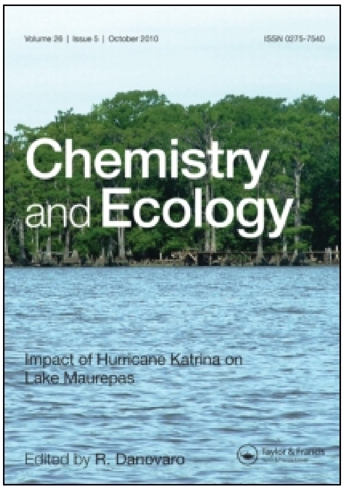

Chemistry and Ecology
Publication details, including instructions for authors and subscription information:
http://www.informaworld.com/smpp/title~content=t713455114

Landbased Pollution Sources and Marine Environmental Quality in the Caribbean

N. C. Singh[a]; R. E. Ward[b]
[a] Executive Director; Caribbean Environmental Health Institute [CEHI], St. Lucia [b] Caribbean Environmental Health Institute [CEHI], St. Lucia

To cite this Article Singh, N. C. and Ward, R. E.(1992) 'Landbased Pollution Sources and Marine Environmental Quality in the Caribbean', Chemistry and Ecology, 6: 1, 259 — 270
To link to this Article: DOI: 10.1080/02757549208035276
URL: http://dx.doi.org/10.1080/02757549208035276

Chemistry and Ecology, 1992, Vol. 6, pp 259–270

LANDBASED POLLUTION SOURCES AND MARINE ENVIRONMENTAL QUALITY IN THE CARIBBEAN

N.C. SINGH* and R.E. WARD**

*Executive Director; Caribbean Environmental Health Institute [CEHI], St. Lucia.**
*Caribbean Environmental Health Institute [CEHI], St. Lucia***

(Received 29 July, 1991)

The near shore coastal and marine environment of several Caribbean islands is their most biologically productive and economically important zone. However, almost all landbased activities possess the real potential of degrading the quality of near shore waters and ultimately diminishing the utility of the marine resource. This condition is largely attributed to the individual smallness of the islands and their geographic proximity to each other.

A summary of the major land based sources of marine pollution (including sewage, industrial effluents and agricultural run-off) in the insular Caribbean is presented.

Available sanitary water quality data from across the region indicated that while recreational areas are in general safe for water contact activities, bacterial densities in excess of several international criteria are consistently recorded in harbours. Organochlorine pesticide residues were generally in the 5 ng l^{-1} range in unfiltered sea water but were significantly higher (1–100) ng g^{-1} in limited samples of sediment and biota. Additional data requirements to gain further insight into the current state of the Caribbean environment are also identified.

KEY WORDS: Caribbean, bacteria, organochlorine residues, land-based sources

INTRODUCTION

The Joint Group of Experts on the Scientific Aspects of Marine Pollution (GESAMP, 1990) concluded that in contrast to the relatively clean open ocean where detected contaminant levels are considered to be biologically insignificant, the margins of the sea are affected by the activities of man almost everywhere. They noted that "A wide range of activities on land contributes to the release of contaminants to the sea either directly or carried by rivers and the atmosphere, while sea-borne activities make a minor contribution." The bulk of the contaminants remains in coastal waters and has built up to significant levels in poorly flushed areas. The near shore marine environment of the Caribbean* islands and other small coastal states is no exception to these conclusions.

Marine environmental problems in the Caribbean are compounded by the generally small size of individual states, the relatively small distances between them, and the proximity of all land based activities to the coast. As a consequence, garbage, sewage and other forms of excreta disposal, industrial effluent discharges, and run-off from agricultural areas directly affect the near shore marine environment. Of pressing concern to these countries is the mitigation and/or control of the possible

*The Caribbean region in this paper will refer to insular Caribbean and the Coastal States of Guyana and Belize.

adverse environmental effects which may accrue from these contaminant loadings since the coastal and marine environment is their most biologically productive as well as economically important zone – it is their *sine qua non*.

