state or the federal government to recognize, to acknowledge that there are cumulative effects associated with a series of individual activities over time. Those are difficult to measure, but to ignore them causes us at some point down the road to really be up against the wall based on potentially some serious problems that we don't know anything about. It seems very important that we try to get some type of baseline established, even if it isn't the baseline that we would like to have for Nome in 1890. If we don't have something to measure change against, how can we say good things are happening or bad things are happening? Are there some mechanisms, Dr. Kelley, that you see in the state that we could use to seek out funding sources to do a baseline study? How would you envision something being done if you wanted to do a human health baseline study? What would be a good scenario for pursuing that?

Kelley: These kinds of studies are usually done cooperatively (as I mentioned before) through the local medical care people, be they federal, state, or whoever, You need to have a plan of exactly what it is that you want to determine. Who would be your target population? You'll be hearing a lot more about this from Dr. Marsh if you haven't already heard some of his comments. He has some excellent ideas about this; he listed peak populations who are at risk and not at risk. His recommendation has been to do mercury analysis of hair, which is relatively noninvasive. The samples can be collected [with reasonable ease]. They can be stored after being analyzed so you can have some historical information if you need to go back to it, I think if you did both the native Alaskan and non-native Alaskan population in that area, you would probably then have some control on subsistence versus nonsubsistence diet that would be important to have. As far as the mechanism for using the state resources, probably the Division of Public Health would be the division that would be the lead working with the medical community. Generally speaking, when these are done, they are usually run through our section of epidemiology because that is where we have most of our physicians and nurses who work with the local public health nurse and local providers to collect samples and arrange for them to be shipped out and to get the data together and analyzed.

Meacham: Tim, I don't have the benefit of the last few days. The Doctor began her discussion by saying the folks in that general Nome area live off subsistence, which leads me to a list of questions: 1) What percent of the food they ingest comes from subsistence? What part of their diet is indeed from subsistence? 2) Of that part, which part would be marine resources? What part of the marine resources are indigenous to the area? They would be there for a lengthy feeding time.

Holder: I think those questions came up more or less in the previous two days. As far as we know, good studies on this don't exist.

Armstrong: We don't have any good data, I believe, on diets on people in Nome. We have some for Shaktoolik. I think what is important is that while we do not have exact data on people in Nome, we do know that levels of mercury of people who live in the Yukon/Kuskokwim area are higher than people who live in interior Alaska or Anchorage, significantly higher, and high enough according to Dr. Marsh to create very low levels of effects on fetuses. In this particular study that was done, this was linked directly to the consumption of seal and seal oil. They found that the more seal and seal oil the people ate, the higher their levels of mercury were. That's where the concern has come from. It hasn't been just from what we

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know about **Nome**. We really need to know more.

Emerson: Let's say the MMS monitoring program is able to show no real effects from the dredging activity in terms of the marine environment and in terms of food resources. That's hard to say because there may be long-term trends; the immediate answer probably isn't the answer. Let's say we limited our environmental assessment to the marina resources and marine environment, which is pretty clearly our responsibility. The grey zone seems to be this top predatory man that lives in Nome. Do you think from your experience here in this brief time that your agency sees the responsibility? Maybe there was not an awareness of potential concern prior to this time.

Kelley: That's a possibility. I don't know at this point.

Emerson: Isn't that kind of what your other charges have been? Where there is a potential concern, that's where you focus your resources.

Kelley: The state's resources as far as environmental health work are quite limited; to this point they have pretty much been focused on acute responses. They haven't been, to my knowledge, involved in long-term monitoring programs for environmental things, not health affects, There is a distinction. I think this situation is unique enough that the state needs to take a good look at what their responsibility would be in this situation.

Armstrong: I would like to suggest when the state starts looking at that, and I assume it will be an issue, that someone talk to people in Canada to see what they've done. Their program that Dr. Marsh has talked about might provide some good ideas. Once you do some baseline [studies], you don't need to do an ongoing long-term monitoring program, just an informational type of program of making sure people are aware of the potential problem.

Kelley: That's a good point.

Wright: I still fail to see the real connection with the proposed action here. On the other hand, I don't think what we are talking about is a prohibitively expensive operation; getting hair, which is a noninvasive procedure, doesn't need to be refrigerated, and you don't have to dissect someone to get it, it's easy to handle. What you are basically talking about is just to get money through an administrative action. This is compared to running organics; we are talking pennies as opposed to dollars, and I've kind of come to the feeling that I see no connection with the mining. You people have a problem, and I don't think I would like to live in Nome. (I will say where I come we are number one on infant mortality rate.) You might consider seal whiskers; they intrigue me. Even though one doesn't know how fast they grow, that could be empirically determined. You could watch them grow in the zoo. If you are going to collect hair from the folks who are getting the seals, they must be able to get the livers from the seals, and have them get the whiskers from the seals and shave them and send them in too. I don't see any connection with the mining on this, but something might need to be done about this up here, I don't know what you do if you look to the North Slope and everybody is the same everywhere despite the levels in the sediments or despite the levels in the seals. What does it cost these days for AA per sample as compared to priority pollutants or organics?

Marsh: It's a great number of pennies. (Laughter)

Kelley: Mercury would probably be one of the more expensive metals to analyze.

Marsh: It depends on what you would do with the samples. [You need] to have the previous 12 months, which you would need to take into account seasonal differences. You need to analyze a sample of hair about 12 centimeters in length. If you just analyze that as one sample, then you get the mean concentration, an average concentration for that year. But you would not get data about seasonal differences, so you would be charged the cost of one analysis. But it would be much better to divide that hair into small segments of 1 centimeter or less, and then with 1-centimeter segments, [for] each sample you would have to pay for 12 analyses instead of 1. I can't give you a dollar figure. Like everything else, if you were to

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contract with a lab for a sizable number, it would be less than for a few, but it's not outrageously expensive. We are talking about gold mining here that is going to bring in 200 million dollars or more, so the hair sampling won't cost that much.

Kelley: And the people are worth it.

COORDINATION TEAM MEETING

INTRODUCTION

At 1:15 p.m., Bob Brock called the Coordination Team meeting to order. Bob apologized for the absence of Irv Palmer, who [was] at a meeting in Washington, D. C., and thus unable to attend. He explained that the Coordination Team requested the input of human health medical expertise to the Environmental Impact Statement (EIS) process. MMS found that expertise and then decided to find experts outside MMS on the various aspects of mercury in the marine environment. As a result, the workshop was organized by MMS staff, and now the Coordination Team has an opportunity to hear these experts give summaries of their talks and to ask questions of each of them. Bob then introduced Patty Bielawski with the State Division of Governmental Coordination, who is taking over for Barb Sheinberg.

Patty Bielawski expressed appreciation to MMS for organizing the workshop and for allowing others, in addition to the MMS authors, to attend the workshop. They benefited a great deal from this opportunity. She also expressed the state's appreciation for MMS establishment of the Coordination Team for the Norton Sound Lease Sale. It will be of benefit when the state reviews permits and leases for mining in state waters in the Norton Sound area. Also, the Coordination Team concept may be a good model for state-federal cooperation on other issues in other parts of the state. She has received questions about the role of the state in baseline studies of human health aspects of potential mercury contamination. At this time, she does not have any answers, but she will be checking into what role the state may play and will be working with MMS on this issue. Patty apologized for Bob Grogan's absence at this meeting. He had a long-standing commitment to attend a Coastal Policy Council meeting in Sitka.

Bob Brock cautioned that Coordination Team members should not get bogged down in the question of which part of the bureaucracy is responsible for which issues. It is better to focus on the substantive issues, then a determination can be made later as to which part of the bureaucracy is responsible. Bob then introduced Judy Gottlieb, who is moderating the afternoon session with the invited speakers.

Judy Gottlieb introduced each of the following six speakers as they took their turn and explained that each of the six speakers would give a 5- to 10-minute summary of their talk given during the workshop, and then the session would be opened to questions and answers.

SUMMARY PRESENTATIONS TO THE COORDINATION TEAM

MERCURY EFFECTS ON HUMANS

SUMMARY PRESENTATION TO THE COORDINATION TEAM

David O. Marsh, M.D.

The most toxic form of mercury for humans is the **methylmercury** form. In Iraq and Japan's incidents of mercury poisoning, the most crucial organ is the brain of the fetus. The fetus is much more susceptible to the adverse effects of mercury than adults or children. The following threshold level for effect is very preliminary and needs to be substantiated. In Iraq, the concentration of mercury in the hair of pregnant women was about 15 to 20 ppm. This is for a low-level effect on the fetus in the form of psychomotor retardation, that is, slow to walk and talk, and certainly not death or some sort of massive insult. In the Nome region and along the coast where Eskimo people have a high consumption of seafood (such as fish, shellfish, and marine mammals) that contains **methylmercury**, the mercury levels in humans are probably higher, although we have no direct studies in the Nome region. Seal liver has high levels of **mercury**; while most of it is not **methylmercury**, the **methylmercury** in seal liver is in relatively high levels. Various indicators of mercury in the human body are available, but a very good one is hair.

It is very likely that some Eskimo women of childbearing age in the Nome region right now are at or close to the threshold level. Years ago, when the Food and Drug Administration (FDA) and the World Health Organization (WHO) established threshold levels for adults, a safety factor of 10 was added in order to protect the most vulnerable, that is, the fetus. If we hold an effect level for the fetus of 15 or 20 or 25 or 30, and we think that some Eskimo women of childbearing age may be at that level, then there is no room for a safety factor.

Dr. Kelley made a good point this morning when she said that we may know more about king crab than humans. I don't think we have any human baseline data at all for levels of **methylmercury** for residents in Nome. There is one cryptic reference to mercury in women not too far away, and those levels are equivalent to mercury hair levels with an average of 8 ppm. **With** an average of 8, you can be sure that some women are way above 8, perhaps double that. Those with the peak levels are at or near the threshold, leaving no room for a safety factor. We're in great need of baseline human data.

Furthermore, there is hardly any data on the amount of mercury in seafood consumed. Regulatory agencies like to talk in terms of mercury concentration without reference to the amount. Of course, what matters is the total amount of methylmercury consumed. We need to know something about the concentration of food and the weight of food in the diet. But we don't have this baseline information for the human population in Nome. Some suggestions I would make for collection of baseline data is to collect hair from women of childbearing age in the Nome community, concentrating on Eskimo women, but taking samples from other women for comparison. Although it's not at all related to the dredging, there would be equal reason to have sampling of other Eskimo communities along the coast. That would give some idea of how close to risk levels we are. The hair samples should be analyzed **segmentally**. Hair grows at just over 1 centimeter per month. The hair represents the calendar of past exposure to **methylmercury**, so the hair strands [could] be analyzed in **short** segments; for example, 1-centimeter segments **by** atomic absorption. Because of seasonal variables, what we need is a hair sample 12 centimeters long, then a graph [that] shows the seasonal levels. If all 12 centimeters were analyzed as one, it would not show the peak seasonal level. That's the most crucial part of the data. But we would need further information about the concentration levels of mercury in seafood and something about the amounts consumed. I'm not suggesting a full dietary survey. I've done such surveys, and you can't get dietary data easily. You can in the most crude way correlate the number of seafood meals per week with mercury levels. I understand in the Eskimo community [the people] sit around the table and have seal and the other seafood goodies, and people eat whatever they want from that mass of food. This makes it difficult to measure the weights. The baseline data can then be used to compare to monitoring data.

What I'm talking about is in many ways not related to the dredging operation at all. I know many of you are concerned only about the dredging effects on the food web. This is something I think should be considered with or without the dredging. However, in relation to the dredging, there will be no way you can detect the changes unless you have the baseline data. It's interesting that with so many disciplines represented here,

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I have yet to meet an attorney. (Laughter) Physicians get a little paranoid about attorneys. Looking ahead, one reason to get the baseline data apart from all the scientific reasons is someone suing. A woman delivering a child that has some symptoms may say, "well, you didn't tell me about that dredge". But with the baseline, you could have proof that the dredge did not have any effect on the child's illness.

Education on this issue is difficult, Canadians have had some experience with Inuit and Cree Indian populations that consume large amounts of seafood, Posters in the Cree language read "Fish Poisoning," and that was their word for methylmercury effects, Many people thought this was terrible. While methylmercury may have adverse effects, at the same time fish is an excellent food. It's difficult to balance these two, especially when we do not know the exact levels at which we have effects on the fetus, But there is probably some effect if a pregnant woman eats an enormous amount of seafood, We're not talking about crippling the child, but there could be some diminution of the child's intelligence. This is especially important when talking about an entire community [that] consumes much seafood.

Lots of literature shows that the seafood reduces the chances of myocardial infarction, peripheral vascular disease, and so on, [it's a very good muscle-developing protein. You don't want to wreck traditional lifestyle or make people fearful of all seafood. If surveys show high levels of mercury, determining a cutoff point is difficult, it would not be desirable to change the dietary habits enormously. Canadians have gone through this, The hunting-fishing-gathering family should not be suddenly replaced with the family going only to the store. If a woman has a high mercury level, then perhaps the best idea is to teach the woman to substitute low-mercury seafood for high-mercury seafood. King crab is at extremely low levels, seal liver is at high levels, I don't at this point want to say what the level should be. But I would venture to say that if the hair level shows at 10, then the woman should substitute low-level mercury seafood for high level. FDA and WHO levels have been at 6 ppm for the last 20 years. I suggest a level above that. A high proportion of Eskimo women are probably above 6.

I have not really talked about the effects of the dredging, but I will let others talk about that,

QUESTIONS AND DISCUSSION

Anderson: At the July CT meeting, mercury was talked about, and for the next two days on the radio all we heard about was that mercury is a problem, but not much else about the dredging. I totally respect the fact that these experts have come to share their information, but I am very concerned about the media carrying this information too far. I think the information on this issue needs to be handled with care. It doesn't need to be blasted on the media that these unique people are being treated in a unique way. We've had orphanages and tuberculosis sanitariums. Be careful when the press releases go out.

