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INITIAL ENVIRONMENTAL ASSESSMENT PROFILE OF VANCOUVER HARBOUR

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ENVIRONMENTAL ASSESSMENT

PROFILE

OF

VANCOUVER HARBOUR

Prepared for:
Environmental Protection Service
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REVIEW NOTICE

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COMMENTS

Readers who wish to comment on the content of this report should address their comments to -

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In the preparation of this preliminary environmental assessment profile of Vancouver Harbour information from a variety of government agencies, municipalities and institutions was acquired and reviewed. I wish to acknowledge the assistance of all those participants in this most worthwhile endeavor and thank the contributors for their interest and guidance. I also wish to acknowledge the contribution and guidance of Mr. D. Goyette of EPS, scientific authority on this study. I hope this work will set the stage for a comprehensive integrated approach to the stewardship of this most valuable resource, Burrard Inlet/Indian Arm.

SUMMARY

A great deal of available literature and data on the Burrard Inlet and Indian Arm system has been collected. While many environmental features were reviewed, this report has emphasized environmental toxicological aspects of contaminants in water, sediment and biota.

Historical analytical results for water sediment and biota are limited in use because of the wide variety in technique applied, laboratory methods, lack of analytical controls or use of certified reference standards and restricted to site specific areas. When the reported data is found to be acceptable the precise location from which it was taken in many cases is not given. Recent data, however appears to be more reliable.

The existing data shows distinct areas of concern relating to toxicological effects of inorganic and organic contaminants on the marine resources. Much of this information is specifically related to nearshore industrial sites where process or waste discharges occur or where dredging was carried out. While most of the contamination has been noted in near shore areas, this may reflect the nature of the sampling programs and the focus of effort. Although highly contaminated areas may be localized by dilution, areas of moderate contamination are extensive and may markedly effect the water quality, the composition of sediments as habitats and related biota.

Environmental contamination of the Vancouver Harbour has been and is an ongoing condition affecting water quality, sediment and biota.

The key points from this study are:

1. Vancouver Harbour is chemically exposed to a variety of urban wastes which have severely affected some areas including False Creek, and certain industrial areas.

2. A 1982 review of the global distribution of fish tissue disorders (e.g. skin papillomas in flatfish) has shown the Vancouver area, between 1973 and 1976, to have the highest prevalence (56% to 60%) of those areas examined. Subject to

seasonal and geographic variations the frequency of skin tumors has been linked with urban and industrial activity.

3. While there is substantial knowledge of the oceanography and certain aspects of the chemical and biological elements there is a need to better understand urban waste contaminants in this marine ecosystem.

4. Urban wastes may be affecting the plankton which could be significant to fishery resources.

5. There is a need for a comprehensive biophysical information baseline on the Burrard Inlet system to permit realistic control and evaluation of this resource.

Despite the volume of environmental data on the Vancouver Harbour area studies have tended toward the physical and chemical evaluation overlooking, with some exceptions, fundamental assessment of the marine biology of the area and the effects of contaminants on biota from both a consumptive and biological standpoint. In the absence of this basic knowledge of the marine resources, including species distribution, abundance and habitat use, a critical environmental evaluation cannot be made. In any ecosystem a knowledge of the biota is fundamental as the organisms are the culmination of what the habitat can support representing an integreated temporal and spatial response to elements affecting the environment. Upon understanding these biological characteristics as an integral part of the ecosystem, anomalies represented by contaminant effects can be identified, studied and resolved.

It is apparent from this initial review that there are three areas that should be considered in improving our understanding of Vancouver Harbour environment.

1. Integrate and summarize existing data on a multidisciplinary basis to better understand their spatial and temporal aspects (e.g. Mass Material Balance) of contaminants in water, sediments, biota and tissues. Information review and literature search on a broader context should be conducted.

2. Collect basic information on environmental elements such as fisheries, marine mammal and avian resources, sediments, stormwater, non-point sources of inorganic/organic contaminant loading in the broader context of the harbour.

3. Conduct research on biological resources, (life cycles, distribution, abundance, ecology) contamination effects, and their pathways in the food web and its integration into the whole.

4. Further development of data base systems for the efficient management and integration of past, present and future investigations to maximize the information use in the most cost effective manner.

5. Program development should be undertaken in the broadest context involving all levels of government and users in order that resources and study needs be defined and integrated in the most cost effective manner.

The absence of even cursory long term information on the biota in Burrard Inlet limits our ability to properly evaluate the condition, resource values and biology of many species. Increased demands for urban fishing experiences, and aesthetic and biological interests in a high quality marine environment are prevalent. The gathering, collating and evaluation of information should begin, both to satisfy the increasing demands of the urban environment users and to establish a comprehensive biological baseline in order that trends may be observed and environmental crises as have occurred in other urban marine areas may be averted.

1.0 INTRODUCTION

A preliminary review of the literature and current work relevant to the environment of Burrard Inlet and Indian Arm has been made as the first step in assessing the level of knowledge in different aspects of this marine environment, however, because of the time constraints this report will focus on toxic elements. Literature was searched and contacts in institutions and agencies were made on the broadest environmental aspects: however this report will focus on toxic elements in the water, sediment and biota in the central harbour area of Burrard Inlet. This by no means reflects on the importance of factors such as climate, geology, land use drainage and waste inputs among others, which are critical to structuring a comprehensive understanding of the environment and should always be an integral part of any documentation.

