Regional Synthesis Report

on the

Status of Pollution in the Western Indian Ocean Region

Final Report

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EXECUTIVE SUMMARY

INTRODUCTION

The project "Addressing land-based activities in the Western Indian Ocean" (WIO-LaB) is an initiative of the Nairobi Convention designed to address environmental problems and issues related to the degradation of the marine and coastal environment due to land-based activities in the Western Indian Ocean (WIO) region. The project represents a partnership amongst eight participating countries (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania), UNEP, the Government of Norway and the Global Environment Facility (GEF).

One of the key activities of the WIO-LaB project has been the execution of a Transboundary Diagnostic Analysis (TDA) focused on land-based activities in the WIO region. This Regional Synthesis Report on the Status of Pollution in the WIO Region is based on information presented in the National Status of Pollution Reports, which form the basis for the TDA of the WIO region. The TDA is an important part of the overall strategic planning process, providing a basis for the formulation of the Strategic Action Plan (SAP) and the harmonised National Programmes of Action (NPAs) on the protection of the WIO coastal and marine environment from land-based sources and activities.

The focus of this report is on *land-based sources* of marine pollution, typically addressed under the UNEP Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA) and the Nairobi Convention. It does not deal with *sea-based sources* of marine pollution (e.g. maritime transportation and offshore dumping of waste), which are typically dealt with under other international conventions.

As this regional synthesis is used as input to the TDA/SAP process for the WIO region, a causal chain approach similar to that recommended for the TDA/SAP process and documented by the GEF International Waters Programme (GEF 2005) was followed. The approach uses a step-by-step process:

- Step 1: Information and data 'stock taking' exercise
- Step 2: Identification of priority problems and associated environmental impacts and socio-economic consequences
- Step 3: Analysis of causal chains by identifying the immediate (or direct) causes and underlying sectors (or 'pressures'), and the root causes (or 'drivers') of each priority problem
- Step 4: Governance analysis (or response).

COASTAL AND MARINE ENVIRONMENT OF THE WESTERN INDIAN OCEAN (WIO) REGION

The main ecosystem components of the WIO region's coastal and marine environment are seagrass beds, mangrove forests and coral reefs. These ecosystems serve as habitats for a wide diversity of marine organisms, ranging from algae and invertebrates through to vertebrates, including threatened species such as marine turtles and dugongs. In addition to their direct value in terms of fisheries, provision of food, fuels and building materials, these ecosystems provide critically important indirect goods and services, which include:

- Sediment trapping and stabilization,
- Shoreline protection,
- Provision of oxygen to waters and sediments,
- Turbidity reduction,
- Trapping and cycling of nutrients,

- Visual amenity and shoreline aesthetics, and
- Nutrient uptake, fixation, trapping and turnover.

Populations across the WIO region therefore have strong and direct dependencies on seagrasses, mangroves and coral reefs.

SOCIO-ECONOMIC OVERVIEW

The countries in the WIO region (including Réunion, France) had a combined population of 178 million in 2007. The proportions of the population living in a 25-km coastal strip vary substantially, from 6.1% in Kenya to 100% in the small island states. Opportunities created by urbanisation, availability of ports and harbours and various coast-specific development processes have attracted high concentrations of people in some areas. In addition, a significant percentage of coastal communities in the WIO region depends directly on nearby coastal and marine resources for their livelihood and income generation. The main forms of land and sea use are fisheries, tourism, agriculture, industry, forestry, shipping/ports, mining, conservation, housing and infrastructure.

POLLUTION HOTSPOTS IN THE WESTERN INDIAN OCEAN REGION

Land-based sources of marine pollution in the WIO region are primarily associated with urban areas and river discharges from larger catchments into the sea. At present urban centres in the WIO region are still several hundred kilometres apart, creating distinct hotspots. However, it is likely that rapid urbanisation in the region will result in ‘strip development’ of coastal areas, when smaller coastal towns and suburban areas eventually join up with the main cities, creating larger continuous urban zones along the coastline. Hotspots of land-based sources of marine pollution were identified based on previous studies (e.g. the African Process) as well as work conducted as part of the WIO-LaB project (National Pollution Status Reports and WIO-LaB-supported monitoring programmes).

