ECOLOGICAL ASSESSMENT OF HAIFA CHEMICALS LTD DISCHARGE TO HAIFA BAY

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Prepared for

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1.0 Introduction

Haifa Chemicals Ltd. is the world's largest producer of potassium nitrate and a major producer of phosphate, including cosmetic-grade phosphates. About 90% of the annual 1.5 million cu m of acidic liquid waste comes from the phosphoric acid facilities. These wastes are discharged into the Kishon (Quishon) River at an average rate of 200 cu m per hour (4 million gallons per day).

For the past 15 years the plant has sought alternatives to direct river discharge of acidic (<pH 1) waste. All forms of neutralization and co-precipitation have been ruled out as too resource intensive. The final alternative is discharge to Haifa Bay on the Eastern Mediterranean Sea, making effective use of both the large dilution and great buffering capacity of the sea. Contracted engineers have designed a delivery system composed of an land-sea outfall and a jet diffuser system capable of reaching initial dilutions of over 400:1.

The purpose of the diversion is to help restore the highly-polluted Kishon River and estuary. The need for rapid response resulted from a decision by the Israeli Government and the City of Haifa to begin river restoration immediately. Technion determined that my experience and that of NOAA's was highly relevant to the issues, including predicting impacts from low pH, heavy metals and suspended solids.

2.0 Approach

Issues concerning the effects of the proposed discharge (documented below) were reviewed prior to and during meetings with various officials in Haifa and Tel Aviv during the week of December 11-15, 1994. Technion provided unpublished data on effluent composition (1992-94), trammel net catches along the outfall alignment (1992-93), fish contaminant data, and benthic infauna data. During that week the author also visited various sites on the Kishon River and in the harbor area and had an opportunity to observe day and night vessel and fishing activity. Additional published reports on sea life and contaminants in water, sediment, fishes, plants and invertebrates were obtained from scientists at the Israel Oceanographic and Limnological Research (IOLR) at Tel-Shikmona (December 13, 1994).

A three-pronged approach was initiated to address these issues. First, an iterative screening-level ecological risk assessment (Cardwell et al., 1993) was undertaken to evaluate which of the effluent constituents might be of most concern in terms of protecting marine resources of Haifa Bay from acute, chronic and longterm toxic effects. This approach included collection of, and comparison with, all available and relevant water quality criteria. It also involved commissioning several experiments to document contaminant partitioning. Second, existing ecological effects information was reviewed from other similar and worst-case discharges elsewhere to provide some idea of what might and might not occur, especially in terms of direct fishery impacts, contamination of finfish and invertebrates and biomagnification of contaminants . Third, the possibility of phytoplankton bloom stimulation was evaluated through use of productivity models .

The screening-level ecological risk assessment focused on comparing calculated contaminant concentrations at the edge of the initial mixing with water quality criteria based on acute toxicity, and comparing calculated contaminant concentrations beyond the 200 m radius initial mixing zone with water quality criteria based on chronic toxicity. The results of this work are provided in a separate report (Cardwell et al., 1994). A report on the effects of nutrient inputs is in progress (Y. Azov, Technion, in preparation).

Below, I address ecological, fisheries and contaminant issues from the perspective of existing data and experiences elsewhere. Where appropriate I use a comparative approach, drawing on information from other sea outfall situations where inputs have been quantified and related to longterm monitoring data on the contamination and ecological health of marine resources in and around the discharges. The most relevant experience comes from Southern California in the US, where discharges have been monitored for over a quarter century. Southern California also occurs along the same latitude range as Israel's Mediterranean coast.

A word about literature citations used in this and the Parametrix report. There are literally thousands of excellent references on the fate, toxicity and bioaccumulation and longterm effects of trace elements on aquatic and marine organisms. It is impossible to cite them all here. What is most important are those reports referring specifically to the ecological impacts and injuries of point source and sea outfall discharges of trace metals, a body of literature that is a small fraction of the total. Thus our citations are limited to these. In addition, the reader is also reminded that many hundreds of the marine and aquatic toxicology studies have already been screened for use in establishing acute and chronic water quality criteria offered by the U.S.

EPA and the State of California. Thus reference to these criteria is reference to the most qualified of the toxicity and bioassay literature.

3.0 Haifa Bay and It's Marine Resources

Haifa Bay is a major eastward indentation of an otherwise straight and unrelieved north-south trending Eastern Mediterranean coast. On the north it is bounded by the small peninsula occupied by the city of Akko (Acre). Fifteen kilometers to the south the Bay is bounded by the City of Haifa on the promontory of Mt. Carmel. The smooth curve of sandy shoreline between Akko and Haifa is intersected by two rivers, the Na'aman near Akko and the Kishon near Haifa. The Kishon drains the historic Jezreel Valley to the east. The shoreline and bottom of Haifa Bay is predominantly sandy. However, a pair of long low-relief sandstone outcrops extend several kilometers north-north-east from the promontory of Mt. Carmel.