In this connection it is important to recognize this work as an initial step, supplementing the earlier work developing a preliminary environmental profile by the Environmental Protection Service, Pacific Region. It is considered that this documentation will serve in the planning process for future work in designing studies, development proposals for the port, waste management inventories, ocean dumping applications, receiving environment studies in broadening knowledge of the area's biological resources and their response to contaminants.

Institutional and agency contacts included Federal, Provincial, District and Municipal governments, universities and research institutions. Each paper or publication has been reviewed, included in a bibliographic listing and the salient elements annotated and presented in "An Annotated Bibliography on some Aspects of the Environment of Vancouver Harbour, 1985." For more details than presented here and for bibliographic references in this text the reader should refer to the above document.

In the preparation of this report and the bibliography, five (5) preliminary maps of sampling points by author and date, summarizing where posible key information were developed. The maps are:

Map #	Title
1	Preliminary Environmental Profile Sample Points and Study Areas - 1985 Chart 3495
2	Preliminary Environmental Profile Sample Points and Study Areas - 1985 Chart 3483
3	Preliminary Environmental Profile Sample Points and Study Areas - 1985 Chart 3482
4	Preliminary Profile: Outer Burrard Inlet Sample Points and Areas - 1985
5	Preliminary Profile: Summary of Biological Resources of Burrard Inlet/Inidan Arm - 1985

The preliminary nature of the mapping required their exclusion from this particular report. However, they are available for review at the Environmental Protection Service.

Inquiries on this study and related elements should be directed to Mr. D. Goyette, Environmental Protection Service, Kapilano 100, West Vancouver, B.C. V7T 1A2 or by telephone at (604) 666-6711.

A review of existing data with respect to toxic chemicals in water, sediment and biota, and the methodologies used, is followed by concluding remarks and in a planning context, recommendations for future studies.

2.0 VANCOUVER HARBOUR - A GENERAL DESCRIPTION

Over the years Vancouver has undergone a transition from a natural system supporting a native culture to an industrialized and urban area supporting a multicultural community. As a result of industrialization and urban development the harbour area has changed significantly and the marine ecosystem has been subjected to a wide spectrum of industrial and urban wastes over the years. Direct and indirect effects on the environment have been observed such that today the common use of fish, water and shore areas is not possible due to restrictions, many of them a result of pollutant imputs from sewage and storm water runoff which effects the consumptive use of these local biological resources. While some sewage effects may be easily observed as are physical shoreline development effects other effects, from sewage, industrial and urban wastes are more subtle and definition more complex. Investigations in urban waterways in many areas have recently identified serious environmental and health concerns for which, without remedial action, continued inputs would exacerbate negative environmental effects. Harbours such as Puget Sound, which exhibit similar characteristics, have become polluted to such a degree as to make them priority areas for cleanup. In order to understand the effects of industrial and urban waste streams on the environment an understanding of that environment is required as well as the identification and characterization of toxic chemical inputs in the harbour.

3.0 REVIEW OF SOME ENVIRONMENTAL ASPECTS

3.1 WATER QUALITY ASPECTS

Water quality in Burrard Inlet is considered acceptable mainly because it is a well flushed system (Stockner and Cliffe, 1979). Indian Arm is similarly influenced but is more complex because of its deeper water, sill and fjord characteristic of periodic turnover which is well documented (Dunbar, 1985 and Davidson, 1979). Few apparent influences from urban sources affect the waters except in localized areas and for specific uses such as shellfishing which is closed because of the high fecal coliform levels, a result of sewer and storm water discharges. Water quality data is predominantly oriented towards permitted point source discharges in connection with compliance monitoring, a permit requirement on which a great deal of effort is expended by the Greater Vancouver Sewerage and Drainage District (GVS & DD), Municipalities and industries alike. The former include a large number of nearshore tests to monitor total and fecal coliform levels frequently in water for primary contact purposes during the summer beach high use periods. Swimming restrictions in summer are limited but the levels of coliform do require Burrard Inlet to be closed to shellfishing (Anon, 1984). Inorganic and organic analyses of discharges indicate the zones of influence of point discharges to be restricted to the discharge areas and as such are not as numerous as coliform analyses. Extensive monitoring of metals in the discharges and receiving water show loadings (Tanner, 1973 and Garrett, 1980) and receiving water data (Dwernychuk, 1981; Jordon, 1980; and Stukas, 1981). Some research shows that receiving water metal levels are found to be below typical toxic concentrations given in the literature (Jordon, 1980) however LeBlanc (1979) suggests sublethal effects are at work influencing cell division and C^{14} uptake in diatoms and dinoflagellates. Lewis et al. (1972) and Whitfield (1974) also indicate low level effects in connection with their work on the influence of chelators in marine systems.

Water quality in Burrard Inlet relative to non-point sources has not been addressed and, like storm water and other discharges, may have a marked effect on biota. Industrial landuse areas which predominate waterfront areas would be a major factor influencing water quality (Anderson, 1982).

Fresh water discharges into Burrard Inlet have been assessed including Lynn Creek where leachates from Premier St. landfill emanate (Derkson, 1980 and Lewis, 1983). The Capilano and Seymour Rivers hatchery discharges (Derkson, 1981) indiciate localized effects in the systems themselves but not downstream in Burrard Inlet.

Work on storm water discharge quality is minimal in this area with the exception of Jericho Beach outfall (Garrett, 1980). Again the flushing characteristics of Burrard Inlet appear to be the main feature in allowing the water quality to remain apparently acceptable if not for urban users, for the marine resources except in restricted zones of influence.