At a meeting of the WIO-LaB Regional Working Group on Water, Sediment and Biota Quality Monitoring and Assessment in the WIO region held in Dar es Salaam, Tanzania on 23-25 June 2009, it was recognised that WIO hotspots could be classified into different groupings based on the severity of pollution and significance of impact. A categorisation framework was proposed and evaluation criteria developed to describe four categories of hotspots: Hotspot Categories 1–3, in order of decreasing severity of pollution and significance of impact, and Hotspot Category 4 for potential or emerging hotspots. Using this categorisation system, and based on recent results of WIO-LaB water and sediment quality monitoring programmes, pollution hotspots in the WIO were categorised as tabulated below:

COUNTRY	LOCATION	SEVERITY	SIGNIFICANCE	HOTSPOT CATEGORY	Pollution type		
					Microbiological	Metal	Nutrient
Comoros	Port Famboni			4	X	X	X
	Chindini beach			4	X		
	Chomoni beach			4			
	Mitsamihouli	3	1	2	X	X	X
	Port Moroni	1	2	1	X	X	X
	Port International de Mustamudu	1	1	1	X	X	X
Kenya	Mombasa inshore waters	1	1	1	X	X	X
	Lamu inshore waters	1	2	1	X	X	X
	Malindi Bay and Sabaki Estuary	1	1-2	1	X	X	X

COUNTRY	LOCATION	SEVERITY	SIGNIFICANCE	HOTSPOT CATEGORY	Pollution type		
					Microbiological	Metal	Nutrient
	Diani	2	2	2	X	X	X
Madagascar	Nosy Bé	1	1	1	X	X	X
	Mahajanga	1	1	1	X	X	X
	Toliera	1	1	1	X		X
	Bay de Diego	2	1	1		X	X
	Port of Tamatave	2	2	2		X	
	Port Dauphin	2	2	2	X	X	
Mauritius	Palmar	2	1	1	X		X
	Pointe aux Sables to Baie du Tombeau	2	1	1	X		X
	Grand Baie	3	3	3	X		X
	Flic and Flac			4	X		X
Mozambique	Maputo Bay	1	1	1	X	X	X
	Beira			4	X		X
	Nacala Bay			4	X		X
	Pemba Bay			4	X		
	Incomati Estuary			4			X
Seychelles	Port Victoria	2	2	2	X	X	X
	Anse Volbert		2	4	X		
	La Digue		2	3	X		
	Beau Vallon Bay	2	2	2	X		X
	Mahé East Coast	3	2	3	X	X	X
South Africa	Richards Bay	3	3	3		X	
	Durban	2	1	1	X		
	East London			4	X		X
	Port Elizabeth			4	X	X	
	Eastern Cape and KwaZulu-Natal estuaries (and adjacent coastal areas)			4	X		X
Tanzania	Dar es Salaam	1	1	1	X	X	X
	Tanga	2	1	1	X		X
	Zanzibar	1	1	1	X		X

TRANSBOUNDARY PROBLEMS

Consideration of pollution issues at a regional scale is clearly important when dealing with coastal and marine systems. The transport and fate of land-based pollution is strongly influenced by ocean currents. Transboundary pollution impacts can arise when pollution originating in one country impacts coastal areas of another. Unlike enclosed or semi-enclosed marine water bodies such as the Baltic or Mediterranean, the coastal region of the Western Indian Ocean is much more exposed, with less chance of land-based sources of marine pollution causing transboundary impacts. However, considering the ocean circulation patterns in the WIO regions, transboundary impacts cannot be ruled out. Direct transboundary impacts are easily understood, but marine pollution can also contribute to transboundary issues in an indirect way. For example, land-based activities may affect one or more life stages of migrant marine organisms, thus influencing their distribution and abundance of these organisms in a neighbouring country or region. For the purposes of the WIO-LaB project, transboundary problems were also taken to include land-based marine pollution issues that are *common* to countries in the WIO region, even though they might not necessarily result in direct transboundary impacts in the true sense of the word.

Five priority transboundary problems linked to marine pollution and deterioration of coastal water quality as result of land-based activities are identifiable in the WIO region:

- Microbial contamination,
- High suspended solids,
- Chemical pollution,
- Marine litter (including solid waste), and
- Eutrophication (or nutrient over-enrichment).

These transboundary problems were initially prioritised by regional stakeholders and experts at a Regional Consultative Workshop on the preparation of the TDA held in Nairobi, Kenya in April 2007. The primary method applied for this exercise was a multi-criteria analysis undertaken by over 40 experts from various disciplines and representing all the project countries. Following detailed analysis of the transboundary problems, the prioritisation of problems was further refined by the Scientific and Technical Review Workshop of the TDA held in Mombasa in August 2008, where the various problems and causes were analysed through a step-wise prioritisation exercise. Results are tabulated below.