This paper provides a qualitative summary of the major economic sectors of the islands, the types of waste they produce, the typical disposal practices and the type of receiving environment into which the waste is disposed. It reviews some of the existing data on chemical and microbiological pollution and introduces additional recent data. Although scientific cause and effect relationships have not been attempted, the complementarity of some of the data is striking and warrants cause for concern.

WASTE PRODUCTION FROM LAND BASED ACTIVITIES IN THE CARIBBEAN

A qualitative survey of the major regional land based activities, their resultant wastes, as well as treatment practices and pollution concerns in the coastal and marine environment is presented in Table 1. An issue of critical relevance to the region is that most, if not all, of the activities listed have the real potential to contribute to marine pollution. In addition, the possible additive and/or synergistic adverse environmental effects of the myriad wastes generated and deposited in the low energy marine sites typical of the region, coupled with the fragile ecosystems, could result in the development of unique pollution conditions.

This is not necessarily the case in countries where socio-economic activity is spread over large land masses and sometimes located more distantly inland. In these cases, management strategies to address issues relating to the sources, effects, and possible mitigation of coastal and marine pollution, may either discount or neglect many conditions that might be important realities in the Caribbean.

THE STATE OF MARINE POLLUTION IN THE CARIBBEAN

Assessments, or partial assessment attempts, of the state of the marine pollution in the Caribbean have, typically, lumped together quantities of discharges of wastes from the source, quantities reaching the marine environment and some measurements of levels of contaminants present in the marine environment (UNEP/ECLAC, 1984; IOC/UNEP, 1989; IOC/UNEP, 1991). These have intuitively, but quite erroneously, assumed direct correlations among the quantities they cite. Little or no mention is made of the potential assimilative capacities of the specific marine location to which the pollution refers. As an example, many reports imply or state that approximately 90 percent of sewage discharged into the Caribbean Sea is untreated (Reid, 1981), obviously giving cause for alarm. However, the required level of concern cannot be determined in the absence of statements which qualify the temporal and spatial distribution of the discharges and the local characteristics of the receiving environment – e.g. current patterns, mixing efficiency, water depth, presence or absence of sensitive systems etc.

Reports to date indicate that there is a paucity of regional marine and coastal baseline environmental data. Where data do exist [e.g. sanitary and recreational water quality data], they are often derived from sporadic monitoring efforts, and are

Table 1 Landbased sources of wastes generated by economic sectors in the Caribbean.

Economic Sector and Sources	*Wastes*	*Management/Disposal Practices*	*Pollution Concerns*
1. Agroindustrial and food related enterprises.			
Sugar, rum, rice, fruit juices, spices, jams and jellies, milk and meat, fish, edible oil, coffee, animal feeds.	Thermal effluents, dunder,* high BOD and suspended solids, effluents, bagasse, rice husk, oil, seed kernels and shells, inks and adhesives.	Bagasse and rice husk are reused to some extent as fuel. Liquids are largely discarded into water while solids are burnt.	Water pollution damage to aquatic life. Air pollution with respiratory irritants.
2. Mining, quarrying and related mineral processing			
Bauxite, limestone, kaolin, aggregates, precious stones, cement manufacture.	Dust, noise, red mud, mercury, cyanide	Untreated dusts released into the air, red mud pits, and water bodies. Research on red mud management is in hand.	Land, water and air pollution. Toxic chemicals release into the environment. Potential human health impacts.
3. Household chemicals/cleansing agents			
Soap and detergent manufacture and use, pesticides, cosmetics (including aerosols), disinfectants. laundries, dry cleaners.	Phosphates, pesticide cans, CFC's, Glass containers, trichlorethylene.	Liquids discharged as grey water, Solids in household garbage, CFC's into atmosphere.	Eutrophication of water bodies, contribution to ozone depletion, Fire hazards of aerosol cans in solid waste dumps, ground and coastal water pollution.
4. Construction industry and furniture manufacture			
Lumber, concrete, ceramics, paint, varnish applications, fibre glass.	Dust, organic solvents/vapours, debris, resins.	Pit burials, municipal solid waste dumps.	Air, soil and ground pollution, respiratory irritations.
5. Community			
Households, restaurants, schools, commercial centres	Sewage, grey water, domestic and municipal garbage including glass, plastic and styrofoam.	Over 80% sewage discharged into the sea untreated. Hotels have package plants which rarely function efficiently. Some central sewage systems – pit latrines and septic tanks common. Solid wastes into open dumpsites. Few sanitary landfills.	Coastal and marine pollution and degradation ground water pollution. Vector proliferation and associated public health impacts.