Comments

In reviewing the data and information base relating to water quality in Burrard Inlet and Indian Arm there is an apparent need to integrate a number of disciplines which in general have been studied in isolation when in fact they are all integral parts of the water environment. For instance Municipalities each do their own drainage studies, assessing basin features which link meteorologic, hydrologic, land form and use and geologic data, yet only in a general sense are these addressed in the marine study areas. While this information remains unintegrated, pollution loading estimates,land uses, problem areas in terms of discharges and net pollution contributions to the marine system cannot be understood comprehensively. In this connection there also needs to be a better understanding of species ecology before the water can be considered "acceptable." For instance Marliave (1985) noted the possibility of genetically different populations of cottid larvae in inshore and offshore waters. The urban runoff implications for this and other fisheries resources in this most affected inshore (dilution) zone requires investigation. In essence a total system evaluation of mass balances needs to be addressed in order to to appreciate the significance of urban point and non-point runoff on water quality.

Where as the effects of water quality on biota may be significant in the immediate sense, the effects of sediment quality as a result of chronic exposure from urban wastestreams may be more significant to the long term health of the marine environment and the related effects on fisheries resources.

3.2 SEDIMENTS AND BIOTA ASPECTS

In the following pages the existing data base on toxic chemicals in the sediments and biota are reviewed.

A review of the literature has identified a number of studies which reflect the status of knowledge on sediment contamination in Burrard Inlet. Most of this work has been done since the mid 1970's and has emphasized site specific, rather than broader studies of the harbour, to meet particular project needs in relation to ocean dumping or permit monitoring requirements including analysis of both inorganic and organic components.

3.2.1 Sediment Aspects

i) Physical aspects of the marine sediments in Burrard Inlet is not widely known. Gilmartin (1962), Ronald (1962), Bourne (1974) and most recently Brouwer (1984) made observations in Indian Arm, Burrard Inlet (Third Crossing), Port Moody Arm and its head respectively. Scattered references are also found in other works relating to the ecology of species in the area (Dobell, 1978 and Roelofs, 1983). The most detailed work in the area found in this inventory was by Blunden (1971) on the Third crossing where the author details the marine surface and subsurface materials to bedrock in a section of Burrard Inlet.

ii) Chemical aspects of the sediments have had greater treatment. Inorganic components in the sediments from studies to date indicate concentrations exceeding ODCA criteria (Cd 0.6 ppm, Hg 0.75 ppm) predominate in the shore zone where industrial activity and thus sediment sampling occurs. The most comprehensive compilation by Garrett (1984) summarizes metal levels in Burrard Inlet sediments and includes mercury, cadmium, and lead, the ranges of which are shown below.

	Element (ppm dry weight)		
Location	Hg	Cd	Pb
Burrard inlet	.25-84.5	.25-24.5	5-1710
Port Moody	.05-.10	3.9-4.5	2.4-34

Historic data on the Vancouver Harbour ocean dump site shows extensive use since the 1940's but very little analytical information exists on this site (Ward, 1980). Earlier work by McDaniel et al. (1977) assessed the site photographically noting little fauna on and in the silty-sand of the dump.

The sites for which chemical analyses of marine sediments have been made include Bayshore Westside Development and Vancouver Rowing Club in Coal Harbour, Allied Ship Builders, Hooker Chemicals (CanOxy), Menchions Shipyard and a number of areas in False Creek (EPS files, 1985). In fact the latter has been the most comprehensively studied area. Metal analyses at all sites include Hg, Cd, Pb, Zn and Cu and were originated from generally in excess of ODCA criteria in surface sediments indicating origination from urban sources. Work by Jordon (1980) and Bourne (1974) in Port Moody Arm shows metal distributions in sediments relating to Burrard Thermal Generation Plant and the Arm in general. Jordon (1980) used Al, Cu and Fe as tracers as they appear to occur in increasing proportions in relation to the discharge zone. Levels ranged from 30,000 - 32,500 ppm Al, 120-137 ppm Cu, and 36,000 - 37,300 ppm Fe.

Bourne (1974) conducted an extensive sediment study of 70 samples from the Port Moody area, noting higher metal levels in the fine sediment fractions. Among the metals, lead and zinc were found to range from 1-260 ppm and 44-663 ppm respectively. Sulphur was encountered in higher levels adjacent to the Pacific Coast Terminals dock, a fact also noted by Dwernychuk (1980). Bourne (1974) also noted the higher metal levels encountered are likely generated by automobile emissions, drum cleaning plant and residential runoff among others.

While the spatial distribution on the limited metals data covers a wide area, a great deal more work has been carried out on sediments and their toxicity in the laboratory and the field. Wong (1977) has been studying the natural and artificial origins, pathways and fates in a generic sense in a continuing project which includes Burrard Inlet. Investigations into metal toxicity, mobilization and accumulation using cod larvae and invertebrates by McGreer (1982) and McGreer (1980) in sediments from False Creek and near a ship repair facility show the sediments with high metal levels (Cd, 4.6 ppm; Cu, 428 ppm; Pb, 883; Hg, 1.2; and Zn, 777) to be toxic. Uptake of metals in invertebrates was not apparently related to salinity or contaminant concentration. Whitfield (1974) in this connection showed that sediment extracts reduced toxicity. In the lab studies lead was found to be accumulated the most in the test fauna.

More recent work on sediment toxicity of selected port industrial areas suggests potentially serious problems in the Harbour(Chapman 1984). Using a marine amphipod commonly used for this type of test the researchers identified the sediments of Vancouver Wharves, Neptune Terminals and the east basin of False Creek as toxic.

