ENVIRONMENTAL MONITORING IN THE COASTAL ZONE

NYALI BEACH HOTEL, MOMBASA: Wednesday 23rd - Friday 25th April 1997

A contribution to the UK Overseas Development Administration (ODA) Land-Ocean Contamination Study (LOCS) in East Africa.

Organised by the British Geological Survey and Kenya Marine and Fisheries Research Institute.

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WORKSHOP PROGRAMME

WEDNESDAY 23RD APRIL

Introduction and Coastal Zone Management

9-00	Registration	
9-45	Martin Williams (BGS)	Introduction: background to the ODA LOCS project
10-30	**Coffee**	
11-00	Martin Williams and John Rees (BGS)	Contaminant monitoring in estuarine and nearshore marine systems. 1: Survey framework, design and sample collection
12-30	**Lunch**	

Chemical oceanography and pollution

14-00	Abdalla C Yobe (KMFRI)	Assessment of land based sources of pollution along the Kenya coast
14-20	Peter J Shunula (IMS)	Considerations on sources and control of pollution of the coastal zone in Tanzania
14-40	Alfred Muzuka (IMS)	1. Methods of dating coastal sediments and corals.
15-00	Alfred Muzuka (IMS)	2. Can stable isotope compositions of tropical East African flora be used as source indicators of organic matter in coastal marine sediments?
15-20	R. B. Owen (Dept. of Geog., Hong-Kong)	Heavy metals in Hong Kong coastal sediments
15-40	C. Z. Kaaya (Dept of Geology, Dar-es-Salaam)	Sources of Chemical Pollution in Dar-es-Salaam Coastal Waters
16-00	**Coffee**	

Remote sensing in Coastal Zone Management

16-20	Peter Mumby (CTCMS, U. K.)	Practical remote sensing of coral reefs and seagrass beds: a cost benefit assessment.
16-40	Edmund Green (CTCMS, U. K.)	A Comparative Assessment of Mangrove Areas using Remotely Sensed Data from Satellites and Airborne Sensors.

THURSDAY 24TH APRIL

Interpretation of marine pollution data

9-00	Martin Williams (BGS)	Contaminant monitoring in estuarine and nearshore marine systems. 2: Analysis, interpretation and integration of chemical data.
9-45	John Rees (BGS)	Estimation of residence time of sediment-hosted contaminants, based on interpretation of sedimentological and oceanographic data
10-30	**Coffee**	
11-00	Barry Rawlins (BGS)	Obtaining pollution chronologies in marine sediments
11-30	Jason Weeks (ITE)	Biomarkers in marine pollution monitoring
12-30	**Lunch**	

Biological / Ecological studies

14-00	Nyawira Muthiga (Kenya Wildlife Service)	Coral reef monitoring within protected areas in Kenya
14-20	Johnson Kazungu (KMFRI)	Nitrogen transformational processes in a mangrove ecosystem
14-40	Jacqueline N Uku (KMFRI)	Submerged marine flora as indicators of environmental health
15-00	**Coffee**	
15-30	Omondi Wawiye (KMFRI)	Phytoplankton as bio-indicators of environmental stress: comparison between a polluted and a pristine environment along the Kenyan coastline
15-50	Patrick Gwada (KMFRI)	Regeneration structure of Kenyan mangroves after human perturbation: case study of Mida creek
16-10	Helida Oyieke (National Museums of Kenya)	Coastal zone environmental quality vs biological diversity

FRIDAY 25TH APRIL

Physical oceanography

9-00	Mika Odido (KMFRI)	Tidal flushing of the creeks around Mombasa Island
9-20	Michael Mutua Nguli (KMFRI)	Water exchange and mixing in tropical inlets - a case study of Tudor inlet, Mombasa
9-40	Johnson Kitheka (KMFRI)	Coastal water-circulation, groundwater flux and salinity anomalies at Mida Creek, Kenya

10-20 Coffee

Coastal zone management and GIS

11-00	Dirk Van Speybroeck (UNEP)	UNEP's eastern African Coastal and Marine environment resources database and atlas project
11-20	Dixon Waruinge (UNEP)	Integrated coastal area management in Eastern Africa
11-40	B. A. J. Mwandotto (Coastal Development Authority)	Kenya integrated coastal area management (ICAM) Pilot project
12-00	Prof. J. Bauer (ECO-TERRA)	Holistic coastal zone protection in areas of conflict (the case of Somalia's coast during the last 10 years)

12-30 Lunch

Beach erosion

14-00	Jeremiah Daffa (NEMC)	Oil spills and marine contingency planning in Tanzania
14-20	N. Nyandwi (IMS)	Man induced coastal erosion and its management in Tanzania
14-40	A. M. Dubi (IMS)	Beach erosion and the role of coastal structures in beach protection
15-00	Yohannah Shagude (IMS)	Sediment distribution and transport off the western coast of Zanzibar
15-20	Pamela Aboudha (KMFRI)	Beach erosion and its management strategies in Kenya

Acronyms:

KMFRI:	Kenya Marine Research Fisheries Institute
IMS:	Institute of Marine Sciences (Tanzania)
UNEP:	United Nations Environment Programme
NEMC:	National Environment Management Council (Tanzania)
BGS:	British Geological Survey (U.K.)
ITE:	Institute of Terrestrial Ecology (U.K.)

THE UK OVERSEAS DEVELOPMENT ADMINISTRATION (ODA) LAND OCEAN CONTAMINATION STUDY (LOCS):

A BRIEF INTRODUCTION

MARTIN WILLIAMS
LOCS PROJECT MANAGER, BRITISH GEOLOGICAL SURVEY,
KEYWORTH, NOTTS, UK.

Background to LOCS

In 1995 a coastal-zone pollution monitoring programme for developing countries, the Land-Ocean Contamination Study (LOCS), was initiated by the UK Overseas Development Administration (ODA) Natural Resources Division (NRD), with the British Geological Survey designated as the central coordinating institute. The project was established in recognition of the rapid economic development which now characterises many coastal settings in Africa, Asia and Latin America, and the consequent vulnerability of nearshore marine environments to the effects of increasing urban and industrial discharges.

The specific developmental issues targeted by LOCS are:-

- The growing conflict between (advertent and accidental) waste discharges into the coastal-zone and socio-economic/environmental welfare (e.g. fisheries productivity, habitat preservation, human health).
- The lack of quantitative pollution data for many urbanised coastal margins, on which the design (and cost-benefit analysis) of coastal zone management (CZM) options must be founded.
- The need for a standardised pollution monitoring protocol to assess the effectiveness of mitigation policies at individual sites (and to facilitate meaningful inter-site comparisons).
- The requirement in many developing countries for infrastructural strengthening and technology-transfer in a range of fields including marine chemistry, oceanography, ecotoxicology and coastal-zone planning.

Project structure

The LOCS project structure incorporates three regional case-studies of approximately 12 months duration, each relating to a particular type of coastal-setting or nearshore marine regime. The first, executed during the period April 1995 - March 1996, focused on the behaviour and fate of land-derived contaminants in the inshore lagoonal or estuarine systems and outlying reef-fringed coastal margins of Mombasa, Kenya and Dar es Salaam, Tanzania. The second, undertaken during the period November 1995 - August 1996, entailed a geochemical, ecological and ecotoxicological survey of the more heavily industrialised setting of Jakarta Bay, Indonesia. The third, be completed by December 1997, is dedicated to the evaluation of contaminant dynamics in partially enclosed embayments or lagoons, typified by Sepetiba Bay, Brazil.

Technical reports detailing the methodologies, results and implications of LOCS regional case-studies have been produced under the Overseas Geology Series of the British Geological Survey. Currently, the series includes three reports relating to work in East Africa and three concerning studies in Indonesia. Copies of all reports are available on request from the LOCS project coordinator.