<u>Resources and Resource Uses</u>. Small but significant commercial and artesanal fisheries take place in the southern portion of Haifa Bay. The predominant gear is purse seine for pelagic fish and trammel-net for near-bottom fish and shrimp (S. Pisanti, Department of Fisheries, Haifa, personal communication, December 15, 1994). Small-boat fishermen carry out purse seining at night under artificial lighting between the Kishon River entrance and the end of the outer breakwater. Sought pelagic fishes include sardine (<u>Sardinella</u>), anchovy, mackerel (<u>Scomber</u> spp) and bullet tuna (<u>Auxis</u> spp). Baraccuda (<u>Sphyraena</u> spp), numerous species of sea breams (<u>Diplodus</u>, <u>Oblata</u>, <u>Lithognathus</u>), red mullet (<u>Mullus</u> spp) and several species of penaeid shrimps are taken by trammel net. Further offshore (5-10 km) bottom trawls take shrimp and bottom fish northward to a submarine canyon offshore of Akko.

Other living resources in the area include non-commercial invertebrates and fishes such as mantid shrimps, swimming crab, octopus, squid and urchins. Infauna of the sandy subtidal sediments include a variety of polychaete worms, small infaunal crustaceans and other bentic infauna. Predatory and non predatory gastropods also occur in abundance (Hornung et al). Along the proposed outfall alignment, the abundance of infauna is high inshore (1.5 km) decreasing rapidly offshore (3.5 km). The low-relief outcrops are thickly covered with a unique assemblage of marine seaweeds and animals. Underwater photographs show that the sand adjacent to these reefs is rippled from bottom currents (Galil, IOLR, personal communication). The status and distribution of sea birds, marine mammals and reptiles has not been determined.

Several aspects of the fauna and flora of Haifa bay and the coast of Israel are important to understand. First, the Eastern Mediterranean is one of the least productive marine ecosystems in the world, largely because construction of the High Aswan Dam on the Nile River in the 1950's caused a major reduction of nutrient input into this region. However, this in fact makes the remaining and highly diverse resources more valuable than they would otherwise be, and this is reflected in the high market value of locally caught seafood. Second, a significant portion of the fauna of this area is derived from organisms that have been entering the Mediterranean since the opening of the Suez Canal over a century ago (Galil, 1990). This "Lessepsian" fauna includes fishes, seaweeds, crustaceans and many other organisms. The reef outcrops of Haifa Bay are the northern-most point of attachment of epibenthic Lessepsian seaweeds and invertebrates and therefore represents a unique ecosystem.

Other Potential Sources of Pollution. Haifa Bay receives domestic industrial, agricultural and natural runoff and pollutants from several cities, the two rivers, harbor vessel activity and, in the past, from a chlor-alkali plant near Akko (Roth and Hornung, 1977 and Hornung et al, 1984). The lower Kishon River receives wastewater inputs from the Haifa Sewage Treatment Plant, from a large refinery, and from two fertilizer plants. The river and wastewater flows into Haifa Bay after passing through a small fishing vessel basin and the Haifa shipyards, and enters the Bay between a pair of rip-rap breakwaters. Aerial photographs taken during heavy rain period in the winter of 1992 (Haifa Chemicals, Ltd., personal communication, December 13, 1994) and other years (Haifa Town Council Office, December 14, 1994) show sediment-laden plumes entering Haifa Bay from the Kishon. Sediments of the lower industrialized part of the Kishon are heavily contaminated by petroleum hydrocarbons and trace metals (Cohen et al., 1993; Kochava and Eilon, 1993). Concentrations of nitrogen, phosphorous, fuel, organic matter, nickel, chromium, copper, vanadium and zinc in the upper 15 cm of lower Kichon River sediments have been 5 to more than 10 times higher than normal (uncontaminated) sediments prior to dredging episodes that occur at two to three year intervals (Kochava and Eilon, 1993). These dredged and contaminated Kishon River sediments are dumped offshore of Haifa Bay.

An oil-fired power plant takes in cooling water from inside the breakwaters and discharges it at the surface outside the southern breakwater. Southwest of this are the commercial docks including a large container-ship port, a grain terminal and a cruise ship dock area, all protected by the outer breakwater. A long riprap breakwater extends two km eastward from the Haifa promontory, protecting commercial, military and cruise ship docks of Haifa Harbor. An active ship anchorage occurs outside (northwest) of this outer breakwater. All these facilities - within the river, within the harbor and outside the harbor - are potential sources of domestic and industrial pollution to Haifa Bay.