Comment

In reviewing the data it is considered that only the most recent information is reliable. Analyses conducted more than three years ago did not generally use measurements of accuracy or standards to allow for comparison. Programs are presently being put in place by Environment Canada and Fisheries and Oceans to reduce this uncertainty. This is particularly relevant to commercial laboratories which do much of the marine sediment analysis in connection with ocean dumping and research. Except in recent reports methodologies have been very sketchy on procedures concerning sample collection and analyses. However in spite of the critcism even the earliest information (Bourne, 1974) provides an idea of the extent of contamination and distribution of metals in marine sediments. It is apparent that most of the data on metals is reported as total or dissolved fractions and there exists no data on speciation, as done for organics. Total metal concentration, while providing a measure of the areal distribution of contaminated sediments, does not necessarily indicate what is biologically available.

Further the research has shown toxicological effects of sediments on laboratory fauna and information on total metal levels can be used to map areas of concern. It would however appear that the information on toxicology could be better and more realistically delineated through assessing benthic resources than depending on laboratory evaluation entirely.

iii) Organic contaminants in marine sediments have only recently been examined in Burrard Inlet and False Creek. Like inorganic components from urban waste streams, receiving water contributions have been made in varying degrees over the last one hundred years or more. Organic chemicals have been developed and used in proximity to the marine enviroment and as with inorganics, the sediments are a repository for organic materials.

Organics in sediments range from wood wastes to very complex toxins such as polychlorinated biphenyls (PCB's) or benzo (a) pyrene (B(a)P). Wood wastes tend to be selective on benthic recruitment depending on the relative proportions of wood to sediment. Optimum benthic production was found with 10 - 40% wood (Kathman, et al., 1984). This data is particularly relevant in areas of Burrard Inlet where there is a history of extensive booming. In this connection little definition of the wood waste and its effect in the harbour exists except in a generic sense (Duval, 1980). Research on the presence of organics in sediments has been summarized by Garrett (1984) whose work in this area on Priority Pollutants is ongoing. In Burrard Inlet observed levels of certain organics were as follows: PCB, ND - 14.4ppm; PAH, 2.7 - greater than 1000ppm (Garrett, 1984) and B(a)P 105 ug/kg (Dunn, 1980). In another paper (Dunn, 1980) the levels of PAH isomers of 5 or more fused rings in the sediments of the inner and outer areas of Vancouver Harbour were shown to exhibit 100 fold variation in the respective areas. In analysis of the relationship of Benzo (a) pyrene to these high molecular weight PAH's, significant correlation was found (Dunn, 1980). These data again suggest a relationship between human activity and high PAH levels. In comparing different sample types at the same location Dunn (1980) noted that there is a correlation between PAH levels in sediments and in marine organisms. Sediments are the major sink of PAH's in coastal waters and it appears that with few exceptions the levels are reflected in the flora and fauna of the area. An exception was in Coal Harbour where marina activities appear to have masked sediment effects on levels of B(a)P in Fucus sp. and mussels (Dunn, 1980). The author suggests the patterns of PAH isomers in sediments which provide a fingerprint of PAH isomers in the area and in marine organisms may reveal characteristics of uptake and retention of PAH. Dunn and Stich (1976) showed a gradation of B(a)P contamination toward a sewage outfall with levels ranging up to 121 ug/kg (dry wt.) not unlike that noted above (105ug/kg) for harbour areas. These are both high compared to data of 0.4 -4ug/kg for non-harbour areas. Unfortunately there is no data on B(a)P or PAH isomers in areas of Burrard Inlet affected by storm water effluent and more than the general reference to location given by Dunn (1980) is required for the data to have other than a generic value. More recent work on sediments from False Creek and specific areas of

Burrard Inlet by Hall (1983) conducted analyses of 12 Priority Pollutants, identified no chlorobenzenes, but found 13 PAH's ranging from Fluorene (16ppb) to Anthracene (165ppm). In False Creek 12 PAH's and Phthalate Esters (PE) were found in quantities greater than 1ppm. While these samples were selected at specific sites no relation to upland activities is noted. In other work however Hall (1984) identifies PAH and Phthalate Esters (PE) sediment concentrations to be greatest in the vicinity of storm water discharges and sewer outfalls respectively. Organics, like the inorganics, in sediments influence the distribution, abundance and condition of benthic flora and fauna.

Comment

Organic analyses of sediments for materials as noted above and those as required of specific projects such as under ODCA guidelines provide only a cursory overview of the levels and distribution of Priority Pollutants in Burrard Inlet. The scattered data that is available shows there is fairly wide spread sediment contamination particularly along the shoreline of Vancouver Harbour.

Since most of the organic data are recent there is a common basis in technology. However, a comparative analysis of techniques both for field sampling and laboratory analysis should be carried out along the lines of Dunn (1980). Any questions relating to the validity of data and techniques should be clarified now before a program of collection and analysis is carried out.

3.2.2 Biota

Since the mid 70's and in the past 2-3 years in particular tissue analysis for inorganic and organic contaminants in Burrard Inlet flora and fauna have been undertaken by a number of researchers.

Much of the information has been acquired in connection with studies attempting to determine the zones of influence of point sources of inorganic and organic pollutants and their bioavailibility to different fauna. Little of the work however has directly related to the consumptive aspects for people. In the following discussion inorganic, organic and pathological aspects are addressed.

i) Inorganic contaminants in the water column and sediments of Burrard Inlet have been observed to accumulate and affect marine fauna. Metal levels in biota are summarized in a comprehensive report by Garrett (1984) giving ranges encountered on a regional and local basis. In general mercury, cadmium and lead exhibited ranges of 0.05 - .74ppm, 3.3 - 7.5ppm and 31 - 770ppm respectively in tissue. The literature showed the Blue mussel (Mytilus edulis) to be the predominant organism used in tissue metal analysis although others including Macoma balthica, Tube worms (var.sp.) and Capitella capitata have also been used (Garrett, 1984). There are no data on metals in fish tissues in Burrard Inlet but some were found for False Creek which showed bottom fish to have higher metal levels than more pelagic fish (EPS/Fisheries Unpublished Data).