PROBLEMS	SEVERITY	SCOPE	OVERALL RATING
Microbial contamination	H	H	H
High suspended solids	H	H	H
Chemical pollution	M	L	L
Marine litter and debris	L	L	L
Eutrophication	L	L	L

Assessment was made of each of the priority transboundary problems in terms of severity of pollution (including analysis of water and sediment quality data from WIO-LaB-funded monitoring programmes to render the assessment as up-to-date as possible), as well as associated environmental impacts and socio-economic consequences.

Microbial contamination

Microbial contamination is a problem in many WIO marine pollution hotspots. It is typically associated with inappropriate disposal of municipal wastewater (including sewage), contaminated surface and sub-surface runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing, and industrial effluents (mainly from food-processing industries). Causal chain analysis of microbial contamination in the WIO region identified the key contributing sectors as urbanisation, tourism, agriculture, industry and transportation (harbour and port waste). Microbial contamination can have severe socio-economic consequences in coastal waters, including human health risks associated with contact recreation or ingestion of contaminated seafood, and reduced quality (and economic value) of seafood cultured or harvested in a particular area. These consequences affect stakeholders across society, from local communities to international tourists, as well as industrial and aquaculture operations. Loss, or potential loss, of the recreational value of coastal waters, due to unacceptable levels of faecal bacteria (typically used as indicators of microbial contamination), is evident throughout the coastal zone of the WIO region. Areas of concern are usually near larger urban centres where poorly treated or untreated waste and wastewater is problematic. In many areas the situation is accompanied by unpleasant aesthetics and bad odours, also a consequence of inappropriate waste and wastewater management.

High suspended solids

High concentrations of suspended solid loads enter coastal waters of the WIO from land-based sources, including municipal and industrial wastewater discharges, river discharges and surface runoff. Dredging activities (usually associated with ports and harbours) can also significantly contribute to this transboundary problem. Key sectors contributing to high suspended solid loads in the marine environment are agriculture (soil erosion in river basins/catchments), industry (particularly those discharging effluents containing high suspended solid loads) and transportation (primarily linked to harbour dredging). The urban sector (e.g. local municipalities) also contributes through inappropriate disposal of municipal waste, while aquaculture may contribute to the problem through the disposal of waste containing high suspended solids.

High suspended solids have chronic and acute effects on marine biota, by clogging of gills and feeding apparatuses of marine organisms. Smothering of biota and discoloration of coastal waters causes modification of species compositions in marine biological communities. The consequences of this type of pollution affect stakeholders across society, from local communities to large international tourism concerns. Aquaculture and agro-processing industries are also affected. The social and economic consequences of increased suspended solids in coastal waters include loss of aesthetic value, reductions in quality of seafood, and loss of artisanal, commercial and recreational fisheries resources and revenue.

Chemical pollution

Chemical contaminants are compounds that are toxic, persistent and/or bio-accumulating. They can be grouped into three broad categories: heavy metals, hydrocarbons and persistent organic compounds (e.g. pesticides). The key sectors contributing to chemical pollution of coastal and marine waters in the WIO region include industry (disposal of toxic substances in wastewaters), agriculture (persistent organic pollutants) and transportation. The major industries contributing to chemical pollution in the WIO region include manufacturing; textiles; tanneries; paper and pulp mills; breweries; chemical, cement, sugar and fertiliser factories; and oil refineries. Inappropriate utilisation, storage and dumping of agrochemicals are of increasing concern. Accidental spills of oil or chemicals in harbour areas or along transport routes near the coast are another cause of chemical pollution.

Specific environmental impacts linked to chemical pollution include discolouration of coastal waters, chronic (e.g. affecting growth and reproduction) and acute effects on marine biota and, therefore, modification of species compositions in marine biological communities. The consequences of chemical pollution affect stakeholders across society, from local communities to large tourist developments. Commercial and artisanal fisheries, as well as aquaculture and seafood production industries, may also be affected. Socio-economic consequences include loss of artisanal and/or commercial fisheries, reduction in quality of seafood products cultured or harvested from a particular area, and human health risks associated with contact recreation or ingestion of contaminated seafood.

Marine litter

Marine litter (which either floats or sinks) is introduced into coastal waters of the WIO by inappropriate disposal of solid waste, and represents a serious problem in most of the coastal urban centres in the WIO region. The main sectors contributing litter in marine environments include the urban and tourisms sectors, industry and transport. Major environmental impacts of litter are ingestion by or entanglement of marine organisms, resulting in loss of biodiversity. Socio-economic consequences include loss of aesthetic value of coastal areas and risks to human heath through contact with contaminated waste products (e.g. medical waste). Marine litter affects stakeholders across society, from local communities to large tourist developments, through its negative impact on the aesthetic value of coastal areas and the risks it poses to human health.