Table 1 cont'd.

Economic Sector and Sources	*Wastes*	*Management/Disposal Practices*	*Pollution Concerns*
6. Tourism			
Seaports, airports, utilities	Sewage and solid wastes	As at 5 above.	As at 5 above.
7. Agriculture, Fisheries Forestry, Livestock	Agricultural run-off including pesticides, fertilizers and eroded soil. Fish parts from processing. Farm residues. Livestock wastes.	Fish parts incorporated into stockfeeds, Agricultural run-off into fresh water and marine environment. Livestock wastes used to a small extent in biogas plants, some composted, most discarded into waterways.	Fresh water and coastal and marine pollution.
8. Imported Wastes	Variable range of industrial chemicals, but contain used oils and solvents, possibly incinerator ash also.	None; attempts being made to ship these to the region from time to time.	Various toxicity and pollution impacts with which the region cannot cope.
9. Industrial Chemicals Manufacture			
Paints, solvents, petroleum, refining, fertilizers, pesticide formulation, gases.	Solvents, resins, petroleum hydrocarbons, pesticides, hydrated lime.	Small amounts disposed of in pits. Remainder discharged into water ways or landfills.	Water and soil pollution. Toxic effects on humans and animals. Marine pollution.
10. Pharmaceuticals Manufacture and Formulation	Alcohol based effluents containing common drugs tablet excipients.	Mainly discharged into nearby streams.	Damage to aquatic life.
11. Laboratories			
Schools, universities, medical, agricultural.	Chemical solvents and reagents, pesticide residues, contaminated soil/plants, human tissue.	Through the sink into the sewer system. Low levels of recycling of solvents. Solids into municipal garbage.	Damage to bacteria in sewage, fire hazards, chemical pollution of the marine environment.
12. Hospitals/Health Centres	Infectious wastes, human tissue, bandages.	Incineration mainly, some sent to municipal garbage.	Spread of infections from municipal dumps. Efficiency of incinerators and potential for air pollution.
13. Energy/Transport			
Electrical power generation, motor vehicles, service and maintenance operations, charcoal and wood for cooking.	Petroleum hydrocarbons, PCB's (from transformers), carbon dioxide, thermal effluents.	Discharge into atmosphere, marine environment or landfills.	Ground water and coastal and marine pollution contribution to greenhouse effect. Carcinogenic potential of PCB's.

*Dunder – liquid effluents from sugar cane alcohol distilleries.

of little statistical value in describing the ambient environmental conditions which prevail.

Nevertheless, Wade (1976) described the pollution status of Kingston Harbour, Jamaica and correlated his findings with significant ecological degradation. He reported elevated bacterial counts [$\geq$ 2,400 MPN per 100 ml]. well above the limit regarded as safe for human contact. Benthic dissolved oxygen, identified as the most serious limiting factor from an ecological standpoint, reached levels as low as 3.02 mg l^{-1} compared to the outer harbour value of 5.13 mg l^{-1}. During the frequent plankton blooms reported, total oxygen demand exceeded possible supply and anoxic conditions developed (Wade, 1976). As a result of the changing environmental conditions over the 1968–1974 monitoring period, a significant decline in the benthic community diversity of the Harbour was also noted (Wade, 1976).

Faecal coliform [FC] densities on the order of 1×10^4 organisms per 100 ml were consistently reported in Havana Bay, Cuba, between 1981–1988 (IOC/UNEP, 1991). Total coliform [TC] and FC levels within the ranges of 1.4×10^2 to 1.7×10^6 per 100 ml and 250 to 1.2×10^6 per 100 ml respectively, were recorded at the Playa del Chivo beach in close proximity to sewage outfalls in the Bay (IOC/UNEP, 1991).