4.0 Issues and Concerns (Resources at Risk)

A wide variety of issues were identified during meetings and on site visits to Haifa and Tel Aviv on December 10-15, 1994. The author, accompanied by Dr. Rick D. Cardwell, Parametrix, noted concerns from various groups including staff of Technion, of the Israel Oceanographic and Limnology, of Haifa Chemicals, Ltd., of the City of Haifa, of The Israel Ministry of the Environment, of TAHAL Engineers, Ltd., and of the regional federal fisheries officer, Haifa Chemicals Ltd. The primary concerns are with long-term ecological and fishery injury from toxic chemicals and settleable solids, and potential ecological impacts of, and recovery from, a system failure. The ecological concerns include acute and chronic (long-term) toxicity to marine organisms, contamination of marine organisms and biomagnification of trace metals. These issues come together in determining not only the efficacy of a sea discharge but also its location offshore. The specific issues brought to the authors attention are;

<u>Contamination of Marine Life and Seafood</u>. In addition, there is concern that fish and shrimp may become contaminated with metals from the discharge, both through bioaccumulation and biomagnification. *What is the chance the proposed discharge will promote bioaccumulation and biomagnification of trace metals in the fishery food web?*

<u>Fisheries</u>. Small but significant commercial and arsenal shrimp and finfish fisheries occur in and offshore of Haifa Bay. There is concern that the proposed outfall discharge may adversely affect the distribution, abundance and catchability of shrimp and fish resources. *Will the discharge, directly or indirectly, reduce the catch or value of fishery products? What is the optimal location for the diffuser to minimize injury to fishery resources?*

<u>Disturbance to Reef Communities</u>. As noted above, approximately 3 km from shore and running parallel to the shore for several kilometers are two long low relief outcrops of sand stone colonized by a luxuriant growth of attached seaweeds and animals. These reef areas, otherwise surrounded by coarse sand, also provide sanctuary for fish and crustaceans (Galil, personal communication). The concern is with both potential injury of this marine life from exposure to toxic metals and from potential exposure to settling solids. *How close to these reefs can the diffuser be located without injuring the reef community?*

<u>Disturbance to Benthic Infauna</u>. There is concern that settling solids containing heavy metals may accumulate in the sediments around the discharge points, smothering normal benthic infaunal communities and also providing a secondary source of metal contamination to benthic and pelagic organisms. There is also concern about the impacts of construction on resident marine life. *Will solids accumulate in the sandy sediments to the*

extent that benthic marine life will be injured? Will deposits, if they accumulate, become a significant secondary source of metal contamination to bottomfish, shrimp or pelagic fish? Will construction damage bottom life and if so how long will recovery take?

Outfall Breakage Impacts, Emergency Response and Recovery. The proposed outfall is within reach of anchors from ships. If the outfall is extended to deeper water (beyond 3 km) the presumed risk of damage from anchors increases. If the diffuser is broken, effluent will be released with low dilution and since it is heavier than seawater, may spread only partially diluted over the sea floor injuring benthic resources and bottom fish. The ease in which the diffuser can be repaired and the flow temporarily stopped is of concern. *What resources might be injured by an accidental release of poorly-diluted effluent and how long would recovery take? What discharge location is safest to minimize system damage and what backup or emergency capabilities are needed?*

Water Contact (Swimming and Diving). One year ago (1993) a bloom of noxious algae occurred in Haifa Bay. Swimmers complained of itchy stinging conditions. It was assumed by many that nutrients, stored in water and sediments of the Kichon River, were released during storm events and was the cause of the nearshore plankton bloom. This outbreak leads to concern that nutrient inputs from the proposed Haifa Chemicals Ltd. outfall may stimulate more frequent blooms of noxious algae. *What is the possibility of causing red tides and other outbreaks from nutrients discharged offshore? Is there a location offshore beyond which algal biostimulation, if it occurs, will not cause a problem?*

Aesthetics. There is concern that suspended and settling solids from the discharge will produce a plume visible in the clear water beyond the discharge zone. In addition, there is concern that nutrient input may stimulate blooms of visibly noxious algae beyond the discharge zone. *Will the plume be visible?*

The balance of this report address the first five of these issues. The issue of most concern appeared to be metal contamination of marine life and sea food and so this is given the most effort, below. Issues concerning nutrient impacts and plume visibility are being addressed by Technion (Y. Azov, in preparation).

5.0 Effluent Composition, Contaminants of Concern, Mass Loading

To properly address the issues it is important to understand the amount, mass loading and fate of effluent contaminants.

Average concentrations and mass emission rates of effluent components are summarized in Table 1. The primary contaminants of concern are the trace metals cadmium (Cd), chromium (Cr), copper (Cu) and zinc (Zn), suspended solids (SS) and nutrients. pH is not an issue under normal operation.

Of the contaminants of most concern, the Haifa Chemicals outfall will discharge per year 10 metric tons (mt) of chromium, 2.6 mt of copper, 2.3 mt of cadmium, 8.4 mt of nickel and 54.3 mt of zinc and substantially smaller quantities of arsenic (As, 0.6 mt), lead (Pb, 0.5 mt), silver (Ag, 0.25 mt) and mercury (Hg, 0.02 mt). Compared to 1992 permitted wastewater discharges into the Southern California Bight, mass inputs from the Haifa Chemicals discharge will be within the same range or lower except for chromium (about a factor of 4 higher), cadmium (about 10-fold higher) and zinc (about twice as high). However, compared to past permitted inputs from the California outfalls, the inputs from Haifa Chemicals are all considerably smaller (see below).