Eutrophication

Eutrophication refers to artificially enhanced primary production (e.g. algal and phytoplankton growth) and elevated organic matter loading due to the increased availability or supply of nutrients. Wastewater with a high organic content (high biological or chemical oxygen demand) or containing high levels of inorganic nutrients (e.g. nitrogen and phosphate) is a major cause of eutrophication. While eutrophication in the true sense of the word hardly ever occurs in the WIO region's coastal and marine zone, harmful or nuisance algal blooms resulting from nutrient enrichment are problematic in some areas. The key sectors that contribute to eutrophication and algal blooms in coastal waters include the urban sector (municipalities responsible for waste disposal), industries (generating wastewater with high oxygen demand and nutrient loads) and agriculture (from inappropriate use and disposal of fertilisers). Environmental impacts of eutrophication/algal blooms include nuisance or harmful algal blooms which affect both aesthetics and biodiversity, discolouration of coastal waters affecting light-dependent benthic species, smothering of benthic communities during die-off of algal blooms, mortalities of marine biota (e.g. caused by anoxic conditions generated on decomposition of organic matter) and modification of species compositions in marine biological communities. A broad range of stakeholders are potentially affected by eutrophication/algal blooms, from local communities to larger sectors such as fisheries, aquaculture and tourism. The socio-economic consequences of eutrophication include loss of aesthetic value, risks to human health from contact recreation and ingestion of contaminated seafood, and loss of artisanal and/or commercial fisheries and aquaculture.

CAUSAL CHAIN ANALYSIS

Direct causes and underlying sectors

From the above discussion it is clear that in the WIO region transboundary marine pollution problems and their associated impacts can be attributed to a number of direct causes and underlying sectors. There can be several causes for a particular marine pollution problem and, on the other hand, a single direct cause can result in several different problems. This is summarised below:

TRANSBOUNDARY PROBLEM					DIRECT CAUSE	UNDERLYING SECTOR
Microbial contamination	Eutrophication	Marine litter	Suspended solids	Chemical pollution		
√	√		√		Disposal of untreated or under-treated municipal wastewater	Urbanisation, Tourism
√	√		√	√	Industries discharging untreated or under-treated wastewater	Industry
			√	√	Dredging activities	Transportation
√	√		√	√	Waste from coastal mining and exploration	Mining
√	√	√	√	√	Contaminated surface and sub-surface runoff (e.g. from municipal, industrial and agricultural areas, as well as from accidental spills)	Urbanisation, Tourism, Industry, Mining, Transportation, Agriculture
			√		Destruction of coastal forests contributing to high suspended solid loads	Forestry
√	√	√	√	√	River discharges transporting high suspended solid loads (as a result of soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchments	Agriculture, Urbanisation, Industry
	√			√	Leaking and leaching of agrochemicals	Agriculture

TRANSBOUNDARY PROBLEM					DIRECT CAUSE	UNDERLYING SECTOR
Microbial contamination	Eutrophication	Marine litter	Suspended solids	Chemical pollution		
					(fertilisers and pesticides) from inadequate storage facilities, dumping or return-flows	
√	√				Runoff from livestock-rearing areas	Agriculture
	√			√	Atmospheric emissions (e.g. incineration of waste, vehicle and industrial emissions and wood/coal burning)	Industry, Urbanisation, Tourism, Energy production
√		√		√	Inadequate collection, treatment and disposal of solid waste	Urbanisation, Tourism, Industry, Transportation
		√			Public littering on beaches and in areas where litter can be transported into coastal areas	Urbanisation, Tourism
	√		√		Waste products from aquaculture farms (high in nutrients and suspended solid loads)	Aquaculture

Direct causes of marine pollution can therefore be divided into a number of key underlying sectors:

- Urbanisation and tourism
- Agriculture and forestry
- Industry and mining
- Transportation (including harbours)
- Energy production
- Aquaculture.

Urbanisation and tourism

Rapid and often uncontrolled urbanisation and tourism development is occurring in coastal areas of the WIO region. This is accompanied by increases in municipal wastewater, municipal solid waste and atmospheric emissions (e.g. from burning of fossil fuel and vehicular traffic). These pollution sources are often not properly managed or controlled.