McVee: How would you respond to a series of studies being done along the coast south of Nome and up the Kuskokwim River where naturally occurring cinnabar is known to occur?

Marsh: My guess is that in coastal areas, hair concentrations would be high,

Wright: Let's be careful about the term "sea food." I don't consider seals, walruses, and whales as seafood. They're mammals, just like cows.

Marsh: I use the term literally; that is, seafood is any food coming from the sea, from shellfish to fish to carnivorous fish to seals, walruses, and an occasional whale, This is what I meant by seafood.

Highsmith: If people are close to threshold levels, then monitoring the effects is critical, because a slight increase in mercury could push some over the threshold,

Marsh: I've tried to impress that the threshold level is hard to determine, but certainly the old safety factor is not valid, I would be surprised if a safety factor of twofold [of the threshold level] is possible. Psychological testing is the most sensitive, but even that would probably not show all the effects. So some

Marsh: *Summary Presentation*

small safety factor is desirable. The general principle of what you're saying, I agree with. If the dredging should increase the levels of mercury in the food web, this could result in an elevated level for a pregnant mother to threshold. Also, it could result in the frequency of this affect. The risk is a small risk, say 5 percent, and it could push up this same small risk to 7, 8, or 10 percent. It would be crucial for the occasional individual.

Highsmith: Is there any way of preparing the food that could reduce the risk?

Marsh: No, no one has found a method of preparation that reduces the level.

Highsmith: Is this concentration in marine fish in Nome?

Marsh: There's **methylmercury** in all fish. The concentration depends on whether they are at the top or the bottom of the food web. If it's a carnivorous or **piscivorous** fish at the top of the food chain, shark or swordfish, the concentrations tend to be high. **Within** the species, the older and longer the fish, the higher the concentration, Freshwater fish, in Canada, for instance pike, have levels as high as any ocean fish, 6 to 8 ppm, although this is in part due to contamination. This is a concern among native peoples in Canada.

Highsmith: Does it concentrate in certain tissues?

Marsh: It's equally distributed through the muscle,

U.S. ENVIRONMENTAL PROTECTION AGENCY
REGULATIONS AND CRITERIA FOR MERCURY IN WATER
SUMMARY PRESENTATION TO THE COORDINATION TEAM

David J. Hansen

I will give a very short summary of toxicological and **bioaccumulative** characteristics of mercury as detailed in EPA's "water quality criteria" document. The acute toxicity of mercury for both freshwater and marine species has been extensively tested. There's been a total of 29 saltwater and 28 freshwater genera tested acutely. For the third of the species that are the most sensitive, invertebrates predominate. These invertebrates include crustaceans, mollusks, and **polychaetes**. The way the EPA uses this acute toxicity data to derive a **Criteria Maximum Concentration (CMC)** is to use a statistical methodology to calculate the slope associated with the **LC50s** for the four most sensitive genera and then using the total number of genera tested to calculate the concentration where 5% of the most sensitive species would reside. In the case of **saltwater** species, the predicted LC50 for that 5-percentile species would be 4.1 **ppb**. This concentration is the Final Acute Value (**FAV**). The CMC is set at half of that, because the difference between the LC50 and the LCO is typically a factor of 2. The CMC is designed to protect from acute lethal effects most of the species most of the time but not all of the species **all** of the time.

The chronic toxicity data are less voluminous. They have some unique features. Fishes are much more chronically sensitive to mercury than invertebrates. Data from life-cycle tests demonstrate that reproduction is much more sensitive than survival or growth. In early life-stage tests, mercury affects survival and causes deformities. Typically, with most chemicals, criteria continuous concentrations are derived using the relationship between acute and chronic toxicity, which is reasonably constant. Mercury is unique among all the chemicals we've worked with to **derive** criteria. Fishes are least sensitive acutely and most sensitive to chronic effects.

Mercury **bioaccumulates** in marine organisms because the uptake rate is rapid and the **deposition** rate - the ability of organisms to flush mercury from the body - is slow. Deposition half life is from 2 1/2 to 3 years in studies with brook trout, and most of that dilution of concentration is due to growth. Decrease in temperature **results** in a decrease in uptake, deposition, and **bioconcentration**. Mercury is accumulated from water and from food chain transfer. Both contribute to the total body burden associated with exposed fish and invertebrates. Crustaceans do not particularly accumulate mercury, whereas fishes **bioconcentrate** inorganic mercury and **methylmercury** very affectively. Concentrations in organisms range from 10 to 80,000 times the concentration in water. **Bioaccumulation** of mercury is more **important than** chronic toxicity in deriving the criterion.

Given the FDA action level of 1 ppm, the projected concentration in the water (based on accumulation of mercury in oysters) that would be acceptable is 0.025 **µg/l**. That is the Final Residue Value (**FRV**) and the Criteria Continuous Concentration (CCC) that is quoted in the **EIS**. Mercury's form in the environment is not always easily predicted. The criterion statement in the water quality criteria document is identical to essentially all other criteria statements in other water quality **criteria** documents in that it has a chronic number (CCC); an acute number (**CMC**) based on acute toxicity; an averaging period of either 1 hour or 4 days; and a 3-year return frequency. But with mercury, the criterion statement is unique. The form that mercury has in the environment may vary from site to site, and we are concerned about residue limits on **methylmercury** only. Therefore, if the CCC of 25 parts per trillion is exceeded, then monitoring of local populations of seafood organisms for **methylmercury** is required. If the FDA action levels are exceeded, you've exceeded the criteria. The final criterion is not the water concentration, it is exceedence of the FDA action level. This is important.

Finally, the EPA recognizes that there may be site-specific conditions that will require the national number be modified. The local indigenous populations of organisms may be either more sensitive or more resistant to the chemicals than the organisms tested in the national database; or water **quality** factors may affect the form or **bioavailability** of contaminants. In the case of the data we've seen for the **EIS** that it's clear, at least to me, that this is happening here. The concentrations in the water measured in total mercury exceed the CCC, but with limited monitoring data, mostly concentrated on just a few species and mostly on the king

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crab, the FDA action levels are not exceeded.

We've been asked to propose a monitoring plan. I believe the monitoring should consist of two parts. One part should focus on characterization of what the background conditions really are. The EIS does not provide us with enough detailed information to be totally confident that the background conditions have been characterized. These include the water concentrations; Dr. Fitzgerald will talk about the sources of error in previous measurements, Concentrations in local biota should be expanded, particularly to include benthic species that are filter or deposit feeders because mercury concentrations are highest in the sediment. Concentrations in humans and wildlife also need to be characterized as part of the background analysis. As far as the dredging operation itself, our experience with monitoring programs of dredging operations points out the need to not just focus on chemical concentrations but to also include biological testing, These two types of monitoring should be considered spatially (around the dredge) as well as temporally designed, Both short- and long-term indications of this dredging operation should be measured.

QUESTIONS AND DISCUSSION

Anderson: The preliminary draft EIS gave the nationwide criteria for mercury. It seemed that some other nation gave instead of chronic 0.025, it was 0.5. How come?

Hansen, David: I can't comment on the 0.5. Because it was in the table in the EIS; the EIS doesn't show how it was derived, We know from research projects that biological effects can occur in chronic exposure to methylmercury at concentrations at tens of parts per trillion. That was seen with *Daphnia* at 40 µg/l and with brook trout at less than 100 µg/l. We know that tissue accumulation will occur at concentrations much less than the 0.5 µg/l that would exceed FDA action levels and might affect marketability, I think the 0.5 µg/l value would not be protective.

Gottlieb: I have a question about site-specific criteria. Could you tell us a little about what that is?

Hansen, David: The EPA has a document, part of the technical support documents for the water quality-based approach to effluent permitting, that details three methodologies for deriving site-specific concentration criteria that are different from national criteria, The first one examines species-sensitivity questions. The second one examines the effect of water quality on toxicity. The third one examines both of them together. Those methodologies are quite simple, relatively cost-effective, and have been applied at several locations. But the magnitude of change in the national criteria has not been great. In the case of mercury in Norton Sound, concentrations in the local biota could be more rigorously quantified to determine if methylmercury concentrations in fish and shellfish exceed FDA limits. This would be the site-specific procedure most meaningful to this location.

Gottlieb: It might be something the EPA would ask for?

Hansen, David: No, I think perhaps it should be part of the EIS. Maybe it should be included in the monitoring plan. If one is interested in seeing an elevation of contaminant concentrations as a result of dredging, one would want to characterize background a little better, and you could assure yourself you were below effect concentrations by knowing concentrations in organisms.

Emerson: Do you have any help on the 1 ppm FDA action level?

Hansen, David: The aquatic criteria numbers are designed to protect the presence and uses of aquatic life; one of the uses is marketability, another is consumption by wildlife or avian predators. Relative to the aquatic water quality criterion, the FDA action level is not a human health-based number. Those numbers are contained in the 1980 criteria document which lists the human health criterion. This document and its authors should be consulted.

MERCURY TOXICOLOGY IN BIRDS AND MAMMALS

SUMMARY PRESENTATION TO THE COORDINATION TEAM

Anton M. Scheuhammer, Ph.D.

We've had a lot of discussion in the last couple of days, and I think we're starting to reach a consensus of opinion that we have two quite separate issues. First, we have no good data to indicate the present state of affairs with respect to mercury exposure to humans and other animals. Second, we then are asked if a dredging operation will increase, decrease, or not cause any change in the **bioavailability** of mercury and whether this will cause any increased health risk. That is in a sense a separate question. The two could be combined and perhaps should be combined in the following way. Whether you're concerned with question one or question two, you could do a good, integrated monitoring program. We've heard from Dr. Marsh about human health and that some form of monitoring [should] be done to measure the level of exposure to **methylmercury** in the human population. We may extend that and ask what the bigger picture is for the state of the environment in general. That includes top predators in the marine food chain, mammals, and birds; and that's more or less my specialty.

When I refer to mercury, it is **methylmercury** that I mean because this is the form [that] is very efficiently absorbed from diet. It is absorbed essentially 100 percent from the ingested dose, and it is **methylmercury** that **biomagnifies** through the food chains. It is, therefore, **methylmercury** that we should be primarily concerned about.

These are the food chain relationships that **are** known to occur with **methylmercury** accumulation (referring to slide on screen for the audience). What **it** indicates is that top predators in marine or other aquatic food chains are at greatest risk for exposure to **methylmercury**. The major toxic effects of exposure are death, if the exposure is high, and neurological impairment or reproductive impairment. The reproductive impairment, as is true in humans, occurs at very much lower dietary mercury levels than overt neurological toxicity in adults. In many birds and mammals, we know from both field research and controlled laboratory studies that the toxic effects are associated with fairly similar kinds of levels of mercury in tissues; and that's true of a wide range of species. The reproductive effects occur **at** much lower tissue levels than are needed to cause overt neurological problems or mortality. These levels of 5, 6, 7, 8 ppm in liver and kidney are not excessively high levels. They are levels that one might expect to see in a marine environment, particularly one that is associated with a lot of environmental mercury, which is what you apparently have.

As a rule of thumb, we can state reproductive effects occur at levels of mercury in the diet that are about **one-fifth** those required to produce overt toxicity. I say in adult birds, but that occurs in mammals as well. If we want to advise on a monitoring program, the purpose of which is to assess the current state of affairs in terms of mercury accumulation in organisms and then in the future assess whether there is some kind of continuing trend towards an increase, decrease, or steady state, we need to pick out appropriate indicators to use to tell us what the risk of exposure is. One can go out and measure mercury levels in all kinds of dietary **items**. This is **a very** tedious, expensive, and inconvenient type of thing to do, as it is in the case of human exposure. What is better is to find some tissue that is an indicator, an integrator **if** you will, of what the dietary exposure is.

In humans, as you have heard, hair is a good integrator. In the case of mammals, fur, and in birds, feathers serve the same role. We know in the case of **methylmercury** exposure the **endogenous** mercury that accumulates in the feather is very high, whereas exogenous contamination of mercury onto the feather is very low. We also know that leaching of mercury **out** of the feather, once it has accumulated, is typically very low. So mercury is very stable in feathers. **It** also accumulates in feathers in a dose-responsive manner. We know, for example, that if there is an approximate tenfold increase in the dietary mercury levels (that's **methylmercury**), there is approximately a tenfold increase in the mercury that is actually accumulated into the growing of feathers. So this becomes a very useful indicator of dietary consumption at the time the feather is growing. The same can be said of fur of mammals.

The other thing is that there is a much higher level of mercury in the feathers than is present in the diet. There is at least a fourfold-higher mercury level in the feathers than is present in any other tissue. So it becomes a good indicator because it is conveniently measured. You're not having to measure very, very

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low trace levels of mercury when you measure mercury in feathers, The other indicator that can be used, and has been used, is eggs. Mercury concentrates in eggs as a function of the level in the diet. We see in egg albumen a level of about 2.5 ppm mercury when the dietary mercury level is 0.5 ppm. This [goes] up about tenfold when the dietary mercury level increases tenfold. These two indicators are convenient; they're dose-responsive; they can be collected without having to sacrifice the animals involved.