Table 1. Comparison of Proposed Haifa Chemicals and 1992 Southern California mass emissions.

Haifa Character	Haifa Value (1)	Haifa Unit	Haifa mT/Y	1992 Mass Emission Rates., So. Cal. Outfalls (SCCWRP, 1994) JWPCP (2)	HTP (3)	OCSD (4)	PLTP (5)
Flow	200000	L/Hr	-	47945205.5	52739726	35388127.9	28310502.3
Density	1.065	25C	-				
pH	<1		-				
H+	0.24	g/L	420.48				
HCl	7.4	g/L	12964.8				
Cl-	80.2	g/L	140510.4				
P205	1.7	g/L	2978.4				
Total P				2768	2169		
Ca	37	g/L	64824				
NO3	2.2	g/L	3854.4	101	104		
NH3-N	0		0	17706	10390	7148	7857
Na	2.9	g/L	5080.8				
K	6	g/L	10512				
Amyl alcohol	0.1	g/L	175.2				
TSS	1	g/L	1752	31256	15647	14287	17870
Cr	5.5	mg/L	9.94	7	1.9	2.5	-
Cu	1.5	mg/L	2.63	12	15	12	8.9
Cd	1.3	mg/L	2.28	bd	0.2	0.3	bd
Zn	31	mg/L	54.31	37	28	15	18
Ni	4.8	mg/L	8.41	17	5.5	8	bd
Mg	400	mg/L	700.8				
F	550	mg/L	963.6				
SO4	550	mg/L	963.6				
Fe	60	mg/L	105.12				
As	0.34	mg/L	0.6	1.6	2	1.1	0.79
Pb	0.28	mg/L	0.49	bd	0.6	1	bd
Ag	0.14	mg/L	0.25	2.6	2.8	1.5	bd
Hg	0.014	mg/L	0.02	bd	bd	bd	bd

1-Data provided by Technion, "Chemical analyses of Haufa Chemicals Plant Wastes" , Table 1. November, 1994.

2-Joint Water Pollution Control Plant, County Sanitation Districts of Los Angeles County

3-Hyperion Treatment Plant, City of Los Angeles

4-County Sanitation Districts of Orange County

5-Point Loma Treatment Plant, City of San Diego

6.0 Marine Life and Seafood Contamination

All of the trace elements in the Haifa Chemicals Ltd. plant effluent occur naturally in the sea and in marine life, but at very low concentrations. Most, such as chromium, zinc and copper are required by living organisms and, within certain ranges, their concentrations in tissues are regulated. At concentrations outside this range, which differs among organisms, these may be limiting (low concentration) or toxic (at high concentrations). In the dissolved form, all of them will bioaccumulate in marine organisms given appropriately high concentrations and durations of exposure. Cadmium and mercury have no know biological function, when accumulated in tissues the depurate slowly.

Will metals from the proposed discharge will contaminate seafood and wildlife species?

Although there is concern that marine life in the area may become contaminated with metals from the discharge, several lines of evidence suggest that, either through direct bioaccumulation or biomagnification, there will be no measurable excess accumulation of metals in fish or most invertebrates.

1) *No Excess Contamination from Contaminants already Released in Haifa Bay*. Seafood and marine life of Haifa Bay and the adjacent Israeli coast already contain concentrations of trace metals. Since the mid-1970's Hornung and colleagues have conducted extensive studies of the levels of trace contaminants in fishes and invertebrates of the Israeli coast, including Haifa Bay (Roth and Hornung, 1977; Hornung et al., 1984, Hornung and Kress, 1991). These data generally confirm that with the exception of mercury, concentrations of trace metals in fish and shellfish are low and comparable to concentrations found in similar species in other parts of the world. Mercury, the notable exception, also occurs naturally in Israeli coastal fish and shellfish but has been found in elevated concentrations in fish and gastropods from Haifa Bay due to emissions of organic mercury from the chlor-alkali plant (Hornung et al., 1984 and Hornung and Kress, 1991); .

2) *Forecast from Screening Level Ecological Risk Assessment (SLRA)*. The results of the SLRA (Cardwell et al., 1994) indicate that the most stringent acute and chronic water quality criteria will be met at the edge of the acute and chronic mixing zones. As noted by Cardwell et al. (1994), these criteria (especially US EPA) are designed to protect against excess bioaccumulation as well as chronic and acute toxicity. The limiting assumptions to this forecast are that (1) Israeli species are no more sensitive or susceptible than the many tropical and temperate species used to develop the US EPA or California criteria and (2) that the variability of concentrations in the effluent is not substantially greater than what has been measured so far (see Cardwell et al.,

1994). These assumptions can be tested only through additional follow-on measurements of contaminants in selected species and continued documentation of contaminant concentrations in the effluent.

3) *Experience Elsewhere..* Current trace metal inputs from the four Southern California wastewater discharges are not contaminating marine life beyond the initial dilution zones (Mearns, 1992). In the past, under larger mass loadings, there were cases of contamination in some invertebrates, but not in finfish. For example, in 1974 when SCCWRP surveyed contaminants in fish around the LA County discharges at Palos Verdes, California, mass emission rates for cadmium and chromium were 8.5 and 43 times higher than the projected Haifa input. Sediments around the outfall were highly contaminated with these and other metals: 10 to over 100 times background.