Untreated sewage from sanitary facilities (septic tanks, pit latrines and malfunctioning wastewater treatment plants) is a major source of marine water quality degradation in many WIO countries. Available information on municipal wastewater loads in coastal areas in the WIO region varies from one country to another, with some countries having detailed information on waste loads and others with very limited and often only qualitative information. The level of treatment of municipal wastewater, as well as the type of treatment (or lack thereof) also differs from country to country. To varying levels, municipal wastewater enters marine environments through seepage or rivers in all of the countries of the WIO region. Microbial contaminants, nutrients and suspended solids are the main pollutants in untreated municipal wastewater. The highest concentrations of these pollutants are therefore found close to the major cities in the region, although in many rural coastal areas, low-level sewage contamination from defecation on beaches is common.

Information and data on the quantities of solid waste disposed in coastal areas of the WIO region also varies considerably from one country to another. However, a feature common to all countries is that most land-based sources of solid waste are associated with urban centres (particularly informal settlements, industrial and commercial areas), and that wastewater runoff is the main distributor, via rivers, streams and stormwater drains. The major land-based sources of marine litter are solid waste dumpsites (legal and illegal) located on the coast or on river banks, surface water runoff (from stormwater drains, untreated municipal wastewater, river discharge and flood waters, industrial wastewater discharges and public litter on beaches and other coastal areas.

Urban and tourism activities that contribute to marine pollution through atmospheric emissions include fossil fuel fires (a large majority of coastal communities in the WIO region use fossil fuel for their domestic energy needs), traffic emissions, and forest burning to clear land for urban development. Atmospheric pollutants can also originate from solid waste dumpsites and burning of waste.

Agriculture and forestry

Agriculture is the backbone of the economies of most countries in the WIO region and is central to the alleviation of poverty and revenue-generation. Agricultural activities mainly contribute to marine pollution in that they produce elevated levels of four types of pollutant; suspended solids (the result of erosion due to inappropriate land-use practices), inorganic nutrients (excessive use of fertilisers), pesticides (persistent organic pollutants) and microbial contaminants (typically associated with runoff from livestock-rearing areas). Slash-and-burn clearing for subsistence agriculture adds to the atmospheric pollution in some countries. Pollutants from agricultural activities usually enter the marine environment through river discharges, although agricultural activities adjacent to coastal areas can directly contaminate coastal waters through surface or sub-surface runoff. The physical effects of soil erosion in river basins and the subsequent impacts related to suspended solid loading and siltation in coastal systems are currently of greater concern than agrochemical pollution in most countries throughout the region.

Agricultural activities in WIO countries are increasing and are becoming more mechanised and commercial. This trend increases the risk of pollution associated with soil erosion and the use of agro-chemicals. Even without substantial scientific evidence of existing impacts, it can be expected that marine pollution associated with agricultural activities will increase in the coming years, unless appropriate environmentally-sustainable agricultural practices are promoted in large river basins discharging into the WIO region.

Industry and mining

Major industries and mining activities situated within coastal areas of the WIO region include textile industries, tanneries, paper and pulp mills, breweries, chemical factories, cement factories, sugar refineries, food processing industries (e.g. fish factories and slaughterhouses), fertiliser factories, oil refineries, and oil and gas exploration (an emerging activity). These contribute to transboundary marine pollution problems through inappropriate disposal of liquid wastewater, solid waste or atmospheric emissions.

Transportation

Almost all of the large urban centres within the WIO region have large commercial ports and harbours. Activities such ship maintenance and repair, disposal of garbage and dredging contribute to transboundary marine pollution. Industrial zones are often located close to the major ports and harbours, and further contribute to marine pollution problems.

Energy production

Energy production influences marine water quality mainly through thermal discharges of cooling water and atmospheric emissions from combustion of oil, gas, or coal. Pollutant loads from these activities have not been properly quantified for the WIO region, thus no conclusive statement can be made about their contribution to marine pollution.

Aquaculture

Aquaculture activities in the WIO region are currently largely limited to the farming of crustaceans (e.g. shrimp, prawns and crabs) and seaweed in the Seychelles and Madagascar; crustaceans in Mozambique; and seaweed in Tanzania. Although aquaculture is still poorly developed in the region, it is an emerging sector that could have deleterious effects on coastal water quality, in terms of organic/nutrient pollution from uneaten feed or waste products, cleaning fluids and antibiotics in the feeds, and suspended solids from cleaning of ponds.