Again tissue analysis took on a sporadic occurrence as did the analysis of sediments. Invertebrate samples, which predominate the field, were collected from areas of known discharges to define effects of pollutants. M. edulis has been found to have consistantly greater metal levels near sewer outfalls (Popham, 1982). In a long term study (12 months) at 2 locations Popham (1982) found that, with the exception of copper, there was a correlation in the seasonal distribution of trace metals (dissolved) in sea water with that of mussel tissue.

At another location, Port Moody Arm, Jordon (1980) undertook tissue analyses of a composite of benthic invertebrates, predominated by polychaetes, for Al, Cu and Fe and found Fe to be in a higher range than found elsewhere. A study on cadmium bio-availability to M.

balthica and C. capitata in False Creek sediments suggested the metal was sulphide bound in the sediment and based on body burden analysis primarily available from the water column (Reid et al., 1981). The toxicological effects of contaminated sediments, as discussed earlier, were evident in experiments with Pacific Cod Larvae and M. Balthica where survival and burrowing ability respectively were examined (McGreer et al., 1980 and McGreer et al., 1981).

Body burden analyses for Cd, Mg, Pb, Zn and Cu in M. edulis have also been undertaken by the Waste Management Branch in the mid-70's which showed a tendency to reflect local conditions within a zone of influence. Samples, mainly from industrial port areas along the north and south shores of Burrard Inlet and in Indian Arm show M. edulis to be a good indicator organism (Gough, 1974 Unpublished Data). Pb levels were found to be high at Hooker Chemicals and Hg levels were suggestive of point source contamination at B.C. Ice and Cold Storage, Vancouver Wharves (E) and Hooker Chemicals. Zn was found to be high at all industrial locations. Stump et al (1979) conducted a similar tissue program using X-Ray Energy Spectroscopy (XES) to analyze M. edulis tissues (gills and viscera) from 9 locations in Burrard Inlet. It was noted that gills and viscera accumulate metals differently and should be taken into consideration when using mussels as bio-indicators of metal contamination. As in the work by Gough (1974) high levels of lead were encountered in tissues from Burrard Inlet/Vancouver Harbour.

Comment

The inorganic analyses of tissues, like those in the sediments, are drawn from a variety of locales, at different times and by different methodologies, providing a spotted and otherwise incomplete picture of information at this gross level of investigation. As with other chemical analyses conducted on inorganics in the past there are some questions cast on the accuracy of the analyses in the absence of what are now considered adequate control measures using common standards. In this respect caution should be exercised in using the data, ensuring before hand that the analytic controls were acceptable. While the data may be questioned it still provides an overview of conditions in the harbour. It does not however, address the broader issue of impact on the biota in terms of effects on survival and fecundity nor does it address the effects on other species which may exhibit greater sensitivity. This again points to a need for a better understanding of the biology of epibenthic and benthic infauna in the inlet. The relationship of these sediment data to the pre-feeding stages of Euchaeta japonica (Lewis, 1973 and Whitfield, 1976) or the juvenile survival of benthic fauna for instance is not known, but this research suggests it could be of significance to the fishery even though metal levels are tolerable to adult M. edulis. Recently much work has been done on metallothionein and its relationship to bioavailable ions and related organic chelator production by phyto-and zooplankton. Research at this level and that of the pollution control/compliance testing should be integrated.

ii) Organic contamination of biota in Vancouver Harbour and Burrard Inlet has only recently been documented in a few tissues from a limited number of areas. The most current comprehensive compilation of data in the area is on the Fraser River estuary by Hall (1984) and Garrett (1980). Hall (1984) determined that naphthalene, fluoranthene and benzo (a) pyrene were the most prevalent organics in fish (Starry Flounder) in the Fraser River estuary. Chloroplenols were in greatest evidence nearest the landfills. Garrett (1980) using limited existing data, found organo-chlorinated pesticides to be low and industrial and sewage discharges to exhibit localized PCB concentrations in biota. Data from the last two years in the study show chlorinated phenols and phthalate esters and other PAH's occur in effluents and these may be reflected in the biota. In later work Garrett (1983) in a province-wide summary of PCB's summarizes data for the area noting that highly industrialized areas such as False Creek and Burrard Inlet contain wide spread moderate levels of the substance. Elevated PCB levels (90 - 16,800ppb dry weight) have been detected in Vancouver Harbour particularly near ship building and repair facilities and these are reflected in tissues of crab and mussels (9 - 400ppb wet weight) from four areas. PCB (1254) was found to accumulate considerably in laboratory studies (McGreer, 1980) which agreed with field data by Garrett (1983). Since the mid 70's detailed studies of the concentration of specific PAH's have been conducted in a few locations in Vancouver Harbour. In particular Benzo (a) pyrene was found to accumulate in mussel tissues and marinas and piles were found to be the most significant contributors of B(a)P to the environment (Dunn, 1975). The data suggested that a correlation exists between B(a)P levels and proximity to human activity (e.g. English Bay mussels - 2ug/kg, False Creek mussels - 42ug/kg). B(a)P release from mussel tissue was found to occur very slowly, reflecting compartmentalization in tissues, thus making the organisms (M. edulis) attractive as a bioaccumulator in montoring programs which may be required to investigate implications for the public health of mollusc consumers (Dunn, 1976). Monitoring procedures for chemical carcinogens have been developed and shown to be rapid, sensitive and reproducible (Dunn, 1976). In an investigation of PAH's in the inner and outer Vancouver Harbour, Dunn (1980), found that Benzo (a) pyrene (B(a)P) levels correlated well with the high molecular weight PAH's (of 5 or more fused rings). Mussel and Fucus sp. exhibited a 40 fold variation in PAH levels in the study area. In Coal Harbour for instance, Fucus sp. was found to have quite high levels of PAH's, suggesting effects from the marina activities prevalent in the area.