Edible tissue (mainly muscle) from twelve popular seafood species - six finfish and six invertebrates - were collected in triplicate composites from both the Palos Verdes outfall and uncontaminated control sites and analyzed for trace elements (Young et al., 1981). Despite the high input and high sediment contamination, there was no elevation of cadmium in fish muscle tissue above a detection limit of 0.01 ppm wet weight (Young et al., 199??). Two of five invertebrates had outfall-area elevations of 2x background (lobster muscle) and 2.8X background (scallop muscle). Two species, prawn (penaeid) and sea urchins, had depressions such that control site animals had 1.3 and 3.3 times more cadmium than outfall-area specimens. Thus in this worst case situation, involving mass input of cadmium 43 times higher than predicted for the Haifa Chemicals discharge, there was no increased contamination of fin fish, urchins, prawns, crab or gastropods and at most a 2-fold increase in lobster and 2.8-fold increase in scallops collected within the influence of contamination.

Likewise, there were no elevations of chromium in finfish above a detection limit of 0.01 ppm at the Palos Verdes outfall area of high input and high sediment contamination. Three of six shellfish (abalone, scallop and crab) in the outfall area experienced 100x, 10 x and 2x increased concentrations of chromium in edible tissue compared to uncontaminated control sites; three invertebrates - lobster, prawn and sea urchin - experienced no excess contamination. Thus in this worst case situation, involving mass input of chromium 8.5 times higher than predicted for the Haifa Chemicals discharge, there was no excess contamination of chromium in edible tissue of finfish, lobster, prawn or sea urchin, a slight (2X) excess in crab, but a significant increase in gastropod and bivalve mollusks (abalone and scallops).

DeGoeij et al (1974) also discovered lack of metal bioaccumulation in liver tissue of flatfish exposed to the same contaminated sediments and discharge several years earlier: in fact several contaminants, notably cadmium, were lower in livers of fish from the contaminated site. Similar results were reported in a second study except that chromium was found to be elevated in liver and gonad of sole from the heavily contaminated outfall area (McDermott et al., 1976). More recently, Roy-Burman et al (1989) reported a similar lack of relationship between tissue and sediment metal contamination for another flatfish species collected from contamination gradients near the Hyperion Sewage Treatment Plant outfalls in Santa Monica Bay, California. Finally, an independent US federal study (Meador et al., 1994) concluded that, with the exception of mercury, there was no obvious positive relationship between metals in sediments and fish liver for the entire US west coast.

4) *No Biomagnification.* It is popularly believed that all pollutants discharged to the marine environment experience biomagnification through the food web, i.e.., increased concentration with increased trophic level. While this is true for organic mercury compounds and chlorinated pesticides, these are the exception, not the rule. There is abundant evidence that copper and chromium do not biomagnify in aquatic food chains (ATSDR, 1990 and 1992b). For cadmium, ATSDR (1992a) notes that while there is strong evidence for food chain bioaccumulation, the potential for biomagnification is uncertain and in need of study. For zinc, ATSDR (1994) notes that it does not biomagnify through the terrestrial food chain, but makes no mention of aquatic or marine food chains.

Of the trace elements of most concern in Haifa Chemicals effluent - cadmium, chromium, copper and zinc - none have been demonstrated to undergo biomagnification in marine ecosystems. Some evidence for this was presented in the previous section - i.e., under the massive inputs experienced at the Palos Verdes discharge in the 1970's there was some contamination of several mollusk species, but no excess in muscle or liver of finfish. Much stronger evidence comes from studies specifically directed at establishing correlations between tissue contaminant concentrations and trophic levels of marine organisms derived from food habit analysis and from analysis of chemical indicators of trophic level such as the cesium:potassium ratio (Young, 1984 and 1988; Young and Mearns, 1994; Young et al, 1980, 1987 and 1988). For a calibrated food web of the Palos Verdes outfall area concentrations of the non-pollutant cesium, and the pollutants mercury, DDT and PCB's increased with trophic level whereas cadmium and chromium decreased and copper and zinc exhibited no trend (Young et al., 1980). The mean trophic amplification factor for mercury in 12 food webs was 5.2 per trophic level (Young and Mearns, 1994). By contrast, all other metals either had no significant amplification factor, or negative ones (Young, 1988).

As part of this investigation D.R. Young (EPA, Newport, Oregon) and I did a brief analysis of trace metal biomagnification potential using unpublished 1992 and 1993 Kiryat Yam and Haifa outfall alignment data provided by Technion. Diets of the 12 species of fish were estimated from literature reports and the taxa assigned provisional trophic level assignments. These ranged from herbivorous (Trophic Level 2) fish (e.g., rabbitfish, Siganus rivulatus) to the predatory (Trophic Level 4) baraccuda (Sphyraena sphyraena). Based on these data Young (personal communication, December 31, 1994) calculated a mercury amplification factor of 5.4, r=0.89. This is entirely within the range of the Southern California examples (4.5 to 6.5) suggesting a potential structure no different from that in Southern California. I then fit the exponential model to the other contaminants: none were significant (r's less than 0.4 and mostly less than 0.2) and half were negative (suggesting bio-dimunition). This analysis, though very preliminary, suggests that Israeli nearshore food webs have a bioaccumulation (and biodimunition) potential no different than for these other cases.