Dissemination of case-study results and promotion of the generically applicable survey methods formulated and tested under the LOCS programme is to be ensured through the staging of regional workshops of which this event in Mombasa forms the first. A second workshop to be held in Jakarta, Indonesia, is scheduled for June 1997.

National and international collaboration

Scientific counterpart institutions in the targeted LOCS study nations have played a central role in the execution of regional case-studies. These local counterparts, without whom the LOCS programme could not have been undertaken, include the Kenya Marine and Fisheries Research Institute (KMFRI), the Institute of Marine Sciences (IMS), Tanzania, the Indonesian Institute of Sciences (LIPI) Research and Development Centre for Oceanology (RDCO), the Universidad Federal Fluminense (UFF), Brazil and the State of Rio de Janeiro Environmental Protection Agency (FEEMA).

Vital expertise in several non-geoscientific aspects of the LOCS project (including coral community structure analysis and ecotoxicological impact assessment) has been provided by the Institute of Terrestrial Ecology (ITE) and the University of Newcastle, Centre for Tropical Coastal Management Studies (CTCMS).

Methodological handbook.

Much of the material presented at this LOCS regional workshop is currently being compiled into a procedural manual (anticipated publication, July 1997). The aim of the manual is to provide technical guidelines for government departments, NGO's and international agencies involved in the design and/or execution of geochemical, hydrochemical and ecotoxicological surveys of nearshore marine environments. All methods described will be equally appropriate for environmental baseline provision or for deployment in the context of systematic monitoring. To a considerable extent, the methodologies described for site selection, sample collection, analysis and data interpretation are of generic applicability, with emphasis where possible on the promotion of techniques requiring low cost hardware.

Further information about LOCS.

Further information about any aspect of the ODA LOCS project can be obtained by contacting the LOCS Project Coordinator (Dr T M Williams), British Geological Survey, Keyworth, Nottingham, NG12 5GG, UK.

CONTAMINANT MONITORING IN ESTUARINE AND NEARSHORE MARINE SYSTEMS 1: SURVEY FRAMEWORK, DESIGN AND SAMPLE COLLECTION

Martin Williams and John Rees
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Introduction.

In this presentation, the rationale underlying the design and selection of sampling procedures adopted during LOCS project case-studies in East Africa and SE Asia will be outlined. (The analytical, interpretative and data-storage aspects of marine contaminant surveys in each LOCS case-study setting will form the subject of an independent session).

Collation of contaminant inventories.

An insight into the probable location, composition and magnitude of pollutant inputs is a vital precursor to any nearshore marine pollution survey. Important inputs can include point and non-point source contaminants ranging from domestic waste or sewage, to landfill leachate, agricultural pesticide runnoff and industrial discharges. A knowledge of these inputs can assist in determining both where to sample and what methods to adopt. In all LOCS surveys, sampling campaigns have been preceded by the compilation of inventories of catchment industrial activities and (where possible) existing effluent data. For Mombasa, this was assisted greatly by the provision of a KMFRI report (originally compiled for the FAO) "Assessment of Land-Based Sources of Marine Pollution along the Kenya Coast". Additional valuable data were compiled by UNEP under sub-project 6 of the Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the East African Region.

Prioritisation of marine resources.

In most urbanised coastal settings the marine system is recognised as being multi-functional. It will thus be used as a convenient recipient of land-based effluent, with certain areas characterised by lower water/sediment quality than others. The aim in ICZM must therefore be to minimise conflicts between waste disposal and the many other uses for which the nearshore zone is required. Identification and evaluation of potential conflicts should be considered during survey design and sampling in potentially sensitive areas should receive particular attention. In Mombasa such areas include artisanal fisheries, marine parks and recreational zones, information for each of which is available on the UNEP / KMFRI EAF14 database. In Jakarta Bay, the coral islands of Pulau Seribu were identified as a focus for geochemical, hydrochemical and ecological monitoring on the basis of UNESCO directives.

Establishing the sedimentological and oceanographic framework.

The design of LOCS surveys, notably the selection of appropriate sampling locations and media, can be undertaken effectively only with a detailed understanding of the inherent geological, sedimentological and oceanographic conditions prevailing. Factors such as the residence-time of water in nearshore or estuarine systems and the pattern of sedimentation are fundamental to the siting of sampling points and to the interpretation of results. Oceanographic and sedimentolofical surveys can, however, be costly and time consuming. The use of pre-existing information in the development of physiographic models for any given case-study area should therefore be encouraged.

From experience gained in the LOCS case-study areas, pre-existing datasets of particular value may include (i) bathymetry, (ii) sediment maps, (iii) geophysical data, (iv) current and tidal data. Where vital gaps in such datasets exist, new surveys must be commissioned (ideally ahead of the main geochemical sampling programme). In Dar es Salaam, for example, a detailed echosounding survey, current and tidal measurements were undertaken by IMS to support LOCS sediment mapping and tidal prism calculations for the estuarine and inshore waters.

Planning and survey design.

Following the establishment of basic information regarding the objectives, physical setting and cultural/industrial perspective for a nearshore marine contamination survey, it is necessary to consider the sample media which may be most appropriate, and the optimum positions of sampling stations. Some considerations of relevance to this process include:- (i) integration with pre-existing pollution datasets, (ii) technical capabilities and resources.

Most pollution surveys of nearshore marine environments undertaken over the past two decades have focused on sediments as a sampling medium. In many settings, inorganic micro-contaminants are predominantly introduced to the nearshore system in particulate form, or are rapidly sorbed by clays or colloidal flocs following translocation into a high salinity regime. Accordingly, sediments provide a major sink for the contaminant load. Data derived from surficial sediments offer additional advantages in providing a relatively long-term 'average' impression of the spatial contaminant load unaffected by the very short-term (e.g. tidal cycle) fluctuations often apparent with respect to nearshore water quality. They are also collected with relative ease, offer few storage of preparation problems and typically hold metals at concentrations well within the limits of detection of most common analytical techniques (eg. AAS).

With improvements in analytical technology during the past decade, sampling and analysis of other media, notably water and suspended particulate matter (SPM), is now quite possible in almost any part of the world. Accordingly, the LOCS project has endeavoured to incorporate and promote methods for the collection and analysis of such media, using cheap, low-technology equipment wherever possible. The value of water data has been exemplified during LOCS case-studies of Mombasa and Jakarta Bay, providing an impression of mobile contaminant phases at their ambient environmental level. Concentrations are, however, at least an order of magnitude lower than those prevailing in most sediments and analytical problems related to the high salinity matrix must be overcome. The value of SPM in reflecting short-term ambient conditions is analogous to that of water, but additional information regarding sorption to ultrafine particulates, colloid chemistry and toxin assimilation by algae is also provided. While technically easy to collect, SPM samples tend to be small (<10 mg) and are highly prone to contamination during preservation and analysis.

Spatial coverage

The two most fundamental considerations underlying the design of all LOCS surficial sediment surveys were: (i) the desire to gain the most comprehensive picture possible within given time and capital constraints (ii) the need to ensure data comparability between sites. Failure to consider the second of these critical issues has, in many previous surveys, resulted in contaminant monitoring surveys utilising a rigid geometric grid. In each LOCS survey, this approach has been substituted by a more complex procedure involving the siting of individual stations on the basis of lithological comparability, thus reducing the need for tenuous normalisation of the geochemical data ultimately procured. In the case of Jakarta Bay, this procedure allowed the number of silt/clay sites to be increased dramatically, relative to the number which would have been achieved using a simple geomethric grid.

Sampling procedures

Sampling hardware for the collection of water, SPM and sediment varies considerably with respect to cost and technical sophistication. A sysnopsis of the techniques adopted for use under the LOCS project will be provided, with comment on the strengths and weaknesses of a range of options for each medium.