IMPORTANT ROOT CAUSES

From the above discussion it can be concluded that the main sectors contributing to the transboundary pollution problems in the WIO region are urbanisation, agriculture and industry. All have cross-cutting impacts. Aquaculture, tourism, mining, transportation, and energy-generation and consumption are associated with specific types of pollution. Finally, the root causes for pollution problems can be identified. Root causes (or drivers) are usually cross-cutting to transboundary problems and their direct and underlying causes and can typically be divided into the following categories:

- Population pressure,
- Poverty and inequality,
- Governance inadequacies,
- Inadequate knowledge and awareness, and
- Inadequate financial resources.

Population pressure

Population growth is a fundamental root cause threatening marine resources in coastal areas of the WIO region, because it increases the demand for goods, services and resources. Urbanisation is associated with people’s conversion to high-consumption lifestyles, which results in increased generation of waste. All of the countries in the WIO region have experienced rapid population growth and urbanisation in coastal areas, particularly the larger coastal centres. The increase in population and demographic changes have been a significant factor in the increased demand for land for housing and associated infrastructure (e.g. sanitation and waste management). Rapidly changing lifestyles, including increasing and changing consumption patterns and rising expectations, are a major root cause of the pressure on ecosystems. Populations along the coast are not evenly distributed, but are mostly associated with larger urban coastal centres. Specific aspects of population growth that pose potential risks to the natural environment are, amongst others, sanitation and solid waste. If not provided for adequately these issues can result in severe pollution impacts.

Poverty and inequality

The WIO region is characterised by some of the highest levels of poverty in the world. Lack of adequate financial resources is one of the main reasons for insufficient or unsuitable sanitation and solid waste disposal facilities in many of the WIO countries. Alleviating poverty is a major challenge, requiring transparency, progressive development, sound management of land and water resources, education on effective technologies for both commercial and subsistence farming, and appropriate policies for food security. Education, healthcare and empowerment of the people are essential elements for poverty alleviation.

Governance

Governance concerns the values, policies, laws and institutions by which issues are addressed and it defines the fundamental goals, the institutional processes and the structures that are the basis for planning and decision-making. Management, on the other hand, is the process by which human and material resources are harnessed to achieve a known goal within a known institutional structure. Thus, governance sets the stage within which management occurs. Inefficiency in the level of governance of marine pollution issues varies from one country to another. In many of the WIO countries some of the important building blocks for effective governance are not in place.

Knowledge and awareness

Empowerment of people in society and allowing them to play an active role in effective governance and management of natural resources (including marine resources) is an important factor in alleviating poverty. Knowledge is a key pillar for people's empowerment. However, within the countries of the WIO region many people do not have access to appropriate knowledge on matters such as:

- Environmental impacts and socio-economic consequences of human activities that, in many instances, are affecting their quality of life,
- Technologies to prevent or minimize the impact on the environment and the goods and services it provides, including appropriate agricultural practices, technologies for municipal wastewater treatment, solid waste treatment and disposal, and
- Existing policies and institutional structures that provide (often legally) enforceable ways of preventing or mitigating impacts on the environment and the socio-economic wellbeing of people.

Financial resources

The lack of financial resources to implement and enforce appropriate technologies and practices in order to prevent or minimise environmental impacts and/or socio-economic consequences of human activities in the marine environment is a concern in many countries in the WIO region. Furthermore, the lack of political commitment, in many instances, to address issues of environmental concern (including marine pollution) is reflected in the low priority given to these issues in the policies and budget allocations of countries in the region. Evidently, the socio-economic consequences of environmental degradation have not been properly communicated to policy-makers. With this knowledge, policy makers and politicians may give environmental issues more attention in national development agendas.

Legislative frameworks and institutional set-ups

Legal frameworks and institutional set-ups (with specific reference to issues affecting marine pollution) are in place in all WIO countries. However, various shortcomings can be identified in the policy and regulatory frameworks as well as institutional capacities in the different countries.

RECOMMENDATIONS FOR THE STRATEGIC ACTION PLAN

Coastal marine environments of the WIO region are currently threatened by numerous anthropogenic activities which cause marine pollution; physical destruction and alteration of habitats; and modification of freshwater inflows. Land-based activities are not the only threats to the coastal and marine environment. Others are, for example, exploitation of living resources (fisheries), maritime transportation, dumping of waste at sea and climate change.

Focusing on *marine pollution from land-based activities*, based on the outcome of this regional synthesis, recommendations for consideration in the SAP and National Programmes of Action (NPAs) are tabulated below. These recommendations are specifically related to three root causes: *inappropriate governance*, *inadequate knowledge and awareness*, and *inadequate financial resources*. The root causes of population pressure, poverty and inequality require much broader interventions, which are outside the scope of this regional assessment on marine pollution.