Ward and Singh (1987) described bacterial pollution levels in the Castries Harbour, St. Lucia, and reported that only those stations located in the extreme outer harbour complied consistently with available international sanitary water quality criteria/standards. Those located in the inner harbour, in close proximity to the known pollution sources of bacteriological significance, repeatedly surpassed the various internationally recommended TC, FC and faecal streptococcus [FS] limits over the 1982–1984 monitoring period (Ward and Singh, 1987). Sections of the inner harbour were used for occasional recreational and/or domestic purposes. In a concurrent study, Shim and Singh (1988) showed that although the outer Castries Harbour supported a healthy ecological community, as inferred from selected species diversity indices, the inner harbour showed signs of environmental stress. However, the area was considered to be biologically healthier than Kingston Harbour, Jamaica and Bridgetown Harbour, Barbados (Shim and Singh, 1988).

Available sanitary water data also suggest that St. Georges Harbour, Grenada, among others, may be under the influence of similar environmental stresses to those noted in Castries Harbour (CEHI, 1991; 1989; 1986; 1985).

These observations readily suggest that recreational activities in the harbours of the region could be hazardous to health and should be avoided. This conclusion would most probably have been reached intuitively by residents and visitors to the region anyway, and should merely serve to reinforce and increase necessary caution.

Work carried out around Trinidad and Tobago also revealed localised "hot spots" of bacterial pollution due to discharge of improperly treated sewage into near shore waters (Norman and Tota – Maharaj, 1982). Several swimming areas including Chaguaramas, Staubles and Teterson beaches were reported to significantly exceed the EPA and EEC recreational water quality limits based on the TC and FC bacterial indicators.

Existing studies on chemical pollution have been restricted largely to either levels of petroleum or nutrients (Bellairs Research Institute, 1989; Wade, 1976). Available data on marine pollution by petroleum and petroleum-based products refers to beach tar, floating tar or to dissolved dispersed petroleum hydrocarbons [DDPH], with marine activities being suspected as the predominant contaminant source. Nevertheless, circumstantial evidence suggests that the potential contribution of land based sources of this contaminant/pollutant category in the region also requires serious further investigation.

Nitrates, as combined nitrite and nitrate, and phosphate concentrations typical of non-polluted coastal waters in the Eastern Caribbean were reported to be approximately 0.70 μg-at l^{-1} and 0.10 μg-at l^{-1} respectively, with oceanic levels being approximately half these values (Bellairs Research Institute, 1989). Nitrate values of over 4.0 μg-at l^{-1} have been recorded at polluted sites, as well as phosphate levels in the range 0.5 to 1.5 >μg-at l^{-1} (Bellairs Research Institute, 1989; Wade, 1976). In addition, repeated observations of excessive algal growth at several locations across the region provide strong biological indications of nutrient enrichment.

RECENT RESULTS

More recent and relevant data resulting from some of the work carried out at CEHI are summarised here as *bacterial pollution* and *pesticide pollution* of some near shore coastal waters in the region. Data on tar on beaches, DDPH, and marine debris are not reported here, since the contribution of landbased sources of these contaminants are not yet well defined.

BACTERIAL POLLUTION

FC and FS bacteriological data from two popular swimming areas in the region are presented in Tables 2 and 3. The areas are identified only as points A and B for reasons of confidentiality. In general, the analysis presented pertains to data collected over the 1989 and 1990 monitoring periods, and compares reported densities with the sanitary water quality criteria of the European Economic Community [EEC] and those recently proposed for the region (UNEP, 1990). Results generated previously are also included, and serve merely to highlight the relative trends in density distributions noted between stations and monitoring periods.

With reference to Area A, the analysis revealed the following:

1. although the majority of stations failed to comply with the guide FC requirement of the EEC criteria [i.e. < 100 FC per 100 ml (80%)]*, particularly during 1990, stations 2 and 7, during 1990 and 1989 respectively, represented the only cases which contravened the mandatory requirement [<2000 FC per 100 ml (95%)]*;
2. only stations 2 and 8 [1990] failed to comply with the guide FS requirement of the EEC [< 100 FC per 100 ml (90%)]*,**;
3. all stations failed to comply with the proposed regional FC limit during 1990 [< 200 FC per 100 ml (100%)]*. Stations 2, 5, 7 and 8 failed this criterion in both years.