Dunn (1976) in a review of methodologies for B(a)P determination illustrated the distribution and sources of B(a)P in Vancouver Harbour, using composites of 10-15 mussels in each sample. Mussels from the shoreline of outer Vancouver Harbour exhibited a mean of 0.55 ug/kg and 200 m from a moderate size marina 1.78 ug/kg (wet weight). Mussels on and near creosoted pilings exhibited very high levels of B(a)P, having means of 49.2 and 45.3 ug/kg (wet weight).

Elevated levels of B(a)P in English Sole were encountered in Vancouver Harbour (Dunn, 1980). These elevated levels were found to correlate with Aryl hydrocarbon hydroxylase (AHH), a PAH induced enzyme.

Comment

In this and related work little research appears to have only touched the surface on organic contamination in Vancouver Harbour. Research and monitoring of PAH effects on invertebrate or vertebrate species development, fecundity and survival in the waters of Burrard Inlet needs a greater emphasis.

iii) Pathological information on the apparent effect of organic contamination has been researched by Stich (1977), Stich (1982) and Popham et al. (1984). In a global context the research shows the Vancouver Harbour area to have the highest occurrence of papillomas in English sole (58%) (Stich, 1977). While the geographical variation in the prevalence of tumors is great it is suggested there is a relationship with human activity. In later work Stich (1982) conducted a comparative analysis of fish tissue from Vancouver Harbour and Port Moody using the relationship of B(a)P and AHH in a pathological study of English sole. Elevated B(a)P levels in sediment from Coal Harbour and Port Moody produced a corresponding increase AHH activity in English sole liver.

Tissue abnormalities have also been observed in higher proportions in English sole from Burrard Inlet as compared to other areas (Popham, 1984). This histological survey identified liver lesions (adenomatous foci) in English sole predominating in Burrard Inlet (Vancouver Harbour) and papillomas predominating off Iona Jetty. The data suggest histological evaluation may be an effective monitoring tool. These researches indicate the Vancouver Harbour area to be unique in the world for histological abnormaliites in fish and suggest that urban activities may be a causative factor in their prevalence.

Comment

Health aspects investigation, in particular, has been a major direction in work with flatfish and the relationship of B(a)P in sediments to the incidence of neoplasms by Stich et al (1982) and to tissue levels in the Blue Mussel (Dunn, 1980). This interest by the Cancer Institute researchers has taken a global perspective which identified Vancouver as unique in the prevalence of neoplasms in certain flatfish.

While from a comsumptive/use-by-humans stand point there is no apparent health risk from histological abnormalities of this type, (Villeneuve et al., 1981) the consumption of tissue-accumulated organics could have long term health consequences.

4.0 A REVIEW OF METHODOLOGIES

4.1 GENERAL

A number of methodologies have been used in the generation of inorganic and organic data for water, sediment and tissue in Vancouver Harbour. While many of the methods for characterizing specific contaminants are well developed, findings in the review of data show a lack of procedures in measuring precision and accuracy which prohibit the use of the information with any degree of certainly in comparative evaluations of apparent changes between data sets in contaminant levels over time. In general the existing data base provides an overview of environmental contamination with recent work being the most reliable.

Recent work by Fisheries and Oceans, Institute of Ocean Sciences and the Environmental Protection Service in developing a standardized format and laboratory assessment will improve confidence in future inorganic data sets. A similar program is required for organic analyses.

Future work should ensure appropriate procedures are followed and proposed programs should be thoroughly reviewed by scientists in each specialty area not only in terms of laboratory but also in the collection and handling of samples from the field.

The following briefly outlines the procedures used in assessing water, sediment and tissue inorganic and organic constituents.

4.2 WATER ANALYSIS METHODS

4.2.1 Inorganic Analyses

Inorganic analysis of water for total and dissolved metals has been successful using an isotope dilution technique (Stukas and Wong, 1983). This method allows very low detection limits in the ppt. (ng/l) range which would be particularly applicable in examining water quality as it effects planktonic stages and plankton of the Harbour. On a macro-level atomic absorption spectroscopy (AAS) has been the standard procedure for most of the data generated to date and will likely be the main procedure in future work.

In terms of the bioavailable fraction of inorganics in the water column, a most important aspect in an examination of environmental effects, work by Lewis et al. (1973) and Giunio - Zorkin (1983) in particular is of relevance. A detailed discussion on methodology describes the extraction procedures and subsequent measurement of bioavailable copper. Giunio - Zorkin (1983) suggests confirmatory bioassays be carried out with this and other metals. The Environmental Protection Service is actively carrying out work in this area.

4.2.2 Organic Analyses

Organic analyses of water have been limited and have generally been carried out by gas liquid chromatography.