ROOT CAUSE	RECOMMENDATIONS
Inappropriate governance	Develop specific management tools (e.g. regional best practice guidelines) and demonstrate best practice technologies and management approaches for: • Municipal and industrial wastewater and solid waste (including governance aspects such as holding product manufacturers responsible for the treatment and recycling of their packaging, applying the 'polluter pays' and 'cradle to grave' principles and introducing economic incentives for low-waste packaging) • Ports and harbours (including issues related to on- and offloading, disposal of waste from vessels, disposal of used oil and oil-related products, and contingency planning in cases of accidental spills) • Agricultural activities (including issues related to soil erosion, agrochemical application and livestock raising).
	Develop regional guidelines for setting ELVs and standards for different industry types based on a technology-based or EQO-based approach.
	Develop targeted investment plans and proposals for the establishment of appropriate wastewater and solid waste management infrastructure in priority hotspots of pollution, e.g. based on the above-mentioned guidelines and lessons learnt from demonstration projects.
	Establish sector-specific ELVs / standards for different industry types using a technology-based and/or EQO-based approach, and develop mechanisms to convert such scientifically set standards into legally enforceable mechanisms.
	Mainstream the above-mentioned guidelines and investment plans into national policies, strategies, legislation and budgets.
	Enforce legislation/regulations for industries to conduct EIA studies and regular audits to assess and evaluate potential impacts on the coastal and marine environment, in alignment with the overarching EQOs and sector-specific ELVs, and ensure that local-level (on the ground) mechanisms are in place to audit and enforce compliance (e.g. monitoring programmes, and incentive and penalty systems).
	Develop a register of municipal wastewater and solid waste management facilities for each of the countries (working towards a permitting system, particularly for central wastewater treatment facilities and landfills).
	Develop a register of manufacturing industries (working towards a permitting system for such facilities).
	Develop a register of agro-chemicals use (e.g. fertilisers, pesticides, herbicides, etc), specifying allowable products and dosages (working towards legally enforcing such specifications).
Inadequate knowledge and awareness	Develop and implement monitoring and assessment programmes to fill gaps in knowledge of priority pollutants (e.g. those identified in the national pollution status reports), including major sources of pollution and their driving forces, with special emphasis on the identified coastal hotspots of pollution.
	Develop and implement regional training programmes to build capacity in wastewater and solid waste management (in many instances focusing on local municipalities and harbour authorities).
	Develop and implement regional education and awareness programmes to inform all sectors of society (including the general public, politicians and managers) on their roles and responsibilities in the generation, collection, treatment and disposal of wastewater and solid waste, as well as the consequences of pollution on the environment and their socio-economic wellbeing.
	Develop and maintain a web-based regional information management system that includes information on best practice technologies, registers (listed above) as well as tools and guidelines for the selection of appropriate technology, institutional and policy frameworks and financial mechanisms.
Inadequate financial resources	Identify and establish sustainable financial mechanisms for investments in the field of wastewater and solid waste management, and cleaner production technologies (including the development of public-private partnerships).

ELV, Effluent limit value; EQO, Environmental quality objective; EIA, Environmental impact assessment

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ACRONYMS AND ABBREVIATIONS

BOD	Biochemical oxygen demand
COD	Chemical oxygen demand
CSIR	Council for Scientific and Industrial Research (South Africa)
DEAT	Department of Environmental Affairs and Tourism (South Africa)
DWAF	Department of Water Affairs and Forestry (South Africa)
GDP	Gross Domestic Product
GEF	Global Environmental Facility
GNI	Gross National Income
GPA	Global Programme of Action for the Protection of the Marine Environment from Land-based Activities
IMO	International Maritime Organisation
NPA	National Programme of Action
SAP	Strategic Action Plan
TDA	Transboundary Diagnostic Analysis
UNEP	United Nations Environment Programme
WIO	Western Indian Ocean
WIO-LaB	UNEP/Nairobi Convention project titled ‘Addressing land-based activities in the Western Indian Ocean’

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1. INTRODUCTION

1.1 BACKGROUND

In 1985 the governments of the Eastern African region came together under the framework of United Nations Environment Programme (UNEP)'s Regional Seas Programme and endorsed the Nairobi Convention for the Protection, Management and Development of the Marine and Coastal Environment of the Eastern Africa region and its related Protocols. The Convention is aimed at maintaining essential ecological processes and life support systems, preserving genetic diversity, and ensuring sustainable utilization of marine and coastal natural resources in the region. Today, the Nairobi Convention has been ratified by all 10 eastern and southern African countries, namely Comoros, Réunion (France), Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa and Tanzania.