* percentage values indicate the proportion of samples which must not exceed the stated bacterial density.

** no mandatory FS limit has been proposed by the EEC.

Table 2 Summary of Median FC and FS bacterial densities between monitoring periods at Area A.

	Faecal Coliforms/100 ml.			*Faecal Streptococci/100 ml.*		
Station Number	*87–88*	*1989*	*1990*	*87–88*	*1989*	*1990*
1	34	25	30	14	2	5
2	36	285	20	20	7	7
3	10	40	10	10	4	4
4	20	50	18	27	2	8
5	10	30	28	20	4	7
6	50	40	99	13	3	8
7	27	390	20	27	10	6
8	38	135	100	52	2	22

Samples were collected and analyzed once per month.
Median values are presented as an index of the more probable density to be obtained on any given randomly selected sampling date.

Table 3 Summary of median FC and FS bacterial densities between monitoring periods at Area B.

	Faecal Coliforms/100 ml.				*Faecal Streptococci/100 ml.*			
Station	*85–86*	*Mar 88*	*Aug 89*	*M–A 90*	*85–86*	*Mar 88*	*Aug 89*	*M–A 90*
1	3	1	100	14	251	1	37	18
2	2	4	25	10	220	1	146	21
3	2	2	55	15	116	2	118	47
4	2	1	60	10	235	1	72	26
5	44	56	93	71	281	46	146	28
6	90	10	86	180	505	28	131	31
7	68	55	80	196	740	70	292	53

Mar 88 = March 1988. Aug 89 = August 1989. M–A 90 = March–April 1990
Post 1986 data refer to the analysis of at least five [5] samples over a thirty day period.

For Area B the following were also noted:

1. FC densities in excess of the recommended guide FC limit of the EEC [100 FC per 100 ml] were found at all stations in at least one case during 1989; reported densities at stations 1–4 were consistently below this limit during 1990. However, all stations had densities which were well below the specified mandatory FC limit;
2. with the exception of stations 1 and 3 [1990], all stations had FS densities in excess of the guide EEC limit.
3. FC densities reported at station 4 represented the only case which consistently complied with the proposed regional criterion regardless of the monitoring period [1989 or 1990].

These findings assume that the rather lax EEC sanitary water quality requirements may be applied to data collected in the Caribbean, and/or in tropical regions in general. However, the observations when compared with the proposed regional criterion are considered to be inconclusive, as the appropriateness of the specified limit, including the associated perceived degree of acceptable risk, is yet to be assessed.

Although based on commonly accepted, though scientifically questionable, criteria, it may be concluded tentatively that while some swimming areas in the region appear to be fairly safe, they might be approaching conditions in which increased health risks associated with water contact recreational activities could become significant.

PESTICIDE POLLUTION

Several analyses for organochlorine [OC] pesticides and polychlorobiphenyl [PCB] residue levels in water were made on samples collected from seventeen coastal sites around St. Lucia between 1986 to 1989. The specific residues monitored, including the results of recovery experiments, are presented in Table 4.

Lindane [5–40 ng l^{-1}], dieldrin [4 ng l^{-1}], DDT and associated derivatives [4–20 ng l^{-1}] were detected at several of the sites examined. All other residues monitored were below the minimum quantitative limit of the analytical procedure used.

Although based on a limited number of samples, the detected OC residue levels reported here were generally lower than those found in North America in 1970s [Table 5]. This observation is not surprising in view of the following considerations:

Table 4 Organochlorine pesticides [OC] and polychlorobiphenyl [PCB] residues monitored in the coastal waters of St. Lucia.