I understand there will likely be a monitoring program instituted for wildlife revolving around the peregrine falcon. This would probably be a good species. The peregrine falcon is a top predator. If it is growing some feathers when it lives and breeds in the area, which I understand it does, then that certainly makes it a good candidate to be included in a monitoring program. What I would like to see as well is some of the prey items, Perhaps some seabirds, eggs of seabirds, that breed in the area, A control population should be included. Perhaps if peregrine falcons are going to be the focus of this monitoring program so far as the wildlife component is concerned, we would like to see the difference between coastal areas and inland areas where the birds are more closely linked to terrestrial food chains rather than aquatic or marine food chains. The basic idea of doing an integrated monitoring program that would include human concerns and other environmental concerns is something you'll hear us repeat again,

QUESTIONS AND DISCUSSION

_: *What sample size would you use for a peregrine falcon?*

Scheuhammer: The sample size depends a lot on the variability inherent in the sample. I don't know what the variability would be. It would depend on how exclusively individual birds were feeding on the same resource base. If you have a number of birds essentially feeding on the same resource base, the variability should be pretty low, If you choose your sample such that you are choosing, for example, a number four primary feather and you know that feather has been grown in that area at that time, that will tend to reduce the variability. Anything over 10, you'd be doing pretty well. A sample of 10 individuals and a sample of another 10 individuals from an inland area. You may be restricted in that you don't have 10 individuals, You have to work with what you've got, Fledglings come into this picture. You could do adults growing feathers in the area during the time they reside there and supplement your sample with fledgling feathers,

THE SIGNIFICANCE OF MERCURY RESIDUES IN MARINE VERTEBRATES SUMMARY PRESENTATION TO THE COORDINATION TEAM

Ronald Eisler, Ph.D.

Most of what I talked on earlier was extracted from the booklet published by the Fish and Wildlife Service (FWS) in April 1987 called "Mercury Hazards to Fish, Wildlife, and Invertebrates." It's a 90-page booklet published for the benefit of the FWS environmental specialists. So it's an informational type of booklet, a review of the literature prepared by research and development for our field people. It's not a criteria document; it does not profess to be an official policy statement of FWS. This document is free. There are other documents on lead and arsenic that were published earlier this year. They are applicable to Norton Sound, I understand. Others are on selenium, chromium, and cadmium.

One of the basic findings from this booklet is that mercury concentrations in marine organisms vary all over the place by many orders of magnitude, both within species and between species. A number of biological and non-biological factors can modify the uptake and retention of mercury by marine organisms, especially vertebrates, and these include age of the organism, the older it gets, the more mercury it accumulates; its position in the food web: if it's a carnivore it has more; if it's a long-lived species like pinniped mammal, it will have higher levels; certainly pollution in the environment affects it; its general health; and its ability to detoxify or otherwise render mercury into some biologically unavailable form such as a mercury-selenium complex.

Let me illustrate. Seals are receiving much attention, In Norton Sound there are four different species of seals, and the maximum levels of total mercury in each species is in the liver, I understand that the seal most commonly consumed in Norton Sound is not one of these four, but it's obvious that the liver levels are extremely high, in some cases, over 100 ppm fresh weight. The mercury seems to concentrate in the liver of seals and birds, unlike fishes and sharks, where it concentrates in the muscle. And in sharks and fishes, it rarely gets over 2 ppm, and most of that is present as methylmercury. [In seals having 100 ppm, the methyl is perhaps 3 or 4 ppm. The EIS gives only methylmercury content.] The rest of the mercury in the seal liver is inorganic mercury, bound up with selenium in some biologically unavailable complex, at least to the host organism. It doesn't seem to represent a health problem to the seals. I do not know what it does when it's fed to another consumer group. I don't know what the digestive enzymes will do to this mercury-selenium complex, Mercury will also complex with arsenic, so here we have a beneficial use of arsenic, which incidentally by itself is an essential trace, whereas mercury has no known beneficial biological function, And of course older individuals of each species have much higher mercury levels.

Mercury, in whatever form that is placed in the environment, whether it's organic or elemental or inorganic such as mercuric or mercurous, can eventually be transformed into methylmercury. Methylmercury is the most toxic chemical species of mercury. This chemical species is the one that causes adverse effects, Inorganic mercury causes harmful effects also, but I would say it's probably about one-tenth or less the effect of methylmercury. All the major poisoning incidents such as Minamata or Iraq, involved methylmercury in large doses over a short period, but this doesn't seem to be the case in Norton Sound. Because relatively innocuous forms of mercury can be transformed by a variety of processes into the comparatively toxic methylmercury species, all forms of mercury in the environment should be considered potentially hazardous,

The methylmercury transformation rate is governed by many factors, including microbial activity, nutrient content, pH, redox, water temperatures, selenium - many variables, In Norton Sound, I don't think there is an adequate baseline level for organisms that are actually present in the environment. Levels in seals are dependent on the rate at which they migrate. Crustaceans such as king crab are poor indicators of any kind of metal contamination because the metal seems to translocate in exoskeleton; and when the animal molts, that's gone, So you might find some king crab that looks relatively clear. It doesn't concentrate in the muscle of crustaceans as it does in fishes or in the liver of birds and mammals.

At this time, it seems that there are reported levels of mercury in the water column in Norton Sound of about 0,3 ppb, or more than an order of a magnitude higher than what the EPA considers adequate for aquatic life protection in its water quality criteria. I haven't seen any verification of those figures in the water column, but it seems that if those levels did exist then they would be reflected in representative sessile organisms,

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and what I consider an appropriate indicator are filter-feeding bivalve mollusks that are actually in the sediment. These would be my first choice and some marine **polychaete** worms second choice, possibly both.

I think it behooves MMS to document satisfactory background levels in Norton Sound, Since the organism is the ultimate arbiter and may not accurately **reflect** what is in this geophysical environment, data on levels in sediments in the water column and in appropriate biological indicators are needed, especially levels of the hazardous methylmercury species.

You may discover that no environmental Hg problem exists at this juncture or you may discover grossly elevated levels of total mercury in your indicator organisms caused by natural mercury contamination. In the latter case, any additional mercury loading should be avoided, if possible.

QUESTIONS AND DISCUSSION

*Highsmith: To what **extent** does mercury concentrate in marine organism in the water column versus the food chain?*

Eisler: In mammals and birds, the diet is definitely the most important route of mercury accumulation. In fish and bivalves, the water column would probably be more important. A lot of mercury, whether it's methyl or inorganic, let's say the methyl, is more soluble in the water column, but the inorganic will quickly come out of the water column and adsorb onto particulate material, and bivalves will usually not filter clear water. It's got to have particulate material, and that's what triggers the pumping action, So the bivalves will act as good integrators. A lot of the small organisms -- **phytoplankton**, zooplankton -- will not actually biologically incorporate the mercury but will adsorb it. It acts as particles in **the** water column, and they may in turn be taken up in the clams, and the clams may act as a food source for higher **trophic** levels. That would be an optimal **bioaccumulator**.

*Highsmith: Do you **know** of any differences between mercury concentrations in the tissue of species of ocean fish as opposed, to nearshore fish?*

Eisler: In any species of the same age, those collected near an industrialized or urbanized area will contain higher mercury levels than those collected from **unimpacted** area, in terms of residues that are considered harmful to some species of aquatic organisms, data on fish are unsatisfactory. The only reputable value that I know is 5 ppm of mercury whole body of brook trout and will result in that animal's death. In terms of migratory species of waterfowl, mostly ducks, values of more than 0.9 ppm of mercury in the egg or 1.1 ppm in the tissue or more than 0.1 ppm in diet, are associated with adverse reproductive effects, In most species of furbearing mammals, any residue in any tissue over 1.1 ppm is associated with an adverse effect. The **pinnipeds**, especially the seals, are exceptions, and total mercury levels in older individual seals of 20 or 20 ppm in the liver are commonly recorded, although it doesn't seem to affect the animal.

I don't know what Hg does to sled dogs, although elevated levels in sled dogs doesn't seem to affect them. Most investigators examine gross parameters such as growth, **survival** and reproduction. Although some of the more subtle effects are more difficult to distinguish. In humans, we are interested in what we are communicating. Symptoms are psychomotive disturbances and important visual constriction shields. These are parameters that are very difficult to measure in the animals of concern.

Highsmith: One reason I ask this question is that salmon feed in the open ocean.

Eisler: There is some evidence that shows that about one-third of the total mercury in the open ocean comes from atmospheric deposition, of mercury vapors, essentially. This has been going on for a long time. There is more mercury in the atmosphere as a result of the burning processes; for example, burning coal. You get more mercury and more selenium too. They may combine. Forest fires will do that, But there was a paper last year that indicated that sometimes perhaps 50 percent of the mercury in the Pacific may

Eisler: Summary Presentation

be contributed to atmospheric deposition.

Fitzgerald: *In some of the open ocean, values are actually larger than inshore values, where there is a great deal of biological activity. The concentration of mercury in the water column may be depressed. Open ocean water values or mercury surface water in the equatorial Pacific are lower than what we have in the Gulf of Alaska. Salmon may encounter higher concentrations because atmospheric deposition is so important. Higher levels may occur in the open ocean because of biological activity. Lead shows a pattern like that. This may involve **biogeochemical** scavenger processes.*

Eisler: It's interesting you mentioned salmon. I worked at the University of Washington College of Fisheries' Hatchery. Before we released chinook salmon, we had to get rid of the **ectoparasites**. At one point we were using **phenylmercuric acetate**, and we had to **watch** the dose very carefully, otherwise you could kill the fish. I wonder how much mercury was taken up at that juncture?

Highsmith: *So that's why we have a mercury problem. (Laughter)*

Emerson: *In this mercury-selenium **complex**, do we have an organic intermediate there?*

Eisler: In mammals, it is generally considered in a 1-to-1 molar ratio. I don't know what form the selenium is in. It's not necessarily negative because this may form a complex cation that might have some anion. It's not just a mercury-selenium tennis ball. There are many things that may gather in on it, and mercury does the same thing with arsenic. That isn't really known. Lead exacerbates the problem. Sometimes the solution to pollution is **multiple** pollution, as in the case of mercury-selenium. Lead would affect a particular biochemical indicator, and mercury and lead together will depress that biochemical indicator even lower at the same enzyme level.

_: *[Is there] something... interfering with **selenium** complex?*

Eisler: I don't know, That's a big area that I think needs research, but I don't know if I'd go as far as Norton Sound.

_: *Are you aware of any study using sea whiskers? Would using liver be preferable?*

Eisler: No, but it was discussed yesterday at great length. Almost all metal research resulted from the Minamata situation. Atomic absorption came into this country in 1963. By the end of the 1960s, it was used for other than medical research. Huge numbers of organisms were collected. Residues were analyzed. There was no differentiation by age or tissue type. That's one reason why reported Hg values may range so extensively in biological tissues.

MERCURY IN SEAWATER

SUMMARY PRESENTATION TO THE COORDINATION TEAM

William F. Fitzgerald, Ph.D.

We have been examining mercury in the open ocean, particularly in the water and the atmosphere, for quite a long time. A number of students have been working on this with me. I will be showing some data from Gary Gill, who is a recent Ph.D. and is now from the University of California. I'd like to acknowledge the high quality of his work. His work will be of some help with respect to Norton Sound. As Ron Eisler has pointed out, the mercury in seawater [has] a chemical reactivity [that] is quite high and the chemistry is quite complex. We know very little about what is going on.

I can give you some idea of the complexity with a simple conceptual model (Figure 1). This is a three reservoir model: atmosphere, water, and sediment. Mercury in seawater or other natural water will be in part mercury II, inorganic mercury. It may also be associated with a variety of anions (chloride, hydroxide, bisulfide) or organic matter. Mercury II may be **methylated** forming monomethylmercury, or perhaps dimethylmercury, or it could be **demethylated**. You have a potential for a high conversion and interconversion of all species of mercury, as Ron Eisler has pointed out. Algae may reduce mercury to elemental mercury, then there may be a movement of elemental mercury from the surface water of the ocean to the atmosphere; and we may have oxidation in the atmosphere; and an eventual return of mercury to the ocean. Mercury is removed probably [by the] most common biological settling processes to the sediment, but it may not remain in the sediment. It may be mobilized in the sediment by the action of the bacteria, which perhaps could reduce mercury to elemental mercury. It may return to the water column, or we may have methylation taking place, with the production of methyl and perhaps dimethylmercury, and again a return. We may have uptake by various types of **biota**. This is conceptual. We know very little about the details of these processes. These are suggested mechanisms. What we have been able to do is make measurements of total mercury and in some cases to fractionate mercury into a particular form.

One reason the development and understanding of the system has been slow is that a lot of poor data is being generated by lack of care associated with the sampling and the analysis of the mercury. I'll use an illustration of this from work that we have been doing recently in Wisconsin. There is a problem with mercury in large fish in a number of Wisconsin lakes, and we have been asked to carry out studies in the water column and also in the atmosphere. These are three different investigations (Figure 2). Our investigation was carried out in 1986 [and had a] yield 2.5 ± 0.5 **picomolars** of mercury per liter. A **picomolar** is 10-12 moles of mercury. To convert to grams, multiply by 200. One **picomolar** represents **0.2 rig//** or **0.2 parts** per trillion. You will notice the difference with the data that we have [on] the Pacific and Norton Sound. Our data in general are in nanograms and fractions of nanograms per liter. There is a factor of 1,000 difference. The Norton Sound data are in micrograms per liter. The **actual** value for the lake is on the order of 2.5 **picomolar**.

In 1983, the factor was almost 600 higher. That's all contamination. You can produce values close to what you see in the Norton Sound by sample contamination. These data are completely in error, but the investigators went back in 1985/1986 and used clean techniques and still had trouble, significant trouble. So the collection of the analyses of mercury and natural water is a challenging **activity**; but it can be done well, and there is a number of labs that do it well. So it is not an impractical problem. For example, I will illustrate excellent oceanic mercury data that were obtained by Gary Gill. I consider this work a landmark profile for mercury in the oceans (Figure 3, page 13, this document). He has a number of profiles like this for the Pacific Ocean from the Equator to the Gulf of Alaska; **50°N.**, **150° W.**; depth is in meters; and mercury is in **picomolar**. You see an **oceanographically** consistent pattern. Not only do you want measurements for which you have quality assurance, but they must make sense. That's the real test of quality of accuracy. Patterns should show oceanographic significance.