AN ASSESSMENT OF LAND BASED SOURCES OF POLLUTION ALONG THE KENYA COAST

D Munga 1, A C Yobe 1, M Owilli 1, S M Mwagumi 2

1 Kenya Marine and Fisheries Research Institute, Mombasa
2 Government Chemist Department, Mombasa

Report presented to the WHO, Regional Office Brazzaville.

The exercise was carried out in 1992 with the objective of assessing types and quantities of pollution contaminating the marine environment from the land based sources along the Kenya Coastal area. The output of this rapid assessment is expected to provide an indication of pollutants that are of immediate concern, which require appropriate action in terms of monitoring and management.

The data and information used in the assessment was obtained from various Kenya Government ministries, local authorities and also directly from the management of some major industrial establishment. The study involved the estimation of waste volumes and pollution due to domestic waste, industrial effluents and agricultural activities including livestock waste.

To facilitate the exercise administrative boundaries were considered because the district authorities are directly involved in planning and sanctioning of development activities in the area.

The Kenya coastal area is made up of the districts, Kwale, Mombasa, Kilifi, Tana River and Lamu. Mombasa is the principle seaport and industrial and commercial centre.

Only 17% of the population of Mombasa is sewered. The municipality operates two separated sewage systems for domestic sewage and storm water runoff which are both unoperational due to overloading and unserviceability. The rest of the inhabitants utilise pit latrines (59%) and septic tanks and/or sewage pits for sewage disposal.

The Municipality operates a refuse collection service which disposes about 60% of the domestic refuse at an uncontrolled dumpsite know as Kibarani. Few industries have facilities for effluent pre-treatment before disposal into the sea. The Mombasa port has no reception facilities for bilge's or other wastes from ships.

No other urban centres along the Kenya Coast have sewage systems and treatment plants. Dumping of solid waste on mangrove shore is practised.

Industrial effluents from Mombasa district accounts for 70% of the total Biological Oxygen Demand (BOD5) with 90% of the organic load die to food and beverage industries. Domestic and solid waste from the municipality and beach hotels generate about 20% of the BOD load.

Industrial effluents do generate about 60% of the suspended solids (ss) with storm water runoff and domestic sewage contributing most of the rest of ss load. At least 65% of waste oils are produced by slaughter house and fish processing plants, with the iron and steel industries contributing most of the rest of the load.

Domestic sewage is a source of about 40% of nitrogenous compounds with storm water runoff contributing 30%. Major contributors of phosphorus compounds are livestock waste and domestic sewage at 50% and 30% respectively.

The assessment gives an indication of emissions of chromium, zinc and iron from iron and steel industries, with relatively lower levels from power generation and petroleum refining. Most of the water from industrial and domestic activities is discharged into the inshore creeks.

In Kwale District, domestic sewage from market centre and beach hotels generate at least 75% of the BOD load. Storm runoff is the source of about 70% of the suspended solid load. About 50% of nitrogenous compounds is due to domestic sewage, with storm water runoff contributing about 40%. Over 80% of phosphorous compound load is due to livestock waste.

In Kilifi District, liquid and solid domestic waste is the source of over 70% of the BOD load. Storm water runoff produces more that 80% of the suspended solid load. Domestic sewage contributes about 45% of nitrogenous compounds, with agricultural runoff and livestock waste making about 45% of the total load. Livestock waste is the source of about 60% phosphorus compounds, with domestic sewage accounting for 30% of the load.

In Lamu District, the few industries generate some 45% of BOD, with domestic waste contributing about 25% and livestock waste attributed to 25% of the total load. The high concentration of donkeys in Lamu attributes 90% of suspended solids, nitrogenous compounds and phosphorous compounds loads generated.

It is recognised that the major rivers, Tana, Sabaki etc are main sources of sediments, nutrients and contaminants resulting from agricultural activities in the river basins. Riverine loading has, however, not been estimated due to unreliable data or discharge rates and other hydrographic parameters.

The high quantities of waste generated along the Kenya coast raises the need for proper waste management to reduce the pollution loads.

Monitoring levels and effects of pollution in sensitive inshore waters areas, for example, the mangrove ecosystems, coral reefs and tourist beach resorts is recommended with great emphasis on the following:

(i) Organic pollution (BOD), microbiological contamination and nutrient level and their effects on the marine environment.

(ii) Heavy metal contamination and effects on biota.

(iii) Petroleum hydrocarbons in the marine environment.

CONSIDERATIONS ON SOURCES AND CONTROL OF POLLUTION IN THE COASTAL ZONE OF TANZANIA

J P Shunula

Tanzania's coastline, running approximately from between 4.7% S and about 800 km long is the home for between 30 and 40% of the country's nearly 30 million people, spread out in several major coastal towns like Dar es Salaam, Tanga, Lindi and Mtwara. In addition there are numerous villages and settlements along the coast.

The coastline is flanked by a strip of hinterland, about 15 km wide running along the entire coastline from the Kenya border in the north to the Mozambican border to the south. A broad range of economic activities take place within this strip, the coastline and nearshore waters. Such activities include, Agriculture, Forestry, Industrial activities, urban and other settlement expansion, fishing and related income generating activities. Such economic activities are well-intentioned for man's welfare and development. Nevertheless, improper management of most of these otherwise necessary human activities leads to most of them becoming sources of pollution.

The sources of pollution can thus be categorised as: Agriculture, domestic activities, fishing and Industrial activities. It was until very recently not realised that human activities no matter how well meant, could have deleterious effects on the environment. Not very long ago, the sea was for example, thought to be the safest sink for almost any human generated waste.

Effective control of pollution therefore rests on proper and interdisciplinary planning and management of all kinds of development projects, be it Agricultural, industrial, domestic town planning, fisheries or tourism. It is important for the scientific community to bring to light even more vividly the often considered subtle connections between seemingly clean projects and pollution.

The paper discusses the need for even closer and coordinated planning of development projects, community sensitivity towards the environment and total commitment towards environmental preservation as the key for halting mounting coastal degradation.

METHODS OF DATING COASTAL SEDIMENTS AND CORALS

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Currently the East African coastal areas are experiencing beach erosion and enhanced input of pollutants. The effect of beach erosion and anthropogenic material to coastal sedimentation is not known. Similarly, rates of fluxes of biogenic and clastic material to the sea floor is not known. To better understand rates of fluxes of material to the sea floor, accurate determination of sedimentation rates are of paramount importance. Also well dated stratigraphic sections helps to evaluating extent of mixing sediments through bioturbation processes. Absolute age dating of sediments is important in establishing sedimentation rates, and some of the methods that may be used to date coastal marine sediments are radiogenic isotopes of carbon (14C) and lead (210Pb).

As pointed out above, the East African coastal areas are experiencing beach erosion. It is not well known whether the trend in erosion is due to local factors or global eustatic change in sea-level. One way of determining rate of sea level change is through dating drowned corals using 230Th. Corals are suitable for documenting sea level changes using radiometric method partly because they tend to maintain sea level by rapid vertical accretion (Buddermier and Smith, 1988). Because of this, ages determined from corals have been used to document rates of changes of sea level rise (eg Edwards et al., 1993; Blanchon and Shaw, 1995).

Thus, the presentation will introduce basic fundamental principals of dating marine sediments and corals using 14C, 210Pb and 230Th. Also some examples from the Gulf of St Lawrence (Canada) and Labrador Sea will be presented to show their usefulness to infer limit of sediment mixing (bioturbation).

References

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Buddermeier R W and Smith S V. 1988. Coral reef growth in an era of rapidly rising sea level: Predictions and suggestions for long-term research. Coral Reefs 7, 51-56.

CAN STABLE ISOTOPIC COMPOSITIONS OF TROPICAL EAST AFRICAN FLORA BE USED AS SOURCE INDICATORS IN COASTAL MARINE SEDIMENTS?