In summary, then, based on several lines of evidence, prediction and experience, it is highly unlikely that fish and most invertebrates in the Haifa discharge area will experience measurable elevation of tissue trace metal content. Only one line of evidence, experience at a very heavily contaminated outfall site in the mid-1970's, suggests there is a very remote chance that some invertebrates (lobster and scallops, none of which are represented in catch data provided to date) could bio-accumulate Cd by a factor not exceeding 2-3 in the immediate outfall . There is also a remote possibility that and that crabs in the immediate discharge area could bioaccumulate Cr by a factor not exceeding 2X while gastropods (carnivorous snails, such as studied for mercury by Hornung et al) could bioaccumulate Cr by a higher factor. Prior to and during discharge, targeted monitoring of several trace elements in liver of flatfish (or other truly-resident fish), of predatory gastropods, and of a bivalve mollusk could be useful in confirming that this risk is indeed negligible as predicted.

7.0 Fisheries

Commercial and artesanal shrimp and finfish fisheries occur in and offshore of Haifa Bay. There is concern that the proposed outfall discharge may adversely affect the distribution, abundance and catchability of shrimp and fish resources. *Will the discharge, directly or indirectly, reduce the catch or value of fishery products? What is the optimal location for the diffuser to minimize injury to fishery resources?*

Two aspects of the health of fishery stocks were brought to the author's attention: (1) direct impacts on adult fish and shellfish and (2) subtle sublethal effects on fish eggs and larvae, with concern that southern Haifa Bay may be a spawning and nursery area.

Based on results of the SLRA forecast (Cardwell et al., 1994), water and sediment outside the 200 m discharge zone will neither be acutely or chronically toxic to fish and invertebrates or their eggs and larvae: the criteria employed are expressly designed to prevent this. However, there may be other interesting impacts on fish and invertebrates. Elsewhere, outfalls have been shown to act as artificial reefs, attracting attached biota (seaweeds and animals) and resident fish populations. Allen et al (1976) described the occurrence of nearly a hundred species, noting that attached and reef community structure changed with depth and distance from shore (0 to 8 km) along the outfall structures. The amount of marine life and harvestable fish that will be attracted to the Haifa Chemicals outfall is uncertain and depends on the nature of the substrate (is the outfall material suitable for attached biota?) and its diversity (i.e.., the extent of rock rip-rap, anchor design, hiding places).

I was unable to obtain evidence that southern Haifa Bay is a spawning or rearing area for Israeli coastal fish and invertebrates (ie, Walline, 1987). Undoubtedly, it is, due to protection from prevailing currents and proximity to elevated primary production nearshore. Again, the SLRA predicts no effects. Only new survey work can confirm this and the extent to which eggs and larvae are or will be affected. However, it should be noted that continued release of pollutants (especially petroleum hydrocarbons) from the adjacent Kichon River should not be excluded as a factor in any impacts seen in subsequent studies. Likewise, entrainment from the power station cannot be ruled out as a significant impact on eggs and larvae.

Otherwise, it is difficult to see that within Haifa Bay, one particular discharge point is preferable to another with respect to protecting fisheries. Egg and larval abundances are likely to increase with proximity to shore so that there may be additional safety in locating the discharge as far from shore as feasible. An egg and larval survey is needed to determine where abundance is high.

8.0 Disturbances to Reef Communities

As noted above, approximately 3 km from shore and running parallel to the shore for several kilometers are two long low relief outcrops of sand stone colonized by a luxuriant growth of attached seaweeds and animals. These reef areas, otherwise surrounded by coarse sand, also provide sanctuary for fish and crustaceans (Galil, personal communication). The concern is with both potential injury of this marine life from exposure to toxic metals and from potential exposure to settling solids. *How close to these reefs can the diffuser be located without injuring the reef community?*

The results of the SLRA indicate that there will be no acute effects on marine life at the edge of the 200 m radius mixing zone, and no chronic effects beyond this. Clearly, the discharge should be located so that the mixing zone does not overlap the reefs. Unless it is demonstrated that some reef organisms are considerably more sensitive to contaminants (including solids) from the diluted discharge than the species used to derive the environmental quality criteria, then it is not possible to offer a better recommendation. However, in the event of damage to the diffuser, there is need for an additional "safety-factor" with respect to discharge location (see below).

Outfall construction could injure attached marine organisms on the reefs, particularly if they are exposed to many days of suspended sediment plumes. However, a greater concern is direct physical damage from anchored vessels: anchor chain is particularly damaging to sea grass beds and attached seaweeds. Caution should be taken during construction to avoid prolonged activity on the reefs.