There is a high value close to the surface. The range is between 0.5 and 2.0 **picomolar** -- range of 4 over the entire water column from the surface to a depth of 4,000 meters. The atmospheric signal is evident in samples from the latitude of Santa Cruz to the Gulf of Alaska. There is a variation in surface readings reflecting differences of input. Then there is this broad minimum, which is a reflection of biological

Mercury in the Marine Environment

scavenging in the water column, removing mercury toward the sediment, As we get down toward the sediment, Hg concentrations **actually** come up a little bit, and this is an indication of mobilization from sediment. The range at the surface is about 1 to 3 or so picomolar. Equatorial data, in the remote ocean, is about 2, and Gulf of Alaska around 1 picomolar. So we have open ocean concentrations higher than inshore, which is an indication of enhanced removal in a coastal area where there is higher biological activity. So again, you have a pattern that makes sense. The North Atlantic yields higher values (Figure 2, page 12, this document), This is a reflection of transport of mercury from the U.S. in the westerlies which have accumulated mercury from a variety of terrestrial processes.

Next Point: The Gulf of Alaska datum is 1 picomolar. The Norton Sound average reported value is 0.6 $\mu\text{g/l}$ which, converted to picomolar, is 3,000; and that's suspicious to me. That's an extraordinary difference. We've never seen anything like that, Because Norton Sound is mineralized, we can't say that's the values are like; but the history of poor trace metal measurements in the oceans suggests that the Norton Sound data for mercury in water are wrong.

To illustrate this further, Narragansett Bay, near Connecticut, is a coastal bay. it has inputs from sewage treatment plants. In the Bay itself, we have about 5 picomolar mercury. It's somewhat elevated, but not greatly elevated, You see another pattern that makes sense. As you move into the river, then the concentrations go up. So we have somewhat of a linear relationship, That's what you should see in general, where you have river sources. As you move into lower salinity, you should see increases in the mercury concentration.

The final point I'd like to make is for freshwater, but I think the analog is reasonably good, This is for a lake in Wisconsin (Little Rock Lake), We find the average fish concentration of mercury to be 0.1 $\mu\text{g/g}$ fresh weight. In the water, it's 10^{-6} $\mu\text{g/g}$, somewhat like the ocean water, So there is a factor of about 5 orders of magnitude (10^5) enhancement from a very low level of mercury. You don't have to have high levels of mercury in the water to have a high level of mercury associated with biota. So the message then is that I'm suspicious of the data for Norton Sound that looks to me to be very, very high; and if they are much lower, then the assessment of impact in the dredging would be in error. You could have a much more significant impact if the levels were more like picomolar range that we see in other ocean regimes, Thus, the question is one of the assessment, as to whether or not the small increases in the background levels of the water are reflected by increases in the biota.

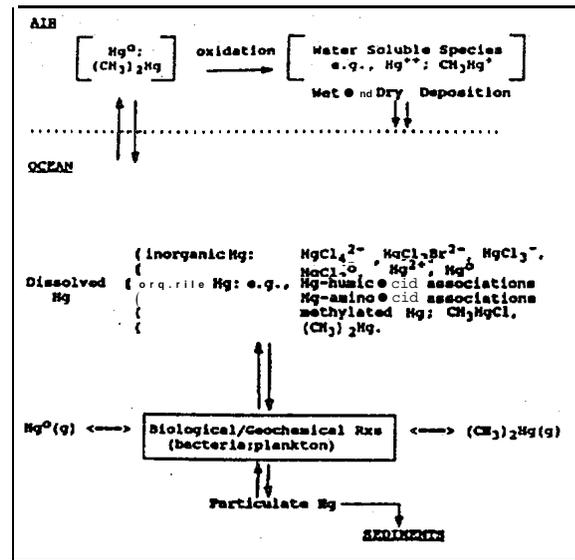


Figure 1 Physico-chemical of the biogeochemical cycling of Hg at the air/sea surface

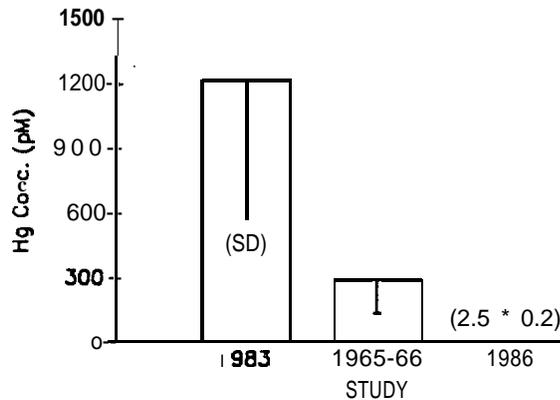


Figure 2. Comparison of three different studies of Hg concentrations in surface waters of Vandercook Lake, Wisconsin.

QUESTIONS AND DISCUSSION

Anderson: Tuesday, we heard from Tom Gosink. He had been hired by MMS to do testing. He was concerned about methods of testing. He was told to follow the EPA method of testing of mercury in sediment and water, but he didn't think the methods were accurate. He felt your methods were better.

Fitzgerald: EPA methodology is not sensitive enough, but that doesn't mean that you should have contaminated samples. It just means that you wouldn't be sensitive enough at certain levels. For the ocean waters in general, you really must have a **preconcentration** technique. The interesting thing is that we concentrate mercury from gold. That's one of the ironies of this Norton Sound problem. Gold is very fine; it traps mercury at about 100 percent effectiveness. We trap mercury on gold. We take a seawater sample, reduce the mercury to elemental mercury, purge it from the **seawater**, and the mercury collects on gold. Once gold is heated to **300°C**, it releases mercury quantitatively. That's the way we concentrate the sample for analysis. The EPA methodology is not sensitive enough at oceanic water levels. These marine concentrations of mercury are much lower than the methodology that Tom Gosink was using is sensitive. His technique is a direct reduction and aspiration into an atomic absorption cell. You simply need a larger sample in which you concentrate the mercury or gold. There would have to be an improvement in the technology. You can't use the methodology that's been recommended if the levels are lower than what's been reported. With the type of technique I'm using, which is very common among oceanographic chemists, in particular, looking at mercury worldwide. The methodology is used in Sweden, Canada, the U. S., and Japan. There's nothing unique or unusual about the methodology.

McVee: is there any work on the effects or chemistry of cinnabar alluvium of either glacial or outwash cinnabar from mineral deposits; that is, how this breaks down in the aquatic environment?

Fitzgerald: I think there is very little information with respect to marine environments. There may be more in freshwater situations; I'm not familiar with that type of work. I do know of **studies** of rivers in Italy that have natural deposits of cinnabar where aqueous **levels of mercury are 50 $\mu\text{g/l}$** average -- still not near the values in Norton Sound. Mechanistic studies, reaction studies of constituents in the marine environment, have been quite limited. Much of the work to date has been descriptive, trying to find out how much mercury is there, how it's distributed, and how it varies from ocean to ocean; that's an oceanographic approach.

Emerson: Your technique with gold filters won't really determine a soluble fraction?

Fitzgerald: Yes, it will when you take a **seawater sample and destroy** and release **all** mercury from the matrix and determine the total mercury in the sample. It's a **straightforward** matter to have two samples in which you filter the water. You have the material on the glass-fiber filter and can **dissolve**, oxidize, or burn it. Thus, you can determine the mercury on the filter, and then determine the mercury in the solution to get the partitioning. That's another technical step but not too **difficult**. The first step is to get the total, how much mercury is there? You do this by releasing mercury from all the components in the sample. You do this by acidification and oxidation, and now you have mercury as mercury II. We have high school students doing some of this. This is not a big problem. If you set up the right protocols, you can get good **data** for mercury. We work in a clean lab with clean techniques. You convert **dissolved** Hg to elemental mercury, you reduce it with **stannous** chloride or another reducing agent, which can then be purged from the solution. You do this in a gas-stripping apparatus and collect the mercury on gold,

Emerson: When you convert the sample, you convert the whole seawater sample? Isn't this a filtered sample?

_: Are you saying that we really don't know the levels of mercury that are in Norton Sound?

Fitzgerald: I am suspicious. Individuals such as myself and others who are doing trace metals are often faced with data that are bad. Why are these oceanic levels we are seeing so low, whereas in Norton Sound the levels are so high? They may be high because of a legitimate geological reason, because of local mercury deposits, cinnabar deposits. If they are just high and unusual; notice how high it will be. [For the]

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Gulf of Alaska, that's 1 [picomolar] in my units [and the] Norton Sound average would be 3,000, so it is an enormous gradient. The history of water sampling shows that taking water samples in the traditional manner is not the way to do it. You must approach the sampling using clean techniques. You have to worry about the quality of the containers, the quality of the water sampling bottle. You can't use regular metal hydrographic cable, etc. That's normal activity for chemists working in the oceans. The oceans in general are quite clean because of the biological activity and scavenging processes, which remove mercury, lead, and other trace metals, It's nature's way of cleaning the ocean.

_: If we went back and redid the analysis in Norton Sound, like Tom Gosink said he would do if he wasn't bound by the EPA method, what would happen if you came up with 1 or 2 picomolar of concentration in the seawater? Would you consider that being a contaminated area?

Fitzgerald: No, I would consider that normal, at least for the water column, but it doesn't mean the area is not contaminated. You can have relatively low numbers for the water column because mercury is continually removed from the water to the sediment, Water analysis is not always the best indication of impact. Biological indicators are much better because they give you a larger term integration of what's going on. I'm suspicious because of the history of trace metal studies in the marine environment, because we've rejected almost everything before 1975,

_: Is this contamination the case for tissue?

Fitzgerald: It can be in certain instances, particularly with lead, It requires a clean lab environment, The size of the sample is important. If you take a large sample, you run less chance of contamination. Analysts like smaller samples, You may end up analyzing not much more of the metal than you would if you were analyzing seawater directly. You may have the same types of problems with tissue, Sediments are the most reliable.

_: In any of your work, have you been able to notice any correlation between mercury in water and related seismic activity?

Fitzgerald: No. Investigators have examined hydrothermal vents in the ocean floor that circulate and contact magma. It does not appear there is mercury being released by contact of seawater with magma, but we haven't made these analyses. It might be because mercury is forming a sulfide and being trapped. We've looked at volcanic emissions of mercury and find a fair amount of mercury in the gas. All high temperature processes will release mercury. Much of the mercury that goes into the ocean is from the atmosphere' because in almost every process, gasoline burning, coal burning, oil burning, cement making, wherever you heat material, mercury is mobilized into the atmosphere, most often as elemental mercury. It has a very long residence time in the atmosphere. It's reactivity in the atmosphere is not large, and it circulates in the hemisphere and slowly comes out. We think there's an average of a factor of 10 more mercury going into the ocean -from the atmosphere compared to rivers. Another comment related to the EIS -- worldwide river input presently for this year [is reported] to be at the same level of what's supposed to be in Norton Sound. I think it's 140 metric tons.

MacLean: If the figures reported are inaccurate and further testing shows the lower limits of mercury, what does that mean for dredging activity?

Fitzgerald: If you have a high level in the water column, and make an assessment based on the high level, then the impact is reduced, because there's a lot of mercury in the water. But if the levels are much lower and the estimates of the mercury released by the dredging operation are reliable, then the impacts would be much greater.

_: Is there a chance that the measurements from the dredging are also elevated?

Fitzgerald: That I don't know. I have no idea. I'm trying to qualify the statements because I am not familiar with the details of the Norton Sound situation.

Fitzgerald: *Summary Presentation*

_: Aren't *your* comments on impacts premised first on mercury being **methylmercury** and second that it's biologically **available**?

Fitzgerald: My impact was one of mass balance, not [of] the chemical form.

_: *That's important, you're talking of mass **balance**.*

Fitzgerald: However, there's much evidence for **methylation** in almost any form occurring. You're dealing with two problems: The mass balance would indicate the impact would be larger. The next question is the form. Would some of this be converted to **methylmercury**?

CORPS OF ENGINEERS DREDGED MATERIAL TESTING PROCEDURES SUMMARY PRESENTATION TO THE COORDINATION TEAM

Thomas D. Wright, Ph.D.

I'm certainly glad to be here, it is not my **first** trip to Anchorage, it's actually my third trip to Anchorage. As the saying goes, I'm from the Government, and I'm here to help you. I'm sort of the odd man out in that august body because the Corps' approach to the evaluation of dredged material, as you will see, is significantly different from that approach which has been used in the evaluation of the material and situation in Norton Sound that is portrayed in the EIS. In the way of background, the Corps either dredges or is the permitting authority for the dredging of some 300 to 500 million cubic yards. To put in perspective to what is going to be dredged here, [I would compare this to] 12,000 cubic yards per day times whatever the dredging season is. Three hundred and 500 hundred million cubic yards, most of which we evaluate for aquatic disposal either under the Clean Water Act or under the Ocean Dumping Act.

Of course, the Ocean Dumping Act is governed and driven by the London Dumping Convention. **This** is an international treaty that we are signatories to along with some 35 or 40 other nations. So our own domestic regulations must follow the London Dumping Convention very closely and be in accordance with it. They can indeed be more rigorous with it, but they can't be more lenient. Our evaluation of this material follows EPA regulations. We have two basic regulations under the Clean Water Act and the Ocean Dumping Act.

Now we come to a parting of the ways because our evaluation of this material under EPA regulations is effects-based. What does this mean? The first thing it means is that we don't care about what kind of chemicals are there or what kind of concentrations they are found in. Why? What are we dealing with? We are dealing with dredged material. What is dredged material? It is soil that somehow has gotten in the water, either in the marine or estuarine or freshwater environment. What does it have in it? It has in it sediment, just sediment. It has in it every element in the periodic table; probably some, who knows, hundreds of thousands perhaps, of natural and synthetic compounds. It would be totally impossible to try to evaluate such a material on the basis of concentrations or presence of chemicals or compounds. **With** the exception, if we had something that perhaps is extremely highly contaminated, this **stuff** might have 500 parts of PCB's in it. We don't really have to evaluate, that falls under the Toxic Substance Control Act (TSCA) and perhaps Superfund.