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The carbon and nitrogen stable isotopic compositions of some flora of East Africa from coastal Tanzania are used to assess if they can be used as terrestrial end member during estimation of terrestrial fraction in coastal marine sediments. The result of carbon isotopic composition of various tree leaves, which average -29.3 1.4%, indicate that these tropical higher land plant species follow a Calvin-Benson or non-Kranz (C3) type of metabolism. The results for grass species, which averages -13.2 2.4% indicate that most of them follow Hatch slack or Kranz (C4) type of metabolism. The nitrogen isotopic values are relatively higher than expected for the terrestrial organic material. The average d15N values for both tree and grass samples are higher than 5% and fall within the range normally considered to be marine. The high enrichment in 15N may be related to the environmental conditions in which plants thrive. Plants growing in sandy, dry and overgrazed environments are expected to be enriched in 15N owing to full utilization of all available nitrogen species regardless of their isotopic compositions. Other processes which may cause an enrichment in 15N include types of clay minerals content, supply of 15N-enriched nitrate through sea-spray, and local denitrification especially in swampy and lake margins where input of organic matter may be higher than the rate of decomposition.

In the savannah environment where contribution of the C4 types of plants might be substantial, terrestrial end member need to be established prior to evaluation of the terrestrially derived organic matter in the marine environment. Furthermore, the results indicate that nitrogen stable isotope seems to have limited applicability as source indicator in coastal waters of East Africa. However, more work needs to be conducted to determine the terrestrial end member value for the coastal areas.

HEAVY METALS IN HONG KONG COASTAL SEDIMENTS

Sandhu, N. & Owen, R.B.

Hong Kong is a subtropical, mountainous territory with land and sea areas of about 1000km^2 each. The coastline is ria-like due to flooding of a large number of palaeovalleys during the Holocene world sea-level rise. This has resulted in a variety of marine situations that partially control pollutant distributions. These environments include low energy embayments dominated by fine grained mud, channels with high current velocities and a sandy sea floor, and open sea conditions with predominantly silt and clay. A large part of the pollutants are delivered to the sea at the beginning of the rainy season and red tides are a frequent problem at this time. The territory has experienced rapid economic growth and a major increase in population (currently 6.2 million) during the last 40 years. This has inevitably resulted in large quantities of polluting industries ranging from electro-plating to textile and manufacturing industries. In recent years, many of these have moved to China and transferred at least some of the pollutants across the border to the north. Nevertheless, "hot spots" of pollution occur around the old urban areas and close to new town developments.

Heavy metal pollution reaches its highest levels in marine sediments near the old urban centres (Cu>130ppm; Zn>300ppm; Cr>50ppm; Pb>87ppm). This study concentrates on Tolo Harbour and Channel, an enclosed body of water, in northeast Hong Kong. Two new towns, Shatin and Tai Po, lie in the catchment basin to the west and the water is open to the South China Sea to the east. Fifteen gravity cores were recovered from various parts of the Tolo Harbour and Channel. These show a two fold stratigraphy with a black silty clay overlying an olive green silty clay. The upper unit contains elevated levels of heavy metals and represents polluted sediment that has accumulated over the last 20 years, since the new town developments began. Close to the new towns this is upper unit is >25cm thick, but rapidly thins along the channel and disappears about 6-7 km from Shatin and Tai Po. Elevated levels of Cu, Zn, Cr and Pb occur, in the silt and clay fraction of the sediments, but these are, at present, generally much lower than values found near the old urban centres. Coral growth occurs at 12-15km from the pollution sources suggesting a relatively "clean" environment.

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Sources of Chemical Pollution along the Dar es Salaam Coastal Waters

The Dar es Salaam Region including the city itself has an area of about 1364 km2 , 70 km long coast line and a population of about 3 million people.The Dar es Salaam City is practically still the administrative capital of Tanzania and the largest and fastest growing business centre in the country. The rapid unplanned growth of population and industrial activities in Dar es Salaam is causing a severe physical, biological and chemical pollution to the dry land as well as in the coastal waters.

The main chemical pollutants are hydrocarbon products (oils & fuel) being released from the Petroleum Refinery, motor vehicles, ships, service garages and other industries. Other chemical pollutants include Lead, Nitrates, Sulphates, Chromium and Mercury from chemical industries, textile, paint, battery, metal industries, breweries, detergent industries, dump sites and from residential houses.

As there are no waste processing facilities in most of the industries, dump sites etc., these chemicals end up in the ground water and in the sea through canals and streams. The concentrations of these chemicals decreases away from the sources and are in general much higher in streams and in ground water than in the sea water.

PRACTICAL REMOTE SENSING OF CORAL REEFS AND SEAGRASS BEDS

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In general, satellites tend to offer geomorphological information on reef structure and lack the technical requirements to distinguish between reef assemblages. However, the airborne instrument CASI has far greater spatial and spectral resolution than satellites and possesses much greater potential for mapping reef assemblages. Surprisingly, satellite and airborne digital sensors have co-existed for over fifteen years but their relative abilities to assess reef habitats have not been assessed. In light of this, a comparative study was conducted for reef habitats and seagrass beds of the Caicos Bank (Turks and Caicos Islands, British West Indies). Digital data were acquired from Landsat MSS, Landsat TM, SPOT XS, SPOT Pan and the Compact Airborne Spectrographic Imager (CASI). To validate the imagery, reef habitats were sampled *in situ* using percent cover in 1 m quadrats. Seagrass standing crop was assessed using a calibrated visual scale. Benthic habitats were classified using hierarchical cluster and Similarity Percentage analyses. Two levels of habitat discrimination were assessed: a coarse level (corals, algae, sand, seagrass) and a fine level which included nine reef habitats.

CASI ~ CASI was set to view 1 m pixels in 8 spectral bands. Overall accuracies of CASI-derived habitat maps were 89% and 81% for coarse and fine levels of habitat discrimination respectively. Accuracies were greatest once CASI data had been processed to compensate for variations in depth and edited to take account of generic patterns of reef distribution. These accuracies were significantly ($p<0.001$) better than those obtained from satellite imagery of the same site (Landsat MSS, Landsat TM, SPOT XS, SPOT Pan, merged Landsat TM / SPOT Pan). Results from CASI were also found to be significantly better than those from 1:10 000 colour aerial photographs from a study in Anguilla (Sheppard et al., 1995). In addition, a good empirical relationship ($R^2 = 0.65$) was found between processed CASI data and seagrass standing crop.

Satellites ~ To map areas larger than 60 km in moderate detail, Landsat TM was the most accurate and cost-effective satellite sensor (SPOT XS when less than 60 km). For maps with moderate habitat detail, aerial photography (from a comparable study in Anguilla) exhibited similar accuracy to Landsat TM, SPOT XS, SPOT Pan and merged Landsat TM/ SPOT Pan. Landsat MSS was consistently the least accurate sensor. A good empirical relationshipwas found for seagrass standing crop and processed Landsat TM ($R^2 = 0.63$) and SPOT XS ($R^2 = 0.69$) data.

Aerial Photography ~ Commission of new aerial photography is not a cost-effective option; satellites are cheaper for coarse habitat mapping and fine-level habitat mapping can be conducted more accurately with CASI for approximately the same cost.

A COMPARATIVE ASSESSMENT OF MANGROVE AREAS USING REMOTELY SENSED DATA FROM SATELLITES AND AIRBORNE SENSORS.

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Satellite (SPOT XS and Landsat TM) and airborne multispectral (CASI) imagery of mangroves was acquired from the Turks and Caicos Islands, British West Indies.