Residue	*Fortification* Level in sea water*	*Percentage Recovery [%]*	*Minimum Detectable Limit*
Organochlorine Pesticides [OC]			
Lindane	42	80	3
Aldrin	42	80	3
Heptachlor	33	85	4
Heptachlor epoxide	33	80	4
o,p DDE	33	85	4
Dieldrin	33	75	4
Endrin	42	75	15
o,p DDT	33	80	10
Chlordane	170	10–70	15
Endosulfan I	50	95	2
Endosulfan II	270	40	10
Methoxychlor	1700	35	200
Polychlorobiphenyls [PCB]			
Arochlor 1248	300	70–80	50
Arochlor 1254	100	65–75	100
Arochlor 1260	270	60–75	100

N.B.: Levels are quoted as ng l^{-1} [i.e.: 10^{-12}].
*"Fortification" is equivalent to a spiked concentration.

1. organochlorine pesticides have low aqueous solubilities at ambient environmental temperature [e.g. DDT = 1.2 ppb, dieldrin = 0.19 ppm and lindane = 10 ppm (Hartley and Graham-Bryce, 1980)];
2. the fate of the OC pesticides is largely that of the particulate matter to which they strongly adsorb, such as marine sediments and colloidal solids;
3. the widespread use of organochlorines in agriculture and public health has been curtailed for several years;
4. the dilution factor for pesticides entering the marine environment from small island ecosystems will be very large, except in sheltered areas subjected a chronic pollution input.

Higher residue levels, as expected, were obtained in analyses of sediments and

Table 5 Organochlorine residue levels in surface waters in North America.

Waters sampled	Pesticide [ng l^{-1}] DDT	Dieldrin	Endrin	Heptachlor	Reference quoted by McEwen and Stephenson, 1979.
Rivers and Streams					
US	8.2	6.9	2.4	6.3	Breidenbach *et al.*, 1967.
US	10.3	2.3	1.4	2.6	Brown & Nishioka, 1967.
US	8.3	5.9	3.6	0.1	Green *et al.*, 1967.
Iowa, US	2.7	6.3	–	–	Johnson & Morris, 1971.
US	9.3	1.1	0.3	1.4	Manigold & Schulze, 1969.
Canada	14.8	1.0	–	–	Miles & Harris, 1971.
General					
US	11.5	7.3	0.1	–	Lichtenberg *et al.*, 1970.
Florida, US	17.1	–	–	–	Kelipinski *et al.*, 1971.
Coastal					
US	4.02	–	–	–	Cox, 1971.
US/Canada	2.4	–	–	–	Cox, 1971.
Great Lakes	ND	ND	ND	ND	Glooschenka *et al.*, 1974a.
Farm Ponds					
Surface fed	20.4	1.4	–	–	Frank *et al.*, 1974a.
Spring fed	8.5	ND	–	–	Frank *et al.*, 1974a.

From: McEwen and Stephenson, 1979. ND = Not detected; = Not determined.

animal tissue [Table 6]. The tissue concentrations reported suggest the possible accumulation and/or recycling of these compounds in the food chain. However, the human health risk associated with consumption of the species studied is considered to be insignificant. The OC concentration ranges obtained in fresh sediment samples can be considered as background levels when compared to those allowed under Schedule 1 of the Canadian Ocean Dumping Control Act (Government of Canada, 1980).

Conclusions

Land based sources are important contributors to marine pollution in the Caribbean. However, the extent of such pollution needs to be carefully documented for use in the development of realistic control strategies. These strategies, in addition to recognizing the need for economic growth and development, must take into account the particular nature of the receiving environment. The strategic assessment and planning framework proposed by Kelly *et al.* (1987) [Figure 1] for dealing with pollution related issues represents one framework which could guide the deliberations of regional decision makers.

REFERENCES

Bellairs Research institute (1989); Sewage Treatment and Disposal for the Grand Anse Area of Grenada. USAID/OAS.

Table 6 Organochlorine pesticide [OC] and polychlorobiphenyl [PCB] residue levels detected in selected marine biota and sediments in St. Lucia.