Somebody said, "Don't shove it off on another agency," but that is EPA's responsibility under Superfund. We recognized in the London Dumping Convention and EPA recognized early on that there are no numbers, there are no relationships between the things that are present in chemicals and their concentration and what's going to happen, so it's effects-based. Effects on what? Effects on organisms, of course. That's the only thing you can take,

How do we bring this about? We look at two things; one or two or both. We look at acute toxicity. In other words, we ask the animals, is this stuff going to kill you? Death is a fairly straightforward end point. In so doing, we also observe perhaps behavioral abnormalities, the animals act strange, and so on. Unfortunately, we do not have, nor does EPA, **although** we are required to look at it, we don't know how, any good chronic or sublethal test. There just aren't any. We tried **and we are still trying to develop** such tests in coordination with EPA. Dave Hansen and the Narragansett Lab are sort of in the lead on this. So we ask the animal, what does this mean to you? Are you going to croak when we put you in there or are you going to be happy? Secondly, depending on what we are concerned about, we look at **bioaccumulation**. In other words, we look at uptake.

I heard several questions that asked if you can get an idea of what is going to happen to the animals with a given concentration of mercury, and the answer has been consistently "no"; and that is absolutely the correct answer. The only way to know what the animals are going to do is to expose them to the material and ask the question to the animal, are you going to take this material up and incorporate it into your tissues? Actually, we can run this in tandem because we do our acute toxicity and, if there are no survivors, we **probably** don't want to dump this out into the ocean. If there are survivors, we perceive they are short-

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term survivors because then they get sacrificed for **bioaccumulation**. It's sort of a nice, easy, clean procedure.

What do we worry about? The environment out there, the physical environment, consists basically of two components, [t consists of a water column, which at its surface is in contact with the atmosphere and at the bottom is in contact with the sediments. We don't really worry much about this water column. Why not? We have looked at the water column for close to 15 years. First off, we are bound by EPA water quality criteria just like everybody else. Even in dealing with materials for, let's say, New York Harbor, which is a pretty cruddy place, and Boston, we don't exceed, rarely do we exceed, the water quality criteria. Secondly, we don't see the effects on organisms in the water column in the way of toxicity or uptake, So we really don't worry much. We will look at it if there is a reason that we believe we ought to.

We have another internal regulation that says we cannot require an applicant to do things that we ourselves wouldn't do. Since we don't like to spend the taxpayers' money on nonsensical testing, we don't require applicants to spend their money on nonsensical testing either. Where we are concerned, most concerned, is in the benthic environment. This is where all the stuff is. This is where we have animals that often don't move very much. They just lay there and wailer around in the stuff. They are going to take it up while they are down and in intimate contact with it and eating it and plowing around and burrowing through it. Again, this is a result of about 15 to 18 years of experience of looking at what happens in these two compartments where the problems are.

Now, we have available for you, if you are interested, **two** implementation manuals. These are cookbooks; these are about how to do it. One of them I will call the "Gold Book," You might notice the title starts off "Ecological Evaluation of Discharge of Dredged or Fill Material"; this is the Clean Water Act manual and it's pretty shabby. Now, I really don't think it's worth much. It's outdated [and] we put it together in a hurry, but it was 'done under EPA regulations. [We have a] better one, which has the same procedures; we use essentially the same procedures whether it's the Clean Water Act or whether it's Ocean Dumping. The difference lies in interpretation, The same test, basically the same animals, and so on and so forth. The interpretation is somewhat different for ocean dumping. It is, in fact, more rigorous, which is an interesting concept, It means we can do all kinds of perhaps not so nice things in our domestic waters that we cannot do in waters covered by the London Dumping Convention.

So maybe you are better off being somewhere that you are covered by the London Dumping Convention rather than the Clean Water Act. We have an implementation manual on that, which is currently undergoing revision. There are some changes. They are mostly nuts and bolts changes, they are not a substantive change of direction. This and the revision that should be coming out in the future in draft form is another ecological evaluation of discharge of dredged material in the ocean waters; and I doubt if you can see it, but you will see that there are two logos on this manual. An EPA logo and Corps of Engineers logo. This is a joint manual developed by both agencies and has the collected wisdom or lack thereof of both agencies in it. We also have a technical note. This summer we revised what we call our dredging regulations, and this is just telling you how we do business. We revised them in 33CFR parts (actually 209335, 338, but 209 is administrative). We revised those and we put out a tech note that says if is a technical note, but it's really not that technical.

What it does is provide guidance for our field people, our districts and divisions; and it tells them we are revising the regulations, and it tells them we are rolling both of these manuals together into one, and here is a generic procedure to follow. These are nuts and bolts. These tell you to put the material in the beaker or in the bottle and screw the lid on the bottle and put the bottle in the right hand and shake the bottle, and so on. These are much more general, and it sort of gives you an insight into why, and it's a little 12-page thing, and I don't have one because Dave Hansen ran off with mine, but you all do have one in the record, right? I didn't bring a big supply, [but] there is still one here,

Going from that, that particular thing, now this just came up as a result of doing more thinking, In going through this in the last two days, we've come up with some philosophical considerations that need to be brought to your attention. The first one is, what is it? "It" refers to the stuff that is going to be coming out of the gold mining operation, not the gold, you can put that in your pockets, but the stuff that is going to

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go out somewhere else? What is it? It is sediment, something off the bottom of the floor of Norton Sound. But that doesn't answer the question because sediment can take lots of forms. It can be classified as dredged material, which in the regulations is defined as material removed from the bottom of the sea, bottom of the ocean, bottom of the river, for purposes of maintaining improving navigation and flood control, and so on. That's dredged material. You can pick A or B, but you have to pick something.

Alternately, the stuff can be processed industrial waste. I don't know how that's defined, except that I have come to find out that powers much higher than us have decided that the material is not dredged material, so clearly they are not dredging. I don't know why they call it a dredge; so they need to get a new name for it, it is misleading. It is an industrial processor that they have out there, which produces processed industrial waste. What is the significance of this? It is pretty significant because it raised the question of how do you evaluate the stuff? We don't have any choice, because somebody has locked you in. It's best to evaluate it by Clean Water [and] Ocean Dumping Act procedures, which are used to evaluate dredged material. No, it cannot be evaluated that way because it is not dredged material, so how does it get evaluated?

Keep in mind this is an effects-based evaluation that asks the organism, what does this mean to you? No, it can't be evaluated that way because it's processed industrial waste; so therefore by definition or legislative fiat, it obviously is best to evaluate it by NPDES procedures. NPDES procedures are designed for processed industrial waste, sewage **outfalls**, sewage sludge, industrial waste, so on and so forth, which is not dredged material. So since they are not dredged material, they have to have different procedures. These procedures are not effects-oriented. These procedures are chemical, concentration-oriented **because** these procedures are developed in a laboratory, in an aquarium, in the water, where you have something in the water column; I mean, let's face it, the sewage outfall puts out **99** percent water. Most industrial waste is largely water; sewage sludge is a good part water, and it at least has neutral buoyancy, so none of these things are like sediments. None of these things are like dredged material, which is **a** sediment.

So you are evaluating this on the basis of NPDES procedures, **which** are chemically-based. So that being the situation, you are dealing with sediments, in essence using tests designed for liquids for things in the laboratory where you can put an animal in and put [in] some zinc chloride and keep it in solution and get a cause and effect relationship, and say so many milligrams per liter of zinc: cause and effect. So here is a number. Or so many milligrams per liter of mercury: cause and effect. So here is a number, up front. We can't determine a cause and effect between chemicals and their concentrations in sediments, so we can't use numerical types of criteria, which are the basis for **NPDES**. That is a philosophical consideration, and I will leave you to grapple with that. It might be that you have not used the most appropriate procedures to evaluate the potential adverse effects of the material, and I don't fault you for that. I guess you could have used them; it might have answered a lot of these unanswered questions if you have done some bioassay to see if it is toxic or to see if this stuff is accumulative and comes out and goes into the animals.

Finally, monitoring straightforward. Monitoring assumes you've got some kind of problem, and so you have got to go out here and define the problem, and I gave the folks an example, A problem might be that you have some shellfish out there and you are worried about them being covered by 5 cm of sediment, then they will smother to death. That's the problem. That problem has a cause and effect relationship, which you demonstrated somewhere, which says that if we put 6 cm of sediment on these shellfish, clams, they are going to die. If it is less than 6, they are not. That allows you to ask the question, is it quantifiable? Can you measure it? Yes, you can measure it, 6 cm, 3, 5, you know unless all you have is a yardstick or a meter stick, and if it is not graduated centimeters, you kind of have to eyeball it. But if you have the proper equipment, you can measure **it** and get quantifiable in other words, numbers.

Then you have to develop some criteria and so we sort of did that up here. But we formalized [and] said that we can't have more than 6 cm of sediments on these animals. You can go out and measure to see if you are exceeding this criteria that you have developed, or you can put it in the form of a hypothesis. We have been measuring it over here, we got 4.8, and over there you have **6.1**, and over here you have 6.3, and you can go through statistical procedures and test the hypothesis that will tell you whether you are causing a problem. Finally, if you don't have this, all else is futile. Once you are causing a problem, you know you have a problem, you have got more than 6, you've got to have some management or remedial

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action. One solution is caused by the dredging; you stop dredging. I don't know if that's a viable solution or not. You might cut off at 4 cm, so then when we get up to 4, because they can't stand more than 6, you are going to move the dredge two miles and let these animals come back up to the top. You might say we are going to shut the dredge down for three days or discharge in a different direction. You have got to have some management remedial action or there is no point in going through all of this. I have tried to wrap up a lot in a short time. If I have comforted the afflicted and afflicted the comfortable, I have done what I came for, Any questions?

QUESTIONS AND DISCUSSION

I-folger: I think you mentioned earlier that in all the dredging materials that the Corps has been involved with, that 300 to 500 million cubic yards a year for the last 20 years, all studies done haven't shown a problem with toxic metals. Is that true?

Wright: Let me clarify that; we have hit bad material with regard to metals. Usually, almost entirely, it has been from organics and not metals. First off, most of these involved mercury or cadmium. A few others, being exceptions, are required elements. So mechanisms are needed to regulate them and cope with them. Secondly, in an aquatic environment you usually have a thin, oxidized layer, and you have bioturbators maybe deeper, and what have you. Sooner or later you can get into reduced conditions where there is no oxygen, and under these conditions the metals are not available. You can measure them chemically and say look at all the metals we have here, but they are invisible to the organism. I can probably swallow half a handful of pennies and it might make my stomach feel heavy and cause other problems, but I don't think I'm going to suffer any severely adverse affects, I might get Wilson's disease if I do this every day, On the other hand, if I swallow the same amount of copper as copper sulfate, I'm not going to feel well, and the same thing is true for mercury. I don't recommend it. You can swig down mercury and it will give you a heavy sensation in your stomach and probably go through you pretty fast, but you are not going to drop dead,

On the other hand, if it is PMA, phenylmercuric acetate, or mercuric chloride, don't try it, because a couple [of] milligrams per kilogram of body weight will kill you, The animals don't see the stuff in the sediments because by and large in the marine environment, and usually in the freshwater environment, these things are simply not available. They are bound up with organics or they are present as sulfides, which are soluble. If you want to cause a horror story, you take these marine sediments and put them upland and let them oxidize. This is terrible stuff to have in water, and suddenly you have streams of cadmium and mercury and all sorts of things coming out of these sediments.

Remember, the sediments got there by moving, they weren't generated there, Those sediments started out as plain old dirt [then] they wandered down a river or they were eroded at a beach, and they bounced along and came in contact with all sorts of things, and eventually they came to rest here. So what you are doing is not adding anything to the system, you are stirring up whatever is there. It had to be moving along to get there in the first place, and so you are going to pick it up and move it around some more. Will that cause a problem? I don't think it will, but you can go back and ask an organism what does it mean to him. He ought to be able to tell you if it will be a problem.

Emerson: You say the problem isn't metals but organics. What happens to the metals when organics are ingested by the organism? Do they stay with the organism?

Wright: Nothing as far as the organism because we use burrowing organisms. These guys are sitting here and ingesting all these sediments and eventually if they do accumulate anything, it's very, very small; so evidently they go right on through the animal and do not do anything.

Emerson: Does the organic metal complex stay intact through that and stays associated?

Wright: I don't know if it stays intact. Either it stays associated or becomes disassociated and does so in

Wright: *Summary Presentation*

such a fashion [it is] not picked up by the organism.

Emerson: So there is no basis for doing bioaccumulation?

Wright: We do it as a matter of course because we are required by the London Dumping Convention in most cases to do it, but we never see much of anything.

Emerson: So basically we don't see much from the acute toxicity, we have to kill them?

Wright: We seldom see that. Usually, if we see it, it is from acute toxicity. That's not to say we don't. We do see bioaccumulation, what we see are some things that aren't so nice, high in molecular weight, PAH's, benzanthrolzine, phenanthrene, those sorts of things. That is the higher arochlor PCB's, 1254 and on up, dioxin, tributyltin, etc. These things are the things that tend to bioaccumulate, and they aren't very toxic. Most of them are bad because they are carcinogens.

Emerson: Let's focus on the methylmercury question. That isn't associated with an organic; it is an organic; and, when it does pass through the tract, we know the reason. It does pass through the tract and is absorbed by the organism, it is because of that very fact. It has that methyl group that passes through the membrane. So that's why we have a concentration factor. Are you saying we don't see a bioaccumulation factor in any mercury-enriched environment?