Hierarchical agglomerative clustering with group-average sorting identified six mangrove classes. Supervised classification of the CASI data mapped these six classes to an overall accuracy of 78.2%. All classifications of SPOT XS data however failed to discriminate satisfactorily between mangrove and non-mangrove vegetation. Classification accuracy of Landsat TM data was dependent upon the method used. Only one method (band ratios, principal component analysis and supervised classification) accurately discriminated between mangrove and terrestrial vegetation (92.3%) but just two of the six mangrove classes could be distinguished. The superior spatial and spectral resolution of CASI allows mangrove areas to be assessed to a greater level of detail and accuracy than with satellite sensors. The cost-effectiveness of each sensor is discussed in relation to the logistics of remote sensing in mangrove areas.

Field data were also used to model the relationship between the normalised difference vegetation index (NDVI) and leaf area index (LAI); NDVI was used to predict LAI for each sensor. LAI data, estimated from *in situ* measurements of canopy transmittance and independent of those used to derive the LAI/NDVI model, were used to test the accuracy of this prediction. Accuracy was high (88-95%) and the mean difference between predicted and measured LAI low (5-13%). Remotely sensed data is thus demonstrated as a powerful tool for estimating the spatial distribution of LAI for whole mangrove ecosystems.

CONTAMINANT MONITORING IN ESTUARINE AND NEARSHORE MARINE SYSTEMS 2: ANALYSIS, INTERPRETATION AND INTEGRATION OF CHEMICAL DATA.

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Introduction.

This session will outline certain aspects of the methodology utilised analysing environmental samples collected during LOCS case-study surveys in East Africa and SE Asia, with subsequent discussion of the approaches adopted for data interpretation. The principal themes to be addressed within the session are summarised below:-

Water analysis and data interpretation.

The analysis of seawater is inherently problematic, due to the very low (ppt level) concentrations of metals and micro-organic determinants generally present, and the high salinity of the matrix. Contaminant problems arising from the use of impure reagents or inappropriate storage vessels are common. Three potential methods of water analysis will be described, with emphasis on the solvent extraction / ICP-MS approach used most widely in the analysis of LOCS samples. A range of physico-chemical datasets from Mombasa and Jakarta Bay will be presented to illustrate the role of hydrodynamic, biological and anthropogenic factors in determining aqueous metal concentrations in inshore waters.

Sediment analysis and interpretation.

The approach to sediment analysis utilised under LOCS will be described. The need to establish an appropriate grain-size fraction for geochemical characterisation will receive particular attention. Although of limited significance in terms of their anthropogenic influx, the systematic analysis of major oxides and organic matter in surficial sediments will be outlined, particularly as illucidators of sediment lithology and provenance. A synopsis of data interpretation techniques will include discussion of statistical methods for highlighting lithological, diagentic and biogeochemical controls on trace contaminant distributions. The interpretation of downcore geochemical profiles through stratified piston cores is complex and requires a full appreciation of the effects of post-depositional diagenesis and variable mass sedimentation. A procedure for deriving reliable anthropogenic pollution chronologies from sedimentologically complex cores will be outlined, based on the use of geochronological dating methods such as ^{210}Pb or ^{137}Cs. The mathematical basis for ascertaining annual contaminant influx rates will also be described.

Interpretation of contaminant flux data in a broader context.

The magnitude of contamination recorded in waters or sediments at any marine location is conventionally appraised either through comparison against internationally established ‘standards’ or empirical data from analogous settings in other regions of the world. Data will therefore be presented to portray Mombasa, Dar es Salaam and Jakarta in their correct international context. Discussion will focus upon the recent rate of degradation of these LOCS sites, and their future environmental sustainability.

ESTIMATION OF RESIDENCE TIME OF SEDIMENT-HOSTED CONTAMINANTS, BASED ON INTERPRETATION OF SEDIMENTOLOGICAL AND OCEANOGRAPHIC DATA

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One of the central objectives of near-shore contamination surveys along urbanised coasts is the provision of data regarding the sources, transport pathways and fates of contaminant metals and selected organic compounds. Whilst a water and sediment sampling programme will show variations in the distribution of contaminants in any nearshore area, an understanding of the pathways and chronology of contaminant transport and storage can only be obtained through an appreciation of coastal morphodynamics.

Estuarine (or quasi-estuarine) morphodynamics are discussed using mainly examples from the LOCS surveys in Mombasa and Dar es Salaam. In these cases, estuarine creek systems, which consist of inland lagoons connected to the ocean by laterally-confined channels, the distribution of sediments reflects the ebb dominance of the creek systems as fluvially derived sediments are generally transported seawards and open marine sediments only occur towards the seaward end of the confined-channels. The sedimentary patterns recognised show that the major bedload transport events are extremely sporadic; their periodicity is unknown. Although those parts of the lagoons that are removed from channels are likely to have the highest sedimentation rates, all parts of the systems may be regarded as potential contaminated sediment sinks because of the degree of active bioturbation in all inter- and sub-tidal environments. Patterns of contaminant abundance at the sediment surface may therefore be expected to be reflected in buried sediments. Such patterns are likely to be controlled largely by residence times of contaminated waters. One-dimensional (segmented) box modelling of the estuarine creeks of Mombasa shows that the average residence time within the lagoons is likely to be less than a week, and less than two days in the confined-channels. Contaminants are likely to reside longer during neap tides and in the wet season, although they will be most widely dispersed during spring tides and in the dry season.

The examples of morphodynamics of more open-marine coastal settings are largely derived from the LOCS survey in Jakarta, as well as BGS work in Hong Kong. In open waters the residence times of water-borne contaminants is controlled by the hydrodynamic setting of the study area. Unlike estuarine hydrodynamics, which is dominated largely by discharge and tidal range, open marine settings are also greatly influenced by waves, and wave-dominated currents. The distribution of sediment-borne contaminants within near-shore open-marine settings is controlled in part by the distribution of clays within these areas. This, in turn, reflects the position of the shoreface. The influence on sediment storage and mobilisation patterns of sea-level changes or anthropogenic alteration of bathymetry in such settings is illustrated.

The examples presented illustrate the importance of understanding the hydrodynamic and sedimentological setting of estuarine and near-shore environments in order to understand the storage and flux of contaminants within them. Although the techniques described were most appropriate for analysis of specific environments and available datasets, the approach adopted will be equally applicable to other coastal settings.

OBTAINING POLLUTION CHRONOLOGIES IN MARINE ENVIRONMENTS.

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Radionuclide dating is an ideal method for determining pollution chronologies resulting from anthropogenic activities during the last 100 years. Dating sediments involves relating the vertical distribution of radionuclide activities in sediment cores to the decay of primordial radionuclides, or known temporal variations in artificial radionuclide fallout. Natural ^{210}Pb dating is based on the constant flux of this radionuclide derived from its decay through the U-Th series. Sediment accumulation of artificial ^{137}Cs is derived from nuclear weapons testing and pollution from nuclear power reactors.

Methods, models and problems of dating marine sediments using ^{210}Pb and ^{137}Cs are described. ^{210}Pb dating models rely on assuming either a constant initial concentration of unsupported ^{210}Pb , or a constant rate of supply of unsupported ^{210}Pb to sediments. The two conceptual models are discussed and the conditions under which their application is appropriate are described. ^{137}Cs dating is applicable to sediments deposited since 1954; it is an ideal tracer because there are no natural sources and its mobility is controlled by physical processes due to its strong adsorption to sediments.

Uncertainties in radionuclide dating methods (including ^{210}Pb and ^{137}Cs) are due to the physical and biological mixing of sediments following their deposition, and the miration of the radionuclides via porewater.