Sample	Organochlorine Pesticide and Polychlorobiphenyl Residues								
	Aldrin	*Arochlor 1254*	*Chlordane*	*Dieldrin*	*Heptachlor*	*Heptachlor Epoxide*	*Lindane*	*p,p DDD*	*p,p DDE*
Mugil curema [Mullet]									
– Lipid fraction	0.21	6.93	13.34	1.04	ND	ND	ND	1.41	1.33
– Muscle tissue	ND	0.13	0.25	0.02				0.03	0.02
Isognomon altus [Flat tree oyster]									
– Lipid fraction	–	8.01	67.05	1.25	–	–	5.96	–	1.61
– Muscle tissue	–	1.06	8.90	0.13	–	–	0.79	–	0.21
Crassostrea rhizophorae [Caribbean oyster]									
– Lipid fraction	–	2.99	13.35	–	–	–	–	–	0.88
– Muscle tissue	–	0.31	1.39	–	–	–	–	–	0.09
Brachidontes exustus [Scorched mussel]									
– Lipid fraction	–	1.81	–	–	–	–	–	–	0.55
– Muscle tissue	–	0.15	–	–	–	–	–	–	0.05

NOTES: ND = Not detected; – = Not determined; biota concentrations are quoted as nanograms per gram of tissue [ng/ g dry weight].

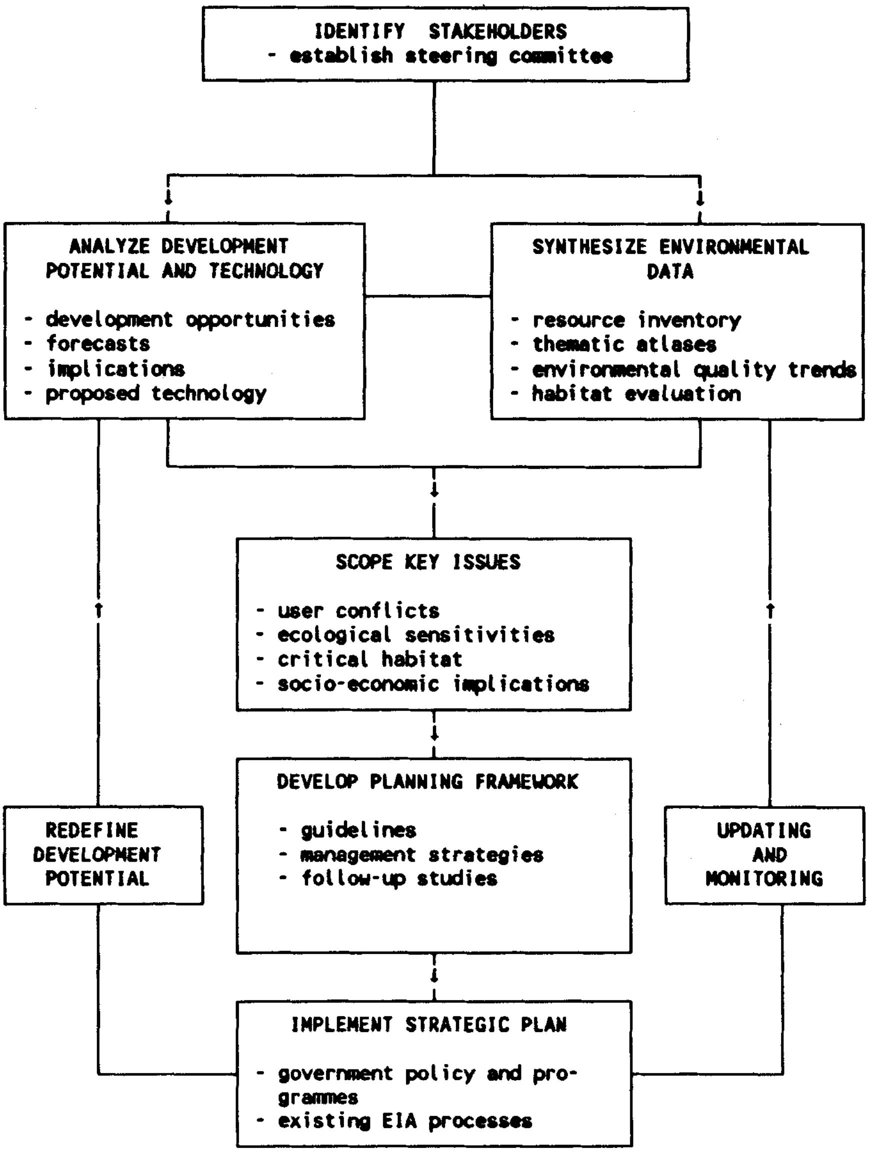

Figure 1 Schematic of an assessment and planning framework for management of the marine environment.