Wright: Yes, we have looked at mercury. Galveston Channel is a naturally mercury-enriched environment. New York has a lot of mercury. We find different things around the country. San Francisco has got selenium, Puget Sound has chromium. We haven't looked at methylmercury. We have looked at total mercury. Keep in mind, we [take material] from the area in which we are going to dispose... [We take] material we are going to put out there. [Then we] put animals in both materials and look and see if there is any difference in what goes on. And if there isn't any difference in what goes on, we are not going to change anything. I'm not aware of anywhere we have had any significant mercury problems that we haven't had much more serious problems with other things such as PAH's or PCB's or phthalates and so forth that have gotten us into trouble.

Emerson: How long are you allowing for your bioaccumulation process?

Wright: Ten days.

Emerson: Isn't that short?

Wright: No, because we have 15 years of empirical data. We are not required to reach steady state, for one thing. We are only required by the London Dumping Convention and the Clean Water Act to show the potential for them, so what we have had to do is basically to develop an empirical database because it is very expensive. Some of these things might take 30, 40, 60 days before you finally reach a steady state. What we have done is taken a look, and we can pretty much tell you from the slope of the line where it is going to go. The exception being, and that's coming out in the revised regulations, some of these more recent things that do indeed have slow rates of uptake. And so if you do it for 10 days. It's so slow that you may not get it up to the point where you can see it. So for high molecular weight things and, in particular, dioxin, nitrofurans and the mono-, di-, and tributyltin 10's [uptake may be longer than 10 days.] ... [Let's say] you are concerned there's a shipyard, I would almost certainly say it is the tributyltin present, I would go ahead and run these animals maybe for 14, 25, 28, or 30 days and see if they are taking up tributyltin. Or, if I believe reasonable dioxin is there, I will run them somewhat longer. For a metal, 10 days may not always reach a steady state; but if you are going to have a problem, it will surely show up in those 10 days.

Then if you want to find out what steady state is, you can run it longer. Keep in mind the longer you run these, the more problems you have with the organisms because you have got them in an environment with stress; and the investigator is looking through every day, and he may be ugly, You have got to feed the animals, keep the air going, temperature monitored, and everything. The empirical base, at least for metals,

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is 3 or 4 days; and you will pick up essentially all you will ever be going to pick up.

_: How have you dealt with bioaccumulation through the food chain?

Wright: Through the food chain? We don't see a lot of bioaccumulation through marine food chains. Most of the time, for most of the animals, it doesn't make a lot of difference what we put in these aquariums, These things are great equalizers, and they all take it up equally within consideration. It depends on lipid content of the organism's storage compartments, We don't get involved with things. As far as I'm concerned, when it goes out of the water it is no longer a part of our aquatic food chain. It goes into a seal or into birds. The only way it can get into the seal or into the bird is by them eating something in the water, We are looking at the things in the water like the polychaetes and the clams and amphipods and the shrimp that they might be eating. This is not to say that if there is some small increment in all the lifetime of a seal, it might wind up actually picking up something from some of these things that are out there.

We don't look at the material while it is in place because you can't tell anything, Remember what we are dredging, we are not out in Norton Sound dredging or the vast blue Pacific but in harbors; and this sort of thing where there's outfalls, ship traffic, there may be wildly fluctuating temperatures, salinities, all sorts of perturbing influences, We rarely evaluate the material in place, [What] one does, and when we first started out at historically used sites, is put this material out, and we look" at animals out there, and this is called monitoring.

I'm not aware of a single documented instance where the disposal of material has resulted in any mortalities or resulted in any bioaccumulation. If anybody knows of an example, I'd like to hear it. I'm not aware of dredged material [that] has been evaluated and which has been deemed acceptable for ocean disposal causing a problem. There is some material [that] is not acceptable for ocean disposal, and we will put it somewhere else. There have probably been 150 graduate degrees generated between Long Island Sound and New York Bight alone, and they all come up with negative results. They say in the Bight, in the mud dump, we're going to have to abandon it because it's becoming a navigation hazard, it's mounded up 70 feet high. We have been dumping there since way back at the turn of the century, and that thing has been sampled to death, It's one of the better grounds out there because it provides relief. You get shopping carts and the dead babies and the bodies and all stuff mixed in with [them]; it provides good lobster habitat and the lobsters are clean,

In fact, we have had to abandon two sites in New England because Fish and Wildlife said these are too good for fishing. Well, they weren't worth anything until they started putting material out there; and whether it is the organics serving as the food source or whether it is the relief provided by the material, now the fishermen really get uptight when they see a dredge coming. Go to the Gulf. They use self-propelled vessels that suck up the sediment; [the vessels] have split hulls so they can go to sea and open the hull. The shrimpers wait around for the hopper dredges, and the hopper dredges go and dump, and within a few hours of the dump, the shrimpers are going back and forth and getting in the way of the hopper dredge the next time it comes out because the shrimp are attracted by the organic, and it seems not to do anything to the shrimp. They are a very popular shrimping area, You can hardly monitor material because when you put current meters out there, the shrimpers will drag them up and destroy them because it has torn up their nets.

: You have looked at bioaccumulation for mortality, but have you looked for any sublethal effects? In much lower levels?

Wright: Yes, we have, I said we are required to look at them, and we don't know how. Starting about five years ago, we spent several million dollars at EPA's Narragansett Laboratory to look at sublethal effects. We sort of gave them a blank check. We said pick the techniques that you feel have the best probability of succeeding and go to it, What did they pick? They picked adenylate energy charge as a basic thing; they picked sister chromatid exchange, a genetic thing; they picked histopathology, is it corroding the animals' gills, resulting in changes? They picked a bioenergetics, which is oxygen metabolism, nitrogen excretion, and some other measurements.

They used scope for growth, and while they were at it, they used everyday toxicity and everyday bioaccumulation. Bioaccumulation worked. By the way, we used some material that we had to get all kinds of special permits to dispose of it. It was the worst material we could find. We wanted the worst case. Out of all those things, they all bombed out except scope for growth, and in this instance, you are looking at whether or not material either retards or enhances growth of the organism, The sister chromatid exchange, the histopathology, adenylate energy charge, the bioenergetic, are essentially negative reports. We have given them our best shot. Either the techniques aren't any good or the material hasn't any affect on these particular parameters. We have these reports, and they are available from Narragansett.

Emerson: Is that it? I thought more recent bioassays [would indicate] sublethal effects that EPA has approved. [EPA is] even going around the country now with the success of let's say fertilization, using sea urchins.

Wright: That has no significant ecological relevance. We have to conduct an ecological evaluation.

Emerson: No ecological relevance? Fertilization? We wouldn't be here...

Wright: That's true, but what you are looking at is an effect that happens in the water column. You have to ask the question, are sea urchins either ecologically important or recreationally or commercially important organisms. The sea urchin's test is basically a short-term, quick test, and you can interpret it from an NPDES standpoint. But you can't interpret it from another. The question to ask is how many sea urchins' sperm are there out there?

Emerson: Every bioassay test run has the same problem of relating it to the ecological significance. None of them are any good then by that line of reasoning.

Wright: I would be more comfortable looking at something that is happening to a shrimp than I would a sea urchin's sperm because other than the Japanese (and sea otters), there are not many people that eat sea urchins; and there are lots of them, and they produce lots of sperm. I daresay most of the sperm is going to die anyway, You are not relating anything to the real world, There is another test that is called a microtox that utilizes a luminous bacterium,

Emerson: Why isn't fertilization related to life in the real world? I'm going to have to tell my wife this. I have two dependents who are really costing us. (Laughter)

Wright: Because it is a time-concentration relationship. The test is designed to look at a pipeline discharge with a more or less constant concentration of some contaminant. It's a fixed system, in other words. Now, that is completely different from something where you do not have a fixed system, where whatever the discharge is, it is here and yonder.

Emerson: Is this related to the sublethal test now?

Wright: No. You are talking about an acute toxicity test

Emerson: The early development stages are much more sensitive than the adult stage.

Wright: That doesn't make it a chronic or sublethal. A chronic or sublethal by definition is something that operates over a long period of time, or perhaps down at the molecular level,

Emerson: Why don't we use that same fertilization test rather than the acute toxicity test and call it adults?

Wright: Because it basically works only in clear water. It is very subject to the presence of any suspended material. It is designed for an industrial affluent or clear water. We don't discharge; dredge material is not clear water. We tried. We let it settle and decant[ed] it. Well, it has to be clear enough to see the organisms. What we find when we try the urchin sperm is the things clump all together in turbid waters. The physical effects, not the chemical effects, clump the sperm together, Now, we don't care about the physical effects,

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we're writing off that disposal area by definition just as you write off the area when you put in a highway or street or shopping center or whatever. You write that area off. We also write off here what we are going to dredge, It's going to be a ship channel.

APPENDIX A
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APPENDIX C

AGENDA

MERCURY IN THE MARINE ENVIRONMENT WORKSHOP

November 29- December 1, 1988

Sheraton Hotel
Anchorage, Alaska

AGENDA

TUESDAY, NOVEMBER 29, 1988

- 8:00 a.m. Coffee
- 8:45 a.m. **Introduction/Purpose of Meeting**
Judy Gottlieb, Deputy Regional Supervisor, Leasing & Environment, MMS
- 9:00 a.m. **Mercury in Water and Sediments**
Moderators: Dick Prentki, MMS; Dick Roberts, MMS
Speakers:
9:00 a.m. Tom Gosink - "Mercury in Sediments"
9:30 am. Questions/Discussion
10:15 a.m. Coffee
10:30 am. William Fitzgerald - "**Mercury in Seawater**"
11:00 am. Questions/Discussion
- 11:45 a.m. Lunch (participants on their own)
- 1:00 p.m. **Regulation of Mercury Levels In Water and Dredged Sediments**
Moderators: Dick Prentki, MMS; Maureen McCrea, MMS
Speakers:
1:00 p.m. Dave Hansen - "Environmental Protection Agency Regulation and Derivation of Criteria for Mercury in **Water**"
1:30 p.m. Questions/Discussion
2:15 p.m. Coffee
2:30 p.m. Tom Wright - "Army Corps of Engineers Dredged Material Testing Procedures"
3:00 p.m. Questions/Discussion
- 3:45 p.m. Discussion Topics
- 5:00 p.m. No host bar

WEDNESDAY, NOVEMBER 30, 1988

- 8:30 a.m. Coffee**
- 9:00 a.m. Mercury Accumulation and Effects In Organisms**
- Moderators: Gail Irvine, **MMS**; Dan Benfield, MMS
- Speakers:
- 9:00 a.m.** Ronald **Eisler** - "Significance of Mercury Residues in Marine Vertebrates"
- 9:30 a.m.** Questions/Discussion
- 10:15 a.m.** Coffee
- 10:30 a.m.** Anton **Scheuhammer** "Mercury Toxicology in Birds and Mammals"
- 11:00 a.m.** Questions/Discussion
- 11:45 a.m.** Lunch (participants on their own)
- 1:00 p.m. Mercury Effects on Human Health**
- Moderators: Helen Armstrong, MMS; Don Hansen, MMS
- Speaker:
- 1:00 p.m..** David Marsh - "Methyl Mercury Poisoning in 'Iraq'"
- 1:30 p.m.** Question/Discussion
- 2:15 p.m.** Coffee
- 2:30 p.m. Discussion Topics:**
- Preparation of Workshop Summaries to be Presented at Thursday's
Coordination Team Meeting
- 5:00 p.m.** No host bar

THURSDAY, DECEMBER 1, 1988

8:30 a.m. Coffee

9:00 a.m. **Final Discussions and Preparation for Coordination Team Meeting Presentations**

10:30 am. **Coffee**

COORDINATION TEAM MEETING

11:00 a.m. **introduction/Purpose**
Tim Holder, Coordinator for the Coordination Team

11:10 a.m. Health Concerns
Dr. Katherine Kelley, Alaska Public Health Laboratories

11:45 a.m. **Lunch** (participants on their own)

1:00 p.m. Call of Coordination Team Meeting to Order
Bob Brock, **Regional Supervisor, Leasing & Environment, MMS**
Patty **Bielawski**, State of **Alaska**, Division of Governmental Coordination

1:15 p.m. **Presentation of Workshop Summaries (5-10** minute talks followed by 20-25 minutes of questions/discussion

Moderator: Judy **Gottlieb**

Speakers:

1:15 p.m. **Mercury Effects in Human** - David Marsh

1:45 p.m. EPA Regulation and Criteria for **Mercury in Water** - Dave Hansen

2:15 p.m. **Mercury Toxicology In Birds and Mammals** - Anton **Schauhammer**

2:45 p.m. Coffee

3:15 p.m. **Significance of Mercury Residues in Marine Vertebrates** - **Ronald Eisler**

3:30 p.m. **Mercury in Seawater** - William Fitzgerald

4:00 p.m. Corps of Engineers Dredged **Material** Testing Procedures - Tom Wright

4:30 p.m. Adjourn

APPENDIX D
TECHNICAL NOTE



Environmental Effects of Dredging Technical Notes



CORPS OF ENGINEERS ' PROCEDURES AND POLICIES ON
DREDGING **AND** DREDGED MATERIAL DISPOSAL
(THE FEDERAL STANDARD)

PURPOSE: This note describes the Federal Standard pursuant to Corps' technical considerations and policies with regard to the disposal of dredged material in accordance with the Clean Water Act (**CWA**), which provides for selecting the least costly dredged **or** fill material disposal alternative, consistent with sound engineering practices and appropriate environmental quality standards. This approach also generally applies to assessments conducted in accordance with the Ocean Dumping Act, even though the following discussion centers on the **CWA**.