BIOMARKERS IN MARINE POLLUTION MONITORING

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In recent years the use of biochemical responses often termed biomarkers have been employed to estimate either exposure or effects of chemicals to biota. The major reason for the continued and developing interest in biomarkers results from the serious limitations of the more traditional approaches of environmental toxicology; that of the requirement to quantify the amount of chemical present in the tissues of a plant or animal, and then through laboratory trials relate this to adverse effects on mortality, reproduction or growth. The major limitations of this traditional approach results from the difficulty in accounting for the differences in bioavailability between laboratory and field situations, and the limited ability to account for the toxicity of resulting from a mixture of pollutants in field situations. This makes the extrapolation of toxicity data from the laboratory to the field difficult, if not impossible. Biomarkers deal with the question of bioavailability of chemicals by integrating biologically the effects of pollutants. Biomarkers are easily applied under field conditions and may also integrate the effects of complex pollution sources, and as such are believed to be useful tools to enable the early warning of ecological damage. This presentation shall introduce the concept of biomarkers in marine monitoring, discuss the advantages and potential disadvantages of employing such techniques, and will focus on key biomarkers of proven utility. Examples of the deployment of biomarkers from SE Asia will be given, and technical advice on relevant and inexpensive techniques presented.

SUBMERGED MARINE FLORA AS INDICATORS OF ENVIRONMENTAL HEALTH

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Seagrasses and macroalgae compose the submerged marine flora found along the Kenyan coastline. Seagrasses (marine angiosperms) have leaves and are attached to the substrate by way of roots and rhizomes whereas macroalgae (seaweeds) are more primitive in structure with a thallus instead of leaves and a holdfast for attachment to the substrate. These marine plants have diverse ecological and economic uses which have been recognised in the region. However, their importance in pollution monitoring, especially in the case of eutrophication from nutrient enrichment, has yet to be realised. These plants are sedentary and as a result they are capable of reflecting changes in the status of the environment. Studies outside East Africa indicate the usefulness of these plants in monitoring programmes. Their use is recommended in East Africa.

PHYTOPLANKTON AS BIOINDICATORS OF ENVIRONMENTAL STRESS: COMPARISON BETWEEN A POLLUTED (KIBARANI DUMP SITE) AND A PRISTINE (MIDA CREEK) ENVIRONMENT ALONG THE KENYA COASTLINE

O Wawiye, T Dzeha, B Ohawa, J Njoya

The phytoplankton populations were monitored in Makupa Creek where there is high anthropogenic input of nutrients from ship waste, sludge from septic tanks, pit latrines and municipal solid waste. Two stations were chosen in the creek, one station adjacent to the point of disposition of the solid waste and the other station adjacent to the Kipevu power plant where there is the influence of thermal stress. A reference station was chosen at Mida Creek where the influence of anthropogenic nutrient loading is very minimal and there is nil counting of faecal coliforms. Multivariate direct gradient analysis was then applied to assess the possible influence of the high anthropogenic nutrient loading on the species assemblages in the three sites. Simpsons diversity index was used to compare the diversity in the three sites. A relation was observed between the species assemblages and the supplied environmental variables after the application of the Monte Carlo permutation test between the Mida and Makupa stations. The species assemblage within the Makupa Creek stations were similar, probably as a consequence of mixing between the two sites. The phytoplankton population in Makupa Creek was very low as compared to Mida Creek and showed a dominance of Prorocentrum micans when there was high count of faecal coliforms indicating recent discharge of sewage or contamination by other anthropogenic sources.

LITTER PRODUCTION IN A MANGROVE FOREST OF A SEMI-ARID INLET CREEK OF MIDA, KENYA.

Patrick Gwada.

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Litter fall by component parts from four dominant species of mangrove trees fringing an inlet creek at Mida, Kenya, are being monitored bimonthly since August 1996. The average daily production shows variability between different species. Within the same species, variations across time are also noticed, an indication of some periodicity in these activities. The Rhizophora - Bruguierra mixed community so far has shown a maxima in shedding intesity at around November - December (more than 1g dry weight /day /m2) made up mostly of leaves. An interesting contrast to this is the shedding maxima in the other species which so far tend to peak a few months earlier before that of Rhizophora. In the Avicennia marina community, this occurs between August and September. In Ceriops tagal plots, it is maintained between August to October. The production of reproductive units into litter is minimal except for few sporadic incidences of propagule fall in Rhizophora-Bruguierra community. In A. marina community, aborted flower buds and flowers are being recoverd in litter catches in high numbers since December 1996. Infact this production alone outweighs that of leaf fall during this period in this community. These spatial and temporary variability in litter production by component parts and by species types are discussed in relation to possible trade-off mechanisms in resource use and allocation strategies across some environmental gradients. The management problems that may arise due to the current shift in species dominance induced by to anthropogenic impacts is raised in the light of these preliminary results.

COASTAL ZONE ENVIRONMENTAL QUALITY VS BIOLOGICAL DIVERSITY

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Numerous physical and climatic processes and factors create a variety of distinct habitats with their own diverse community of organisms in the marine environment. Within these distinct habitats are diverse species of fauna and flora which further exhibit diversity at genetic level. Ecosystem diversity in the marine environment is envisaged to exceed that of the terrestrial environment yet because marine ecosystems are mostly hidden from view humans are less aware of it. In terms of species diversity the ocean has much less compared to terrestrial has freshwater environments. However, this lack of species diversity is compensated by the large population numbers of some groups such as the nematodes, pelagic copepods and benthic molluscs. Furthermore, more than three quarters of the animal phyla recorded have representatives living in the marine environment with about 15 phyla, including comb jellies and echinoderms, being exclusively marine.

The importance of marine biological diversity to mankind cannot be emphasised and yet it is currently under great threat. The concept of biogeography brings out the fact that fauna and flora occur in a particular place only if it can "get there and survive there". Species diversity, biomass and number of individuals in a particular population will vary according to the biological and environmental stress. Availability of optimum levels of nutrients is one major factor that influence marine plant and animal distribution. Apart from nutrients other factors include temperature, plt, salinity, exposure to air, availability of adequate sunlight and the amount of living space.

The bulk of marine species are found in the coastal environment where there is accelerated rate of environmental degradation due to natural changes as well as changes caused by man's unfavourable activities. Maintaining the integrity of living systems means keeping not only the parts of the system (ie species) but also the process that generate and maintain the parts, the ecological connections among living things of which the physical environment is an integral part.

While the Kenyan government contemplates major development activities to take advantage of its Exclusive Economic Zone together with its territorial seas the existing legislation is lacking in its provision on the control of marine environmental degradation including pollution from land-based sources. Furthermore the enforcement of the existing laws such as the Water Act is very weak, the current potential of marine fisheries projected at 200,000 metric tonnes may not be realised if land based sources of marine pollution and the rampant degradation of environment are not controlled.

However, there is hope in the current bill on National Environment Management and coordination which emphasises that environmental considerations should be taken into account in the planning and management of development activities. Furthermore, the current National Development Plan (1997-2000) advocates for the promotion of a sustainable environment and resource conservation among other things.

THE LINKAGE BETWEEN COASTAL WATER CIRCULATION DYNAMICS AND GROUND-WATER FLOW IN A TROPICAL MANGROVE CREEK IN KENYA

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The hydrologic research on coastal water circulation and ground-water flow was undertaken for the period 1996-1997 in a 35 km^2 tropical Creek in Kenya. The research involved measurement and coupling of the hydrodynamic parameters (salinity, temperature, current velocity, tidal elevation) with meteorological data (air temperature, rainfall, evaporation and solar radiation influx) and hydrogeologic data (ground water flow, ground water level variability and permeability).