In other materials (sediments and tissues) more information is available and a variety of methods applied. However as Dunn (1976) points out the problem of the origin, distribution and data of organics (PAH's) in the marine environment has been complicated by the lack of methods of analysis that can be applied to the measurement of trace organics on a routine basis. This is demonstrated by the general lack of organic data as compared with inorganic data. It is likely however that the latter would also be scarce if speciation of metals had been pursued rather than total and dissolved metals data which predominate.

4.3 SEDIMENTS AND TISSUE ANALYSIS METHODS

4.3.1 Inorganic Analyses

Inorganic analyses of sediments have largely been carried out by means of atomic absorption spectroscopy and wet chemical colorimetric procedures, and for total and dissolved metals the methodologies are well developed. Detailed methodologies are presented in most references and government laboratory manuals.

As noted above most of the data generated have lacked acceptable methods for determining precision and accuracy of the measurements. Some recent analyses however are more reliable in that common standards (BCSS and MCSS references) have been used which allow not only confidence within but between data sets for comparative purposes.

In terms of application of recent methodology X-ray Energy Spectroscopy (XES) has been used in assessing inorganic components of marine sediments and tissues in the study area (S. Calvert, personal communication and Popham et al., 1983 and Stump et al., 1979). While this method does not provide as accurate measurement as AAS it is a useful tool for examining the general inorganic composition of sediments and tissues, and could be considered applicable in some areas of environmental assessment.

The determination of biologically available inorganic components should be undertaken. A related methodology to consider in the environmental assessment of contaminants is biochemical assay, based on the toxic effects of trace metals in the production of metallothionein. Brown (1978) used this technique to investigate biochemical pathways of metals and metal binding in the protein pool of mussel tissue which affected growth rates and cell division. Specific relationships to metal tissue ratios, binding site usage by cadmium, mercury and zinc were found.

4.3.2 Organic Analyses

The measurement of organic constituents in sediments and tissues, as in water, appears to be largely carried out by means of liquid gas chromotography particularly where compliance or routine monitoring of sediments and tissues has been undertaken. Recently sediments have been examined using mass spectrophotometry (Hall, 1984) to determine levels of Priority Pollutants in Vancouver Harbour. Work in this regard is ongoing evaluating some 12 Priority Pollutants in sediment samples collected in 1984 (Garrett, Pers. Comm., 1985). This technique however appears to be problematic in that there are no standards equivalent to those used in sediment inorganic analyses. Dunn (1976 and 1980) notes the need for methods of analysis for routine monitoring, and for PAH's describes a rapid, sensitive and reliable technique. The procedure has a sensitivity of 0.1ug/kg and a precision of 6%. In this review any of the methods presented are recommended but high pressure chromatography with a cleanup procedure is prefered (Dunn, 1980).

4.4 OTHER INVESTIGATIVE METHODOLOGIES

4.4.1 Statistical Aspects

As a part of an investigation of polluted and non-polluted conditions Popham (1983) identified the need for pooled samples to achieve a representative sample of a population in order that the results accurately reflect environmental conditions. In considering any future studies the statistical requirements should be assessed in detail in order that the population/conditions under study and the results are representative and not anomalous. Much of the historical data has no statistical merit, consisting of single data for specific points.

4.4.2 Survey Control

In most of the literature accurate locations of sampling points have been recorded, however in some the lack of accurate location control either as longitude/latitude or UTM coordinates and elevation allows the data to be used only in a generic sense. While physical references (e.g. wharves etc.) are by and large the only alternatives available, locations should be converted to a universal system.

4.4.3 Indicator Organisms

A variety of indicator organisms have been selected for use in assessing environmental conditions. In Vancouver Harbour *Mytilus edulis*, *Macoma balthica*, *Rhepoxynius abronius*, *Euchaeta japonica* and flatfish (English Sole) have been used to differing degrees in examining inorganic and organic contaminant effects. It is suggested that these and other indicator organisms be assessed as to their being representative fauna in Burrard Inlet. In particular their distributions and life cycles should be clearly understood.

In this connection little local use has been made of marine flora as indicator organisms. Dunn (1980) uses *Fucus* sp. in an investigation of benzo (a) pyrene in Vancouver Harbour, and other than fundamental algal research algae apparently have not been considered or used to a great degree.

Because of the apparent problems in chemical analytical methodologies and the lack of fishery resource information which has been reviewed but not addressed here, it is suggested that a great deal more emphasis be placed on the biology of species, their abundance and distribution in Vancouver Harbour.

This has been emphasized by Gilbertson (1984), suggesting observations should be made in the environment (e.g. assess conditions, habitat and populations) rather than undertaking a purely aquatic toxicological approach. He notes there is much literature on what pollutants do but not on what they have done. This approach is applicable to the conditions in Vancouver Harbour.

Comment

In summary there are a variety of very good techniques to evaluate the quality of the Harbour environment but all should be carefully reviewed and analyzed from a multidisciplinary perspective as to their suitability, limitations and use of standards before embarking on a detailed assessment of the environment.

5.0 CONCLUSIONS

The following remarks provide an outline of the key points of concern and where effort should be directed.

5.1 KEY POINTS

1. Environmental contamination of Vancouver Harbour by urban wastes is chronic and in some areas severe.

2. Vancouver Harbour has the highest prevalance of tissue disorders (papillomas, lymphocytis) in certain fish than anywhere in the world and there is no ongoing work. On a related matter in terms of consumptive uses of these resources, (eg. crab, groundfish) little or no work has been done to assess the levels of organic or inorganic contaminants in fish or shellfish in Vancouver Harbour.