9.0 Infauna

There is concern that settling solids containing heavy metals may accumulate in the sediments around the discharge points, smothering normal benthic infaunal communities and also providing a secondary source of metal contamination to benthic and pelagic organisms. *Will solids accumulate in the sandy sediments to the extent that benthic marine life will be injured? Will deposits, if they accumulate, become a significant secondary source of metal contamination to bottomfish, shrimp or pelagic fish?*

Roberts (1993) predicted that solids from the outfall may form "mounds" of sediment. By contrast, the SLRA (Cardwell et al., 1994) forecasts that for several reasons there should be no chronic accumulation of contaminated solids (which could smother infauna and contaminate survivors). The primary reason this is not expected is that fine solids do not now accumulate along the alignment. Regardless of the veracity of past current measurements , underwater photos taken at 3 km near the reefs show the occurrence of highly rippled coarse-sand sediments (Galil, personal communication, December 13, 1994). This observation is consistent with a low abundance of infauna compared to densities reported further inshore (based on unpublished data provided by Technion).

In the event that the bottom area is not as energetic as it appears visually, what might an accumulation look like in aerial extent and how might it affect the infauna? The only experience is with past discharges such as in Southern California and at several other industrial outfalls. Note that the solids mass emission from the Haifa Chemicals discharge will be small (1752 mt/y) relative to current (1992) inputs at permitted Southern California outfalls (14,000 to 31,000 mt/y; Table 1). In the past, inputs from these outfalls were considerably higher (some over 100,000 mt/y). Several studies were done to document relationships between the mass SS input and the area and biomass of infauna affected by these inputs (Mearns and Word, 1982); exponential relationships were found. Using one of the published relationships I calculated that an area of 0.016 sq km (16,000 sq m) surrounding the discharge could be occupied by a "changed" infaunal community (as defined by the Infaunal Trophic Index, in Mearns and Word, 1982). If circular, this area would have a diameter of radius of 71.4 m (d=143 m). This area is about one-eighth the area enclosed by the 200 m-radius authorized dilution zone (total area, 125,664 sq m).

While interesting, this comparison may not be particularly valid for several reasons. The Southern California outfalls discharge organically-rich solids that actually contribute to increasing the biomass (and, presumably, the productivity) and decreasing the diversity of the infauna (Mearns and Word, 1982). There is no indication that the Haifa Chemicals effluent solids contain any organic matter. Thus, they will probably not contribute to changing infauna populations through organic enrichment (unless ambient organic matter co-precipitates). (Clark (1992, p 117) cites that may be a useful comparison: the release of 1.5 million tons/year of clay (porcelain) wastes into a British estuary. Although, some bivalves intolerant of this fine material, there was a unique clay waste fauna (polychaetes, bivalves, urchin, holothurian, ophiuroid), all of which were fed upon by plaice, dab and sole.)

Second, settling rates of the sewage solids may be considerably different than for the fertilizer plant solids. No data is available to compare how similar or different these rates may be.

Nonetheless, this kind of calculation gives some rough idea on what the scale of effect might be: for example it seems to be on the order of a fraction of the size of the 200m radius approved zone rather than something orders of magnitude larger (i.e. 1 sq km) or smaller (e.g. 10 to 100 sq m).

Construction activity will disturb the sea floor and benthic marine life, primarily by moving and resuspending sediments along the outfall alignment. No reports could be found on the effects of outfall construction or the recovery of infaunal communities following construction. However, we can assume that fish and crabs may take advantage of sediment disturbance by preying on dislocated organisms such as polychaetes and amphipods (this happened during shoreline washing following the Exxon Valdez oil spill). Once construction activity is over, benthic organisms should begin recovery within days. Also it is like such impacts will be restricted to the immediate area along the outfall and that it would be difficult, without pinpoint sampling, to accurately measure an impact (such as a drop in diversity or change in relative abundance of species) or recovery from such an impact.

In summary, the best available information suggests that solids accumulation will be ephemeral and when it occurs will be within the scale of the 200-m approved dilution zone. Within this area, infaunal communities will undoubtedly be disturbed, but it appears that only monitoring experience will determine the nature of the disturbance (decreased or increased abundance and diversity) and its actual scale and persistence.

10.0 Outfall Break

The proposed outfall is within reach of anchors from ships. If the outfall is extended to deeper water (beyond 3 km) the presumed risk of damage from anchors increases. If the diffuser is broken, effluent will be released with low dilution and since it is heavier than seawater, may spread, only partially-diluted over the sea floor injuring benthic resources and bottom fish. The ease in which the diffuser can be repaired and the flow temporarily stopped is of concern. *What resources might be injured by an accidental release of poorly-diluted effluent and how long would recovery take? What discharge location is safest to minimize system damage and what backup or emergency capabilities are needed?*

Presumably, poorly diluted high-density plume will spread over the sea floor, subsequent dilution dependent on bottom currents. Low pH rather than trace metals is expected to be the primary factor causing mortality to infauna and other benthic resources (such as epibiota on low-relief reefs). For example, at a dilution of 40:1 (Roberts, 1993, page 3) the pH will be 3.0, far below that tolerated by most benthic organisms. Low dilutions will produce lower pH values.