The rate of water-exchange is high at the front water-zone of the creek. Three methods used to calculate the exchange rate provided agreeing results (volume-conservation model: 3970 m3.sec-1; Cross-sectional-Area-Velocity method: 3780 m3.sec-1; Tidal cycle-Area-Tidal Range method; 3920 m3.sec-1). The differences between these methods were insignificant. The residence time of water in the Creek is short at the front-water zone (approx 12 hrs), but longer (>24 hrs) in the middle and backwater zones. The turbid water and pollutants are trapped for longer periods in these zones as compared to the front-water zone. In spring tide, at least 60% of the Creek water is exchanged with the shelf waters in each tidal cycle. In neap tides, only 40% is exchanged. As with tidal water exchange, the rates of tidal flushing are considerably high at the front-water zones (current velocity up to 2.5 m/s), but lower in the backwaters (<0.3 m/s current speed). There is only minor, but no major seasonal fluctuations in water salinity (29-38 PSU) and temperature (24-29%C). But there are spatial differences, influenced by evaporation, solar radiation influx and tides. The backwater zone is a region of low energy (current speed <0.30 m/s, high temperature (>29%C), high evaporation rates (8 mm/day) and high salinity maxima (38 PSU). The front-water zone experience the reverse of conditions in the back-water zone. The spatial salinity-temperature differences between front-water and backwater zone reach 0.80 PSU/Km and 0.45%C/Km respectively.

Freshwater input is essentially via two main sources: rainfall and ground water seepage. The supply of freshwater by rainfall is seasonally variable and in most cases is often <3.0% of the total Creek volume. The volume of freshwater supplied through rainfall is only high during the South-East monsoon rainy season (April-May-June). The highest volume is in May (6.5%) with April and June having 3.1% and 3.2% respectively. In the North-East monsoon, the supply is often <2.0% in over 80% of the time. The ground water storage in the surrounding sandy aquifers is enormous (105 x 106m3), with a permeability rate of 1.25 m/day. The rate of ground water seepage, calculated using Glovers method is 10.0 m3/sec, but it varies seasonally in response to fluctuating climatic conditions. The inflowing brackish ground water causes low salinity in ebb tide as compared to flood tide. The flood-ebb tide salinity difference range from 0.04 to 1.06 PSU. The replacement time of the supplied freshwater and nutrients is 14.6 days (approx 2 weeks).

Modelling research was focussed on the simulation of water temperature and salinity, using multi-variate statistical methods. Simulation was found to be complex and depended on many independent hydrodynamic factors. In the front-waters, salinity was simulated quite well (R-sq: 0.77; df: 35), with water temperature and conductivity being independent of physical factors. The

relationship between the simulated and measured salinity was good (r=0.89; R-Sq; 0.77). Temperature simulation was also good (R-Sq: 0.75; df: 35.0) with water column depth, salinity and conductivity been independent factors. The correlation coefficient for measured and simulated temperature is 0.89 with R-Square of 0.77.

The research provided important information on the hydrologic linkage between coastal hydrography and ground water flow. It also provides important information of potential application in pollution control and abatement, as well as in the sustainable management of coastal and marine ecological systems in tropical areas.

KENYA INTEGRATED COASTAL AREA MANAGEMENT (ICAM) PILOT PROJECT

Bamburi-Nyali-Shanzu Area - Mombasa
H Onganda1 and BAJ Mwandotto2

1 Supported by United States Agency for International Development through the University of Rhode Island; Coastal Resources Centre; Food and Agricultural Organization (FAO), and the United National Environmental Programme (UNEP).

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The Kenyan Coast is endowed with a number of natural resources. There are coral reefs, mangrove forests, lowland and Kaya forests, and sandy beaches. These resources support a number of thriving industries ranging from the multi-million dollar tourism industry, reef fisheries and mangrove harvesting. The port town at Mombasa is also a centre of import/export and other commercial activities supporting a population close to 1.4 million people. The dynamics of the socio-economic, cultural and ecological situations has necessitated the need for sustainable exploitation of these coastal resources. This gave rise to the first pilot study of ICAM in Kenya. Seven (7) Kenyan Coastal institutions drawn from the governmental and non-governmental agencies constituted a working team led by Coast Development Authority for implementing the ICAM pilot study. The study site, an area approximately 100 km2 has an interesting profile consisting of hotels, mangroves, human settlements, roads, marine park and reserve, urban market, research centre, industry and it has a sea front.

The process of fact finding included verbal interviews, personal observations and verification of archive data. The resulting profile was discussed and crystallized at local and national stakeholders workshops. Seven issues were finally identified namely: The need for improved land use management; Provisions for adequate infrastructure and public services; Fresh and coastal water quality degradation; Declines in the reef fishery and the viability of artisanal fishing as livelihood; Degradation of coastal and marine habitats-mangroves, coral reefs, beaches and seagrasses; Coastal erosion; and Increasing on-water and land use conflicts. For all these issues, short and long-term management strategies that are practical in addressing them using local resources were proposed. Some demonstration activities have been employed to amplify the benefits of ICAM to the local communities. Various stakeholders participate in the demonstration activities. To continue the evolution of ICAM process in Kenya to cover the whole of the coastline, a coastal management steering committee has been put in place to oversee the many activities which have been planned in the strategy document that will be carried out by the respective technical (working) groups according to the issues. This study is part of the wider effort to develop ICAM for the whole of Western Indian Ocean Coastal countries including the Island states.

MAN-INDUCED COASTAL EROSION AND ITS MANAGEMENT IN TANZANIA

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Very often man has been identified to be responsible for the degradation of his own environment including coastlines. An assessment of the coastal erosion problems along selected stretches around the Zanzibar islands as well as along the mainland coastline of Tanzania, indicated a significant contribution to the problem by man's activities. During the study 56 eroding beaches were studied to assess the extent of man's contribution to the problem. Man-induced erosion was observed in 9 cases. By interfering with nature man either initiated erosion or enhanced its rate. The activities identified fall into three categories, namely (I) removal of beach material, (ii) removal of the protection against wave battering and (iii) obstruction of sediment supply.

The observed man-induced erosion has occurred as a negative effect resulting from poor understanding of the natural processes. It was found out that sand extraction from the beach for road construction is taking place in Zanzibar because many think beach sand is more needed for the roads than it is needed for the stability of the beach itself. Similarly, mangroves are cleared in front of newly constructed tourist hotels because people are only concerned with a clear view to the sea and absence of mangrove litter to improve the hotel site aesthetics. As such, the mitigation measures that are to be considered in such situations are not expected to be complicated. It is necessary to know what are the possible negative effects of any coastal development action prior to its execution. In some cases managers need only to establish a catalogue of activities that may not be permissible along a given stretch of coastline.

SEDIMENT DISTRIBUTION AND TRANSPORT OFF THE WESTERN COAST OF ZANZIBAR

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A sedimentological study has been conducted in the near shore waters off the western coast of Zanzibar near Zanzibar town, which is characterized by the presence of several topographic structures, in the form of raised coral platforms, submerged sandbanks and other minor reef related structures.

The study deals with the investigation of sea bottom topography, sediment distribution and transport in this near shore area. The investigation of sea bottom topography was undertaken using Atlas 470 echo sounder, while the investigation of sediment distribution and transport was undertaken by collecting sediment samples on the sea bottom, on some of the near shore structures and along the beach. GPS was used during collection of all the above data.

Processing of the sounding data involved correcting the data for tidal variation, converting the GPS fixes corresponding to each depth value to UTM (Universal Transverse Mecator) coordinates of the local mapping system and overlying the transformed coordinates with their depth values on the base map of Zanzibar, digitized using the same units (UTM coordinates). Processing of the sediment data involved sieving the samples for determining grain size statistics (namely Mean, sorting, skewness and kurtosis) as well as analysing the samples for acid soluble carbonate content by weight.

The bathymetric data shows that the depth in the study area increases progressively towards the offshore and also along the northwesterly, so that relatively higher depths are noticeable in the southeastern part of the study area and relatively lower depths are noticeable in the southeastern part of the study area. The depth trends seem to be conformable with the structural trends on the sea bottom.