BACKGROUND : Navigable waterways of the United States have and **will** continue to play a vital role in the Nation's development. The Corps, **in** fulfilling its mission to maintain, improve, and extend these waterways, is responsible for the dredging and disposal of large volumes of sediment each year. Nationwide, the Corps dredges about 230 million cubic yards (**c.y.**) in maintenance and about 70 million **c.y.** in new dredging operations annually at a cost of about \$450 million. **In addition**, 100-150 million **c.y.** of sediments dredged by others each year are subject to permits issued by the Corps. In accomplishing its national dredging and regulatory missions, the Corps has conducted extensive research and development in the field of dredged material management (**Engler, Patin, and Theriot 1988**). Regulations, policies, and technical guidance prepared and used by the Corps are based on operating experience and results from extensive research programs. Federal expenditures on dredged material research, monitoring, and management activities have cumulatively exceeded \$100 million. Additional research regarding current issues relative to the Corps' national dredging program is an ongoing **and** dynamic process. Corps' policy is evolving as dredged material research provides a better understanding of the environmental impacts that can be anticipated from dredging and dredged material disposal. Corps' national policy is reflected **in** the final regulation for Corps' operation and maintenance dredging of Federal navigation projects published 26 April 1988 (33 CFR Parts 209, 335, 336, 337, and 338) and in the final rule for the Corps' regulatory program published 13 November 1986 (33 CFR Parts 320-330).

ADDITIONAL INFORMATION: This technical note was written by Dr. Robert M. Engler, Dr. Tom Wright, **Dr.** Charles R. Lee, and Or. Tom M. Dillon. **For additional information contact** Mr. Dave Mathis (**CECW-D**), commercial or FTS: (202) 272-8843; or Dr. Wright. (601) 634-3708; or Dr. **Engler**, manager of the Environmental Effects of Dredging Programs, (601) 634-3624.

Corps Authorities and Responsibilities

The Corps has regulatory **responsibility** for all dredged material disposal activities that occur within the waters of the United States. **This** authority stems from **Section** 10 of the River and Harbor Act of 1899, **Section** 404 of the Clean Water Act (**CWA**)(**Public** Law 92-500, as **amended**), and **Section** 103 of the Marine Protection, Research, and **Sanctuaries** Act (**Public** Law 92-532, as amended). The Corps' regulatory responsibilities involve review of some 10,000-30,000 permit applications each year as well as appropriate maintenance of, and improvements to, the 25,000-mile congressionally authorized Federal navigation system serving 42 of the 50 states. **Section** 404 authorizes the Secretary of the Army to issue permits for the discharge of dredged or **fill** material into waters of the United States in accordance with the **Section** 404(b)(1) Guidelines (subsequently referred to as the Guidelines) and other requirements of Federal law as discussed below. The Guidelines require compliance with several conditions prior to allowing disposal of dredged material in waters of the United States. Compliance requires the avoidance of "unacceptable adverse effects" to the aquatic environment. The Guidelines specify four conditions of compliance ("restrictions on discharge" per 40 CFR 230.10):

1. There **is** no other practicable alternative that would have less adverse **impact** on **the aquatic** environment.

2. The disposal **will** not result **in violations** of **applicable** water **quality** standards after consideration of **dispersion** and **dilution** (40 CFR 230.10(b)(1)), toxic effluent standards, or marine sanctuary requirements, nor will it **jeopardize** the continued **existence** of threatened or endangered **species**.

3. The disposal **will** not cause or contribute to significant degradation of the waters of the United States.

4. All appropriate and practicable steps have been taken to minimize potential adverse impacts of the discharge on the aquatic environment.

Findings for compliance with condition 2 are based in large part on **Section** 401 of the **CWA, which** allows the individual states to **establish** State water-quality standards. All State-established standards must, at a minimum, be as stringent as established Federal water-quality criteria. However, the individual states have the option under the **CWA**, and several have so elected, to establish more stringent State standards **to** reflect the overriding priority

that these individual states have for environmental protection. Unless waived on a case-by-case basis by the State, or on such **occasions** overridden **by** critical factors **in the national interest**, State 401 Water **Quality Certification** must be obtained prior to **initiation** of any Federal or non-Federal dredged **material disposal activity which** occurs **within navigable** waters of the **United States** (40 CFR 230.10(b)(1)).

The findings of compliance with condition 3 are to be based, in part, on "evaluation and testing" of the proposed dredged material (Subpart G of the Guidelines). The assessment provided by Subpart G is used to determine the potential for significant* adverse effects of dredged material disposal on the aquatic environment (factual determinations required by Part 230.11). According to the Guidelines (40 CFR 230.61), specific evaluation procedures, including chemical and biological tests to determine compliance with the Guidelines and State water-quality standards, are furnished by the Corps as the permitting authority.

The Corps' final decision on any proposed dredged material disposal activity, **however, must be based on a broad public interest** review which not only considers information derived from chemical and biological tests but which also considers an evaluation of the probable impact, including cumulative impacts of the proposed activity, on the public interest. In addition, embodied within this public interest review, is a Corps requirement to ensure that the substantive concerns of over 30 Federal environmental laws, Executive Orders (**EOs**), and other requirements are properly addressed, whenever applicable. These include the Coastal Zone Management Act, the Marine Protection, Research, and Sanctuaries Act, the Endangered Species Act, the Fish and Wildlife Coordination Act, EO 11990 for Federal projects (Protection of Wetlands), and EO 11988 (Floodplain Management). **While** each of these Federal Statutes (including the CWA) is generally resource specific in regard to environmental protection, the Corps' public interest review necessitates full consideration of all relevant information before rendering a decision.

The expected benefits resulting from the proposal must be balanced against its foreseeable detriments. All factors which may be relevant to the proposed activity will be considered, including conservation, economics,

* The term "significant" has no statistical relevance or connotation; it is used in the same general sense as "substantive."

esthetics, historic properties, fish and wildlife values, flood hazards, floodplain, national defense, water supply and conservation, water **quality**, energy needs, safety, food and fiber production, mineral needs, considerations of property ownership, and the general needs and welfare of the people.

The weight given to each factor is determined by its importance and relevance to a particular proposal. A specific factor may be given great weight on one proposal, while it may not be present or as important on another. The Corps' (District Engineer's) final decision will reflect the national concern for both protection and utilization of important resources. As such, the Corps is neither a proponent nor opponent of individual permit proposals, nor of congressionally authorized dredging projects.

Section 404(b)(2) allows the Corps to issue permits otherwise prohibited by the Guidelines, based on an overriding consideration of the **economics** of anchorage and **navigation**.

Federal Standard

The Corps, as agency **policy**, uses a Federal Standard philosophy and **process** in evaluating proposed dredged material disposal activities relative to the general public interest. **This** "Federal Standard" process is intended to meet environmental requirements at the least cost within a consistent national framework. The Federal Standard provides a reference point for Corps field offices in addressing regional issues in dredged material management. The intent of the Federal Standard is to ensure a necessary level of national consistency in the evaluation and undertaking of proposals for dredged material disposal (e.g., testing procedures), while also ensuring a necessary level of flexibility by the Corps field offices to account for region-specific considerations. However, significant deviations from national testing and evaluation guidance require consideration of cost, utility of information, and full technical explanation and documentation in the Section 103.

For proposed permit activities, Corps regulations (33 CFR 320-330) require that unnecessary testing procedures and regulatory controls be avoided, **while** simultaneously ensuring that overriding rights and interests of the general public are fully protected in the waters of the United States. Such rights include, but are not limited to, preservation of water quality, national security, and interstate commerce. These considerations are

discussed in more **detail** in a Corps Regulatory Guidance Letter of 19 August 1987, **RGL-87-8, "Testing Requirements for Dredged Material Evaluation."**

Permit activities

Evaluation of Section 404 permits, for **which** an application has been made to the Corps, normally will proceed concurrently with the processing of applications for permits for other Federal, State, and/or local authorities (33 CFR 320.4(g)), such as **the State 401** Water Quality Certification. The **applicant** for a Section 404 permit **will** receive direction from the Corps as the permitting authority (40 CFR 230.61) concerning appropriate tests that **must** be conducted on material proposed for dredging. This note summarizes the Corps' national guidance given to its field offices on technically acceptable dredged material evaluation procedures. Also to be provided to permit applicants, where applicable and appropriate, are Corps recommended actions which can be undertaken to minimize any identified adverse effects of discharges of dredged material as provided under Subpart H of 40 CFR 230. Depending on the results of the general public interest review, the Corps may issue, issue with conditions, or deny individual permits. **In those** permit cases where denial of State Certification has occurred or is imminent or a state has not concurred in Coastal Zone Management concurrence, the Corps may either immediately deny the Section 404 permit without prejudice, or may continue processing the permit, concluding either in a denial as contrary to the public interest or denying without prejudice, noting that, except for the State 401 Certification denial or Coastal Zone Management nonconcurrence, the Section 404 permit could be issued.

Federal projects

For Federal projects, the Corps is required to use the **Section 404(b)(1)** Guidelines to determine the **appropriate** test and evaluation procedures for delineating the least costly, environmentally acceptable disposal alternative as well as to demonstrate compliance with applicable State water-quality standards.

The Corps submits its findings concerning project compliance with the 404 Guidelines and State water-quality standards to the State via the **Public** Notice process along with a request for State Water Quality Certification. The certification request also includes relevant information to demonstrate compliance with applicable State water-quality standards. The **existing regulatory** framework given in the CWA requires that a Corps-preferred alternative

be developed before the request for State Water Quality **Certification**. However, this does not preclude informal **coordination** with **the** State at a much earlier stage in the project evaluation, and indeed such informal coordination is fully encouraged, particularly if it will shorten the environmental **compliance** process for **the** Corps project.

The Corps Public Notice and Findings of Compliance or Non-Compliance with the Section 404(b)(1) Guidelines serves as a point of reference in any subsequent negotiations with the State on additional requirements or conditions which the State may require for Water Quality Certification.* The Corps' District Engineer has the necessary discretionary authority to develop additional evaluative information requested by the State, which in the District Engineer's opinion, is technically justified and reasonably related to enforcement of the State's water-quality standards. The legislative record for the **CWA** provides congressional recognition that Federal project costs may be increased in some instances to address reasonable and technically appropriate State water-quality **concerns**. However, if the District Engineer determines that on a case-by-case basis a State's requirements are excessive or technically unjustified, he may request that the State or project sponsor fund the additional costs associated with any such requirement. **In** such cases where the State or project sponsor agrees to fund the additional costs, the District Engineer must also determine and notify the State and project sponsor that such additional costs may affect the continued economic viability of the Federal project in question. In the event that the State or project sponsor does not agree to fund the additional cost, the District Engineer may defer dredging while determining whether the dredging project is economically justified and is not contrary to the public interest.

For Federal dredging projects (where Congress has allocated Federal funds), the Corps is responsible, in developing dredged material disposal alternatives; for considering all facets of the dredging and disposal operation, including technically appropriate test and evaluation procedures, cost, engineering feasibility, overall environmental protection, and the no-dredging option. The alternative selected by the Corps should be the least costly alternative, consistent with sound engineering and scientific practices and

* This procedure is also followed for concurrence with certification of consistency for approved State Coastal Zone Management Programs.

meeting applicable Federal environmental statutes. This becomes the "Federal Standard."

Corps of Engineers Technical Disposal Guidelines

The following paragraphs present the procedures by which the Corps regulates and manages the disposal of dredged material **in** the waters of the United States under its authorities and policies described above. These procedures, which evolved over the past decade, are subject to additional change and modification as new information and technology **are** developed and adequately evaluated.

Section 404 of the **CWA** provides that guidelines developed by the US Environmental Protection Agency (EPA) in conjunction with the Corps be applied by the Corps in selecting disposal sites and in the permit application review process. EPA published technical guidelines in 1975 and revised these **in** 1980 for use by the Corps in **making** the required **ecological** evaluation of a proposed **discharge activity**. The Corps **issued** final regulations for the Section 404 regulatory program in **July 1977** to be used in evaluating proposed discharges of dredged or fill material into inland and ocean waters. **In May 1976**, the Corps issued an interim guidance manual as specified in the Federal Register to initiate technical implementation of the program.

The Section **404(b)(1)** Guidelines as well as the 103 criteria are based on the following factors from Section 403(c) and 102(a) of the Clean **Water** and Ocean Dumping Acts, respectively:

1. The effect of disposal of pollutants on human health or welfare, including but not limited to plankton, fish, shellfish, wildlife, shorelines, and beaches.
2. The effect of disposal of pollutants on marine life including the transfer, concentration, and disposal of pollutants or their by-products through biological, physical, and chemical processes; changes in marine ecosystem diversity, productivity, and stability; and species and community population changes.
3. The effect of disposal of pollutants on esthetics, recreation, and economic values.
4. The persistence and permanence of the effects of disposal of pollutants.

5. The effect of the disposal at varying rates of particular volumes and concentrations of pollutants.

6. Other possible locations and "methods of disposal and recycling of pollutants including land-based alternatives."

7. The effect of alternate uses of the oceans, such as mineral exploration and scientific study.

These "legal/technical" considerations form the framework from which the ecological evaluations must be developed.

The **Section** 404(b)(1) Guidelines recognize that compliance evaluation procedures will vary depending on the seriousness of the proposal's potential for unacceptable adverse impacts (40 CFR 230.10) and provide general guidance for evaluation and testing. Pursuant to the Guidelines, specific evaluation procedures, including chemical and biological tests, are furnished by the District Engineer on a case-by-case basis ("interim guidance by the permitting authority," 40 CFR 230.61).

To assist the Corps in the overall long-term management of the disposal of dredged material, a management strategy was developed by the US Army Engineer Waterways Experiment Station (**Francingues** et al. 1985). This strategy has been adopted as Corps policy and is incorporated by reference in 33 CFR Parts 209, 335, 336, 337, and 338, 26 **April 1988** (Corps' Dredging Regulation). The steps for managing dredged material disposal follow:

1. Evaluate contamination potential.
2. Consider potential disposal alternatives.
3. Identify potential problems.
4. Apply appropriate testing protocols.
5. Assess the need for disposal restrictions.
6. Select an implementation plan.
7. Identify available control options.
8. Evaluate **design** considerations.
9. Select appropriate control measures.