3. Existing knowledge is substantial in some areas such as oceanography, hydrography or bathymetry, but poor in others such as sources, distribution and long term effects of urban wastes, and carcinogens in particular, on species biology and our use of the inlet.

4. There are indications of long term changes in plankton species composition which may be of significance to fishery resources.

5. The absence of basic environmental knowledge or baseline of reference data on the biology and ecology of species in the inlet will not allow the evaluation of trends, either short or long term, a pattern which has existed in many urban water ways and which have lead to environmental crises, both real and perceived or imagined.

5.2. STUDY NEEDS AND DIRECTION OF EFFORT

In order to rectify or come to grips with the above points, effort should be stressed in the following areas 1) Summary and Integration of Existing Data; 2) Environmental Assessments; 3) Research; 4) Information Use; and 5) Program Development. The following outlines some of the elements of concern in each of these areas.

5.2.1 Summary and Integration of Existing Data

Work in this area should include a broad literature review on all aspects so as to research existing knowledge on biota, contaminants and harbour environments and environmental impacts. Suggested activities include the following:

1. Physical data

   Integrate data on drainage studies, land uses, hydrology, wastewater and storm water flows and constituents, oceanography and hydrography, meteorology and atmospheric constituents to develop a mass budget of materials.

2. Chemical data

   Integrate chemical data on fresh, marine and waste water inputs incorporating known pollutant loadings and flows to develop a nutrient budget and contaminants fate in the marine system.

3. Biological data

   Integrate biological information on 1) primary, secondary and tertiary levels of production and 2) biota population distributions, life cycles, food and habitat requirements.

5.2.2 Environmental Assessments

While specific needs and details for this component can be better defined after a more indepth review, some aspects requiring attention can be identified:

1. Detailed analysis of stormwater discharges including quality and quantity from point and non-point sources.

2. Assessment of local oceanographic features relating to inshore/offshore waters as they pertain to water quality and storm water/industrial and domestic waste water effects from point and non-point sources.

3. Comprehensive assessment of sediments through a core program as carried out in False Creek to delineate the overall physical and chemical features of the area with emphasis on Priority Pollutants.

4. Comprehensive assessment of Fisheries Resources including:

   i) benthic sampling program to assess the environmental quality and resource values, biology, fecundity and body loadings from inorganic and organic contaminants.

   ii) planktonic study particularly as relates to their use in the food chain, the toxic effects by inorganic and organic runoff/sediment constituents and long term species changes.

   iii) fish distribution, species abundance in the intertidal, benthic and pelagic habitats, feeding and movement habits, life cycles, and habitat type assessment.

   iv) the use of fish as a recreational/commercial resource by creel census and catch data segregation from Statistical Area 28. Ethno-cultural consumption habits should also be reviewed.

v) tissue analysis for inorganics and organics in fish from both consumptive and biological perspectives. This and (iv) above are particularly relevant considering the increased emphasis on shore fishing through reef system development by Fisheries and Oceans.

vi) pathological investigation of flora and fauna taken in each program above to examine resources in terms of lesions, lymphocystis and papilloma prevalence and causative factors and their significance to the species survival.

vii) toxicological studies of lower level flora and fauna (as they are the foundation in the food chain) examining further, for instance, the sensitive stages of planktonic organisms.

5.2.3 Research on Biological Resources

In order to understand the effects of environmental quality on the biological resources of Burrard Inlet and environs there is clearly a need for more work in carrying out basic ecological and biological studies. For instance, some work to date on toxicology has shown the importance in understanding the needs and sensitivities of planktonic life cycles (Whitfield, 1974). This and related research should be pursued. A better understanding of the biology of many species in the harbour and their use of habitat needs to be known.

In general this section should work hand in hand with the above section, Environmental Assessments.

5.2.4 Information Use

Computer systems are available for the incorporation of environmental data and their application to Vancouver Harbour is most relevant not only for environmental assessment purposes but for port users, city planners and developers. A similar application may be found for the False Creek area where physical, topographic/bathymetric, geologic, and chemical data were input on a three dimensional grid. Its development has been a significant factor in allowing users to grasp the complexity of the site and in expediting improvements and evaluations. This type of computer system application should be closely examined and considered as a most important tool in an assessment of the Vancouver Harbour environment.

5.2.5 Program Development

The ultimate purpose for measuring and controlling contaminants entering Vancouver, Harbour is the protection of the marine resources and their use. It would seem only prudent then to identify and priorize control measures, in the face of many complex waste discharges, on the basis of well defined biological responses. This would present the most efficient and cost effective approach to improving and protecting the environment of Vancouver Harbour.

A multiplicity of factors comprises the environment of Vancouver Harbour. In the context of assessing the Harbour a large number of diverse users must be considered. Their involvement in environmental studies is important not only in terms of addressing individual needs but also in terms of the resources the different groups might offer. There is a need for a strong coordinating role to be played by the multidisciplinary organization of the Environmental Protection Service involving federal, provincial, municipal, and district governments, local interest groups and research institutions in developing a study strategy.

The various activities suggested in sections 5.2.1 through 5.2.4 should be adapted to an overall plan setting out objectives, organizing the existing data by type and reliability, identifying data gaps, identifying environmental protection needs, and listing priorities, participants and levels of effort required. Specialists in the respective areas should be identified and overall work objectives discussed and programs outlined and reviewed for an integrated study plan.

By its very nature an integrated study requires a multidisciplinary effort in order to achieve a comprehensive understanding of the harbour environment. As such it is very important that programs be developed with the input and joint participation of all users to optimize the use of resources and to maximize the benefits to all.