The distribution of mean grain size (M_2) reveals that most areas consist of medium sand ($1.0F < M_2 < 2.0F$). Coarse sand ($M_2 < 1.0F$) is limited to places around the near shore structures, while fine sand ($M_2 < 2.0F$) is common in deeper parts. The distribution of sorting shows that most sediments are poorly sorted and that, sorting is probably related to mean grain size distribution; generally the sediments are more poorly sorted in coarse sand areas than in fine sand areas. The distribution of skewness shows that the sediments are generally negatively skewed. Sediments on the near shore structures are generally more negatively skewed than others. The distribution of kurtosis show that most of the sediments are either platykurtic or mesokurtic. The distribution of acid soluble carbonate shows that sediments on the near shore structures and from the southern parts are generally biogenic (>50% $CaCO_3$), while sediments close to the shore and those found further north are siliciclastic (<30% $CaCO_3$).

The present study reveals that shoreward transport of carbonate sand from the near shore structures, which are supposed to be the source of carbonate sand is not very likely. On the other hand there is much evidence supporting the offshore transport of siliciclastic sand from beaches north of Mbweni. This offshore transport of siliciclastic sand that is not replenished is suggested to be the cause of erosion in the study area.

BEACH EROSION AND ITS MANAGEMENT STRATEGIES IN KENYA

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The coastline of Kenya is an area of great physical beauty with palm-fringed beaches of white coral sand. The beach provides a restful setting for picnics, walks along the shore, sun bathing and also encourages more vigorous sports including swimming, jogging, surf casting and surfboard riding. No doubt, the beaches are most important tourist attractions at the Kenyan Coast.

However, coastal erosion is a prevalent phenomena along the Kenyan Coast. Notable areas are Malindi, Watamy, Kanamai, Shanzu, Bamburi, Likoni, Tiwi, Diani and Gazi beaches which are in a state of critical erosion. During low tide, coconut tree stumps can be sited in the sea in some parts of the coast. This is true of Kanamai where a stump that was on the beach in 1971 is now located about 60 m from the present shoreline. The estimated annual retreat at Kanamai between 1971 and 1997 is therefore 2.3 m.

Degradation of shorelines is enhanced by over development of beach hotels, sweeping of the beaches, games like volley ball on the beaches, beach mining, deforestation of mangroves and discharge of waste waters especially from the swimming pools onto the beaches. From Kikambala to Mtwapa, several beach hotels, cottages and private houses have been built along the shore or just a few metres landward. Sweeping of the seaweeds off the beaches has two serious effects on the beach. One, by sweeping off the seaweeds from the beach with a rake, sand is not only exposed but also loosened. During high tide, therefore, more sediments are likely to be eroded and two, by loosening the sand, the waves easily erode the loosened sand from the beach into the lagoons or onto the shore platforms.

In an attempt to prolong the life of beach hotels, stabilizing structures such as sea-walls, revetments and groynes have been used. Sea-walls and revetments prevent waves from reaching erodible materials and they are constructed parallel to the shoreline. Groynes, which are constructed perpendicular to the shoreline slow down the rate of littoral transport and so traps sediments. These structures instead accelerate the natural rate of beach erosion resulting in environmental degradation and alarming economic losses.

Beach nourishment and stabilization of the dunes is practised to a lesser extent for shoreline restoration. Lack of coastal zone management system is a major problem and there is an urgent need for a coastal zone management system and to enact a legislation which would protect coastal resources and environment for their sustainability.

The object of this paper is therefore to provide information on the beach protection measures on the Kenyan Coast and problems arising from inappropriate measures of coastal protection. Basic options are recommended in response to the already existing problems.

BEACH EROSION AND THE ROLE OF COASTAL STRUCTURES IN BEACH PROTECTION

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Shoreline erosion is a natural process in which the boundary between land and water shifts in position and time. When shoreline erosion becomes chronic, coastal communities world-wide are then faced with a difficult and important management problem since the coastal zone consists of high land values, recreational facilities, infrastructure and property.

Erosion is a result of two basic causes, namely: (1) the forces of nature and (2) the human intervention whereby human activities interfere with the continuing coastal processes. The problem of shoreline erosion results in attempts to reduce it by coastal protection measures.

There are several methods of beach protection which can be divided into two categories: (1) direct measures which are meant to prevent or abate the immediate effect of the problem and (2) indirect measures which take away the causes of the problem. Before deciding which measure is to be taken for beach protection, one has to decide what kind of beach protection is actually needed. Since various methods of protection have different impacts on the morphology and aesthetics of the particular area and adjacent areas, one has to look carefully into the size, type and location of the coastal protection, and even more important the economic justification of the solution. An ill-advised design may become too expensive to carry out and affect the coast negatively rather than remedy the situation.

The paper reviews the causes of beach erosion, measures used for beach protection and the impact of the structural intervention on the particular shoreline and adjacent shorelines.

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UNEP'S EASTERN AFRICAN COASTAL AND MARINE ENVIRONMENT RESOURCES DATABASE AND ATLAS (EAF/14)

Dirk Van Speybroeck

The Nairobi Convention, and its Action Plan for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern African region, was adopted by nine countries of the Eastern African region (Comoros, France - La Réunion-, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, Tanzania), and the European Union, in 1985, and entered into force in May 1996. The Action Plan, together with its two protocols, one concerning Protected Areas and Wild Fauna and Flora, and a second one concerning the Co-operation on Combatting Marine Pollution in Cases of Emergency, provides a framework for regional cooperation to tackle problems concerning the region's marine and coastal environment.

The Eastern African coastal and marine environment database and atlas project (EAF/14) is one of UNEP's regional activities under the framework of the Nairobi Convention and its Action Plan. EAF projects are implemented by national institutions, which are selected by the respective Governments on the basis of their expertise. EAF projects are implemented on a cost-sharing basis; ie the institutes to provide the project with infrastructure and human resources, and the Secretariat to arrange for the regional coordination, technical support and the necessary additional resources.

The EAF/14 project's main objectives are to summarise and distribute, first at the national level, and later at the regional level, information on the coastal environment in a format accessible to planners and decision makers, and the wider community alike. Data and information on the coastal and marine environment become available under two formats: (i) through a set of coastal resource maps together with an accompanying textbook on the coastal resources, and (ii) through a coastal resources geographic information system (GIS) database. The coastal resource maps and textbook are freely distributed within the country, whilst the coastal resources GIS database is managed by a national institution, to provide assistance to policy makers in developing and managing the coastal environment.

The geographical scope of the project is limited to the coastal and marine environment of Comoros, Kenya, Madagascar, Mauritius, Mozambique, Réunion (France), Seychelles and Tanzania. The coastal environment, for the purposes of the project, has been identified as a 100 km wide strip, covering at least 50 km of the land and about 50 km of the marine environment. Small island states are entirely covered by the project.

In each of the countries, a number of similar activities, estimated to last for about 18 months, are carried out under the EAF/14 project. These activities include:

- Establishment of In-Country Working Group
- Search and collation of existing data
- Interpretation of satellite images
- Development of a coastal GIS database
- Training in GIS techniques and satellite interpretation
- Production of resource maps

Project activities are finalised in Kenya, with the Kenyan coastal GIS database being fully operational at the Kenyan Marine Fisheries and Research Institute (KMFRI). In-Country Working Groups are established in Comoros, Madagascar, Mauritius, Mozambique, Seychelles and Tanzania, and are at various stages in the data collation and GIS database development. Training in ArcInfo GIS software and satellite image interpretation, as well as the delivery of the project equipment is finished. A project newsletter "EAF COASTAL RESOURCE MAPS" has been distributed in the region since 1995 at more than 200 copies.

Experiences learnt from the EAF/14 project are linked to the issue of copyright of the database and the information distributed within the country and abroad alike, and the effective use of the database for resolving spatial problems related to the sustainable management of both the coastal, marine and river basin environment.