From Kelly *et al.*, 1987.

CEHI (1985) Protection of the marine and coastal environment of the Caribbean islands. Technical report on pollution monitoring component [1982–1984]. Project FP/CR/5102–80–07/2168. Caribbean Environmental Health Institute, St. Lucia [February 1985].

CEHI (1986) Protection of the marine and coastal environment of the Caribbean islands. Technical report on pollution monitoring component [1985–1986]. Project FP/CR/5102–80–07/2168. Caribbean Environmental Health Institute, St. Lucia [September 1986].

CEHI (1989) Protection of the marine and coastal environment of the Caribbean islands. Technical report on pollution monitoring component [1987–1988]. Projects FP/CR/5102–80–07/2168 and FP/CR/5102–88–08/2838. Caribbean Environmental Health Institute, St. Lucia [February 1985].

CEHI (1991) Enhancement of the Coastal and Marine Environmental Monitoring Capability in the Caribbean. Technical report on bacteriological pollution monitoring component [1989–1990]. Caribbean Environmental Health Institute, St. Lucia [March 1991].

GESAMP (1990) The State of the Marine Environment. Reports and Studies No. 39, 111 pp., publ. UNESCO.

Government of Canada (1980) Ocean Dumping Report 3. Department of Fisheries and Oceans, Government of Canada.

Hartley, G.S. and Graham-Bryce (1980) *Physical Principles of Pesticide Behaviour.* Volume 2. Academic Press.

IOC/UNEP (1987) *The State of Marine Pollution in the Wider Caribbean* [Draft]. UNEP.

IOC/UNEP (1989) IOC-UNEP Regional Workshop to Review Priorities for Marine Pollution Monitoring, Research, Control and Abatement in the Wider Caribbean. IOC Workshop Report No. 59, Part 1, Annex VII, pp 1–5, UNESCO.

IOC/UNEP (1991) Review on the Present State of Marine Pollution by Sewage and Present Monitoring and Control Practice in the Wider Caribbean. IOC/UNEP-SWQ-1/6 prov. UNEP.

Kelly, D., Cote, R.P., Nicholls, B. and Ricketts, P. (1987) Developing a strategic assessment and planning framework for the marine environment. *J. Env. Management* **25**, 219–230.

Mc Ewen, F.F. and Stephenson, G.R. (1979) *The Use and Significance of Pesticides in the Environment.* Wiley, New York, pp 274.

Norman, P.E. and Tota-Maharaj, B. (1982); Report of a Bacteriological Survey of Western Chaguaramas and San Fernando Bathing Areas. Technical Working Document – Restricted Circulation. Institute of Marine Affairs.

Reid, R. (1981) Environmental and public health in the Caribbean. *Ambio* **10** [6], 312–317.

Shim, D.S. and Singh, N.C. (1988) Ecological status of the sediment communities of Castries Harbour, St. Lucia – West Indies. *Ocean and Shoreline Management* **11**, 145–158.

UNEP/ECLAC (1984) The State of Marine Pollution in the Wider Caribbean Region. UNEP Regional Seas Report and Studies No. 36.

UNEP (1990); Draft Proceedings of CEPPOL Workshop on Effluent Guidelines and Water Quality Standards. San Juan – Puerto Rico.

Wade, B.A. (1976); The Pollution Ecology of the Kingstown Harbour. Vols. 1, 2 and 3. Research Report from the Zoology Department, University of the West Indies, Mona, Jamaica, No. 5.

Ward, R.E. and N.C. Singh (1987); Bacterial pollution monitoring in Castries Harbour, St. Lucia – West Indies. *J. Shoreline Management* **3**, 225–234.