Following development, the management strategy was used as a framework for an example application for highly contaminated material at Commencement Bay, WA (a Superfund site), under the sponsorship of the State of Washington Department of Ecology, and the Corps (**Peddicord** et al. 1986). This example application considers all alternatives for disposal and provides detailed

technical rationales and flowcharts **for** evaluating disposal alternatives based on the results of appropriate testing.

Since the **mid-1970's** the Corps has been regulating the disposal of dredged material under the authority of 33 CFR Parts 320 through 330 and 40 CFR Part 230 and revised **in** 1980 for waters of the United **States and** under the **authority** of applicable sections of 40 CFR 220-229 (1973) and revised **in** 1977 for ocean **dumping**. **In** fulfilling the obligations and responsibilities mandated by those authorities, the Corps has conducted extensive research under the Dredged Material Research Program (Saucier et al. 1978) and continues to conduct research under the Environmental Effects of Dredging Programs (**Engler, Patin, and Theriot 1988**), **and provides field assistance and management activities under the Dredging Operations** Technical Support Program. In addition, it has published two guidance manuals, one for the **CWA** (Environmental Effects Laboratory 1976) and a joint manual with EPA for ocean dumping (Environmental Protection Agency/and US Army Corps of Engineers 1977); the latter provides much more detailed guidance than the former. Although these documents were state of the art when published, subsequent operational experience has led to changes in specific application. In particular, there has been a tendency for Corps coastal districts to use, depending on the subject of concern, portions or all of the testing procedures in the Ocean Dumping Implementation Manual for **404(b)(1) determinations** whenever estuarine or marine waters are **involved**. Although a **major** reason for this is the detailed guidance, others include similarities between the requirements of the 404 Guidelines and those in Section 102(a) of **Public** Law 92-532 (the Ocean Dumping Act) and the fact that saline waters are **involved**. **Additionally**, shortly after the **issuance** of the Corps/EPA Implementation manual on ocean **dumping**, the Corps and EPA were sued by the **National** Wildlife Federation. The suit was based on the technical validity of the testing procedures and interpretation of test results. Judgment was made in favor of the Corps and EPA and there has been no further challenge. Because of the above factors, the ocean dumping testing procedures and interpretive approaches have been in widespread use and have led to the informal adoption of the general testing and evaluation protocol from ocean dumping to **404(b)(1) evaluations**.

This should not be construed to **imply** that the ocean dumping procedures/interpretation are "required" or "mandated" for **404(b)(1) evaluations**. These procedures should be considered in light of project-specific concerns and,

where appropriate, **may**, in part or in whole, be used. However, they do, **de facto**, constitute an acceptable and widely used technique which has withstood court challenge and for which a major technical data base exists. That no absolute procedure exists for 404(b)(1) evaluations is further evidenced by cooperative efforts currently in progress between the Corps and EPA to establish standard testing and evaluation procedures.

Tiered Testing and Assessments

The national comprehensive testing strategy supported by the Corps is a tiered approach (Table 1) with each successive tier being based on a "reason to believe" that there is potential for unacceptable adverse effects. Each tier **is fully optional** and may be subsequently eliminated if there is sufficient information available to provide an adequate assessment for that tier or if there is no reason to believe that **there** will "be unacceptable adverse **effects** associated with that tier or disposal concern. Such multiple tests are clearly allowed by 40 CFR 230.4-1 ("No single test or approach can be applied **in** all cases to evaluate the effects of proposed discharges of dredged or fill material," and "Suitability of the proposed disposal sites **may** be evaluated by the use, where appropriate, of sediment analysis or **bioevaluation**."). However, such tests are subject to the condition that "In order to avoid unreasonable burdens on applicants in regard to the amounts and types of data to be provided, consideration **will** be given by the District Engineer to the economic cost of performing the evaluation, in light of the information expected and the contribution of that information to the final decision, and the nature and magnitude of any **potential** environmental effect."

The first tier of the **existing** approach consists of an initial evaluation of available information to establish whether there is a "reason to believe" that contaminants are or are not present. This tier is commonly referred to as the "exclusion clause" (40 CFR 230.4-1(b)(1)). If there **is no** reason to believe that contaminants are present and if certain other conditions are met, including grain size and chemical/physical similarity of the dredged material and the substrate at the disposal site, no further testing is required. If **there is** reason to believe that contaminants are present, or if sufficient information is not available, a second tier or evaluation may be conducted which consists of a bulk sediment analysis. Should sufficient

Table 1
Comprehensive Testing Approach for Aquatic Disposal
as Part of the Federal Standard*

<u>Tier 1</u>	Initial evaluation of existing information and "reason to believe there is contamination."	
<u>Tier 11A</u>	Bulk sediment inventory. Reason to believe dredged material is more contaminated than disposal site sediment and potential unacceptable adverse effects may occur.	
<u>Tier IIB</u>	Elutriate analysis. Chemical analysis for contaminant(s) of concern, contrast to appropriate water-quality criteria and/or standard with consideration of mixing. Comparison to receiving water quality and/or bioassay when no standard exists.	
<u>Tier III</u>	Biological tests.	
<u>Tier 111A</u>	Acute bioassay toxicity tests (as appropriate):	
	<u>Water Column (Elutriate)</u>	<u>Select Species</u>
	(Mixing considered)	(As necessary)
	Dissolved phase	Mysid shrimp
	Suspended solids phase	Grass shrimp
		Bivalve
		Fish
		Larva, bivalve
		Other
	<u>Benthic</u>	
	Solid phase	Mysid shrimp
		Amphipod
		Grass shrimp
		Clam
		Polychaete
		Other
<u>Tier IIIIB</u>	Bioaccumulation.	
	<u>Water Column</u>	<u>Select Species</u>
	Suspended solids phase	Grass shrimp
		Clam
		Polychaete
		Other
	<u>Benthic</u>	
	Solid phase	Clam
		Polychaete
		Other

* Table 1 presents the general types of tests and evaluations **in a tiered** and sequential **basis** where each tier (step) is, however, optional and may be eliminated or chosen as appropriate. Test species tested are not mandatory but are shown for consideration to a proposed disposal site region.

information be available from **previous** testing and evaluation no **additional** chemical analyses are necessary.

The bulk sediment **analysis is essentially** an **inventory** of contaminants of concern and **is** used to compare the chemical composition of the dredged material to the composition of the material at the disposal site with emphasis generally placed on heavy metals, **PCBs, PAHs**, pesticides, and other substances of ecological or human health significance. **If** substantially greater concentrations are observed in the dredged material and there is reason to believe that the substances are **bioavailable** and sufficient information is not available, a third tier of testing may be required. **This tier includes testing** for water column impacts and/or **benthic** impacts.

If there is concern regarding water column impacts, an **elutriate** test may be performed to evaluate contaminant release into dredging or disposal site water. The results of the **elutriate** test are compared to water quality standards after consideration of mixing as described in the 404(b)(1) Guidelines. **If there are no water-quality standards or the standards are thought to be inappropriate or inadequate**, a water column liquid and/or suspended particulate phase bioassay may be conducted along with consideration of mixing. Again, depending on where the concern lies, the water column bioassay may address the dissolved constituents and/or the suspended solid particulate phase.

If there is concern regarding impacts to benthic organisms, a benthic bioassay may be conducted. In general, for a comprehensive **assessment of potential impacts**, **three** organisms are generally used: a filter-feeder, a deposit-feeder, and a burrowing species". These relate to potentially different ecological niches at the disposal site. **In addition**, a mysid shrimp may be considered and has been widely used as an internal standard and to form a basis for quality assurance.

If there is a reason to believe that bioaccumulation is of concern, a second component of the third tier consists of evaluating the potential uptake of contaminants. This may be done **either** in the field or in the laboratory, whichever is more appropriate. If done in the laboratory, it is customary to use survivors of the toxicity **bioassays** for **bioaccumulation** assessment if sufficient biomass is present in the survivors.

The **tiered testing** approach described above **is** essentially the procedure followed for the evaluation of the **aquatic disposal alternative** in the

development of the Federal Standard for a **given** dredging **project**. This approach should be applied consistently to each and **every** dredging project, Federal or permit. The approach **is flexible to some extent in allowing** consideration of the three phases of the aquatic environment (liquid, suspended solids, and solid), as appropriate, that potentially could be impacted by the discharge of dredged material. Testing of the appropriate phase is determined by the reason to believe that **a** potential for unacceptable adverse impacts in one or more phases could occur. **Additional flexibility is** incorporated **in** the approach in relation to the selection of bioassay species to be used in the tests. Species can be selected such as a **bivalve, polychaete,** and a crustacean (**mysids,** amphipods, shrimp) or other available, appropriate, developed and evaluated local species. The intent is to evaluate the potential impact on a deposit-feeder, a burrower, and a suspension-feeder representative of major ecological compartments.

The following discussion addresses **in** more detail the Interpretation of bioassay test results from the tiered testing approach used to evaluate the aquatic disposal alternative portion of the Federal Standard. Additional detail on the evaluation of the aquatic disposal alternative can be found in **Peddicord et al. (1986)**.

If there is reason to believe that the dredged material contains contaminants of concern at concentrations higher than those contained in the disposal site sediment and these contaminants are potentially **bioavailable** and could result in a significant* adverse impact, then bioassay tests **should** be conducted. The bioassay tier testing is used to determine whether there is reason to believe contaminants in **the** dredged material will result in an unacceptable adverse impact to the water column and/or the benthic component of the aquatic disposal environment. The water column consists of a **dissolved** phase and a suspended solid particulate phase. An overwhelming preponderance of **evidence** from years of studies has demonstrated that the **potential** of water column **impacts** of **contaminants** released from dredged **material disposal** are generally negligible. While this **evidence** does **not** unequivocally prove that water column impacts will not occur with aquatic disposal, it does indicate that such impacts are sufficiently unlikely that the District Engineer

* The term "significant" has **no statistical relevance or connotation; it is** used in the same general sense as "substantive."

normally should conclude that it is appropriate to focus evaluation on' the other issues rather than testing for potential water column impacts in association with disposal in aquatic sites where the majority of the material is deposited on the bottom and the remainder is subject to rapid dispersion and dilution.

In many cases it will be possible to assess the potential for water column impacts on the basis of previous water column testing and characteristics of the disposal site without conducting additional sediment-specific testing. However, there may be a reason to believe that the suspended solid particulate phase of the water column may result in a potential unacceptable adverse impact to the disposal environment. If this is the case, the suspended solids bioassays may be conducted. Likewise, if there is reason to believe that unacceptable adverse impact may occur in the solid phase, then a solid-phase bioassay should be conducted.

If the results of the bioassay tests show unacceptable toxicity to the test species, further testing may be required. In the case of suspended solids phase bioassay testing, consideration of a mixing zone at the disposal site should be evaluated to determine whether an acceptable mixing zone is available to eliminate significant adverse impacts due to potential toxicity at the disposal site. If unacceptable toxicity is shown in the solid phase test and" mortality is sufficiently elevated above control and/or reference, a significant impact has been shown.

If unacceptable toxicity is not observed in the solid phase test species and there is reason to believe that there is a potential for bioaccumulation, or the results of the bioassays are not conclusive, further testing may be required. The surviving bioassay animals may be analyzed for bioaccumulation after exposure to the dredged material for an appropriate length of time.

Bioaccumulation by bioassay species exposed to the dredged material is compared to that of species exposed to disposal site sediment or an appropriate reference site in the disposal site environment.

The above discussion has addressed the first four steps of the Management Strategy (Francingues et al. 1985). Additional information on the need for restrictions and control measures for aquatic disposal and the evaluation of other disposal alternatives can be found therein and in Cullinane et al. (1986). A more comprehensive discussion of the interpretation of test results is provided by Peddicord et al (1987).

Innovative Assessment Techniques

The enactment of Public Laws 92-532 (the Marine Protection, Research, and Sanctuaries "Act of 1972) and 92-500 (the Federal Water Pollution Control Act Amendments of 1972) required the Corps to participate in developing guidelines and criteria for regulating dredged and fill material disposal. The focal point of research for these procedures is the Corps Dredged Material Research Program (DMRP), which was completed in 1978; the ongoing Corps Environmental Effects of Dredging Programs (Engler, Patin, and Theriot 1988) includes the Dredging Operations Technical Support (DOTS) Program, the Long-Term Effects of Dredging Operations (LEDO) Program, the Wetlands Research Program (WRP), and the recently completed Corps/EPA Field Verification Program (FVP).

While these research programs have allowed the Corps to develop an extensive and effective set of testing protocols and evaluation procedures, there continues to be a requirement for additional research. Less expensive, faster, and improved techniques for predicting the effects of disposal of dredged material are needed. Accordingly, innovative development of new and refined evaluation procedures are being undertaken through appropriate R&D programs of the Corps. However, until new procedures are proven through adequate documentation, existing techniques must be relied upon.

Summary

The "Federal Standard" guidance serves as a consistent national framework and reference point for Corps field offices which provides for consideration of regional issues in dredged material management. In applying the process to different projects or regions of the country, it may be necessary to adopt specific testing procedures consistent with the Federal Standard Philosophy. Corps field office evaluations must be consistent with the national procedures, defensible in light of research results and scientific judgment, cost and time effective, and of direct use in decisionmaking.

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As the Nation's principal conservation agency, the Department of the Interior has responsibility for most of our nationally owned public lands and natural resources. This includes fostering the wisest use of our land and water resources, protecting our fish and wildlife, preserving the environmental and cultural values of our national parks and historical places, and providing for the enjoyment of life through outdoor recreation. The Department assesses our energy and mineral resources and works to assure that their development is in the best interest of all our people. The Department also has a major responsibility for American Indian reservation communities and for people who live in Island Territories under U. S. Administration.