Assuming an acute lethal event occurs, and the discharge is short-lived (a few days), the question is how long will ecological recovery take? The simple answer is that recovery is dependent on planktonic settlement to sediments. Since most organisms experience seasonal changes in reproductive output, recovery of adult populations will depend on what season an accident occurs: for example, if it is in summer, adequate recruitment of animal larvae and seaweed spores may not occur until the next spring.

Unfortunately, we have very little experience with recovery from acute damage to sub-tidal benthic resources. Experience at oil spills, where recovery has been well documented, does not help much since their effects are almost always on intertidal ecosystems. However, we may have some other potentially useful situations, including recovery of benthic fauna and contamination following termination of sewage discharge to 1.6 km offshore at 20 m deep off Orange County. During two decades of continues discharge of 140 mgd of primary effluent conditions at the diffuser included high sediment hydrogen sulfide, organic carbon, lead, and copper, and a super-abundance of bottom feeding fish, pollution-tolerant lucinid clams, a depauperate brittlestar community and low diversity (SCCWRP, 1973; Mearns and Greene, 1975; Greene, 1976; Smith, 1974). Smith (1974 and cited in Mearns and Greene, 1975) concluded that after several decades of continuous discharge, the benthic infauna community recovered within one-half to one year. Within one month of cessation of discharge, fish abundance was reduced 1-2 orders of magnitude. Within 6 months, infauna densities, species ratios and diversity returned to near-control values, and sediment metal concentrations dropped by 50 to 100% (SCCWRP, 1973). Recovery appeared complete within a year at this depth (20 m).

Clark (1992, page 75) cites several other cases of acute stress and recovery on marine communities. For example, in 1965 copper sulfate was illegally spilled on Dutch shoreline. Over several days a body of water containing 0.3 ppm (300 ppb) moved slowly up-coast killing plankton, fish and shellfish. Wind mixing averted major mortality to beds. Unfortunately, Clark (1992) does not cite follow-on observations of recovery times.

Stress and recovery from sea dumping may provide relevant experience. For example, Clark (1992, p. 117) cites a dredging-dumping experience in Uddevalla, Sweden during which there was a major loss diversity, but a one-year recovery. Other cases should be investigated.

Perhaps the community at most risk from accidental undiluted release may be the reef epibiota. If damaged by an acute episode of low pH, attached marine life will re-colonize rapidly. However, the new community will probably take several years to reestablish. During re-development (succession) It will be a productive but different, epibenthic community. If the opportunity arises, it may be worth conducting small-scale clearing and recovery studies to document potential recovery processes and timing.

11.0 Conclusion and Recommendations for Monitoring

Based on the Screening Level Risk Assessment (SLRA, Cardwell et al, in reparation) the proposed Haifa Chemicals Ltd fertilizer plant discharge will pose an small (unmeasurable) risk to marine resources of Haifa Bay. Evidence from other discharge situations appear to confirm this for several issues including bioaccumulation, biomagnification, toxicity to nearby marine life and fisheries. A key to protecting special resources (fisheries, reef biota) appears to be in judicious placement of the diffuser. A key to confirming the predicted safety of the discharge lies in a focused and responsive monitoring and research program.

A sampling and monitoring program needs to be established that provides two basic things: (1) pre-discharge confirmation of the assumptions of the forecasts and (2) operational tracking for longterm trends. Both aspects need to make measurements that can be reported rapidly so that mid-course corrections can be made during the final design and operation of the outfall and the discharged wastes. Cardwell et al (1994) have recommended some of the assumption-confirming measurements that need to be made. In addition to these, this author recommends a pre-discharge evaluation of fish egg and larval distribution in southern Haifa Bay.

In addition, a simple but focused longer-term monitoring program should be initiated prior to and following initiation of discharge. Simple visual observations of great relevance for some of the issues include periodic photo-documentation (day and night) of marine life along the outfall structure, and at nearby points on the reefs, and aerial overflights to document plume visibility and distribution. The potential for bioaccumulation of trace metals can be assessed using caged bivalve mollusks, with two or three cages of mussels or oysters deployed several meters above the sea floor for 3-4 weeks quarterly (at the edge of the 200 m radius dilution zone). Concentrations of trace metals in native organisms should be continued, with focus on a few selected species of resident biota, such as the predatory gastropods and perhaps one species of resident bottom-feeding fish (Mormyra?). These studies will require a remote reference or control situation. Local experts should be contacted to determine where that should be.

For one or two years it may also be valuable to collected benthic infauna at fixed or random stations at the edge of the 200 m radius dilution zone, and at a comparable reference area, to confirm that no changes are occurring as a result of the discharge.

All collected data should be analyzed and reported quickly - i.e.., 30 days - so that there is opportunity for making changes to the system or the effluent quality.

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