The project "Addressing Land-based Activities in the Western Indian Ocean" (widely known as the WIO-LaB project) is an initiative of the Nairobi Convention designed to address some of the main environmental problems related to the degradation of the marine and coastal environment in the Western Indian Ocean (WIO) region, due to land-based activities. The project is a partnership amongst eight participating countries (Comoros, Kenya, Madagascar, Mauritius, Mozambique, Seychelles, South Africa and Tanzania), UNEP, the Government of Norway and the Global Environment Facility (GEF).

The WIO-LaB project was designed as a demonstration project for UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities (GPA), with the following objectives:

- Reduce stress on ecosystems by improving water and sediment quality,
- Strengthen the regional legal basis for preventing land-based sources of pollution, and
- Develop regional capacity and strengthen institutions in the WIO region for sustainable, less polluting development.

One of the key activities of the WIO-LaB project has been to carry out a Transboundary Diagnostic Analysis (TDA) of land-based activities in the WIO region. This Regional Synthesis Report on the status of pollution in the WIO region collates the information presented in the National Status of Pollution Reports, which form the basis for the TDA for the WIO region. The TDA, in turn, formed the basis for the formulation of two major outputs of the WIO-LaB project—a Strategic Action Plan (SAP) and harmonised National Programmes of Action (NPAs) on environmental protection in the WIO region.

The focus of this report is on land-based sources of marine pollution, i.e. issues typically covered under the GPA and the Nairobi Convention (see www.gpa.unep.org/). This report does not deal with sea-based sources of marine pollution (e.g. maritime transportation or offshore dumping of waste), which are typically dealt with under other international conventions such as:

- The Convention on the International Maritime Organisation (IMO, see www.imo.org/)
- International Convention for the Prevention of Pollution from Ships 1973, as modified by the Protocol of 1978 relating thereto (MARPOL 73/78)
- Convention on the Prevention of Marine Pollution by Dumping of Wastes and Other Matter (LDC), 1972

- International Convention for the Control and Management of Ships' Ballast Water and Sediments, 2004.

1.2 APPROACH AND METHODOLOGY

A causal chain approach similar to that recommended for the TDA/SAP process, and documented by the GEF International Waters Programme (GEF 2005), was followed. The approach uses a step-by-step process, including:

Step 1: Information and data ‘stock taking’ exercise;

Step 2: Identification of priority problems and associated environmental impacts and socio-economic consequences;

Step 3: For each priority problem, analysis of causal chains by identifying its immediate (or direct) causes and underlying sectors (or ‘pressures’), as well as root causes (or ‘drivers’); and

Step 4: Governance analysis (or response).

Information and data stock taking (Step 1) was achieved using presentations and discussions from the Regional Consultative Workshop on the Preparation of the TDA for the WIO Region, held in Nairobi, Kenya (17 to 19 April 2007) as well from the following documents:

- Overview of land-based sources and activities affecting marine, coastal and associated freshwater environment in the eastern Africa region (UNEP 1998a)
- GEF MSP - Development and protection of the coastal and marine environment in sub-Saharan Africa: National Report Phase 1: Integrated Problem Analysis for Tanzania, Kenya, Seychelles, Mauritius, Mozambique and South Africa (also referred to as the Africa Process Reports, Francis *et al.* 2002, Kazungu *et al.* 2002, Jones *et al.* 2002, Dulymamode *et al.* 2002, Mong et al. 2009, Hoguane *et al.* 2002, Clark *et al.* 2002)
- National status reports on priority land-based activities, sources of pollution, and pollutant levels in water and sediment in the WIO region (Antoine *et al.* 2008, Anon Mozambique 2007, Anon Mauritius 2009, Mong *et al.* 2009, Munga *et al.* 2007, Mohammed *et al*. 2008, Abdallah *et al.* 2006, Weerts *et al.* 2009)
- UNEP/GEF - State of the Environment: Regional Assessments for southern and eastern Africa (Taljaard *et al*. 2006, Ruwa 2006)
- Regional overview and assessment of marine litter related activities in the WIO region (UNEP, 2008).
- Draft Regional Status Report on Municipal Wastewater Management in the WIO region (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009).

In its simplest form, a causal chain is one-dimensional, like an iron chain (GEF 2005), with a problem linked to some immediate (or direct) cause or pressure (e.g. disposal of sewage effluent). But there can also be several direct causes for a particular transboundary problem and conversely, a particular direct cause can result in multiple transboundary problems.

Direct causes can usually be aggregated into underlying causes. In turn, underlying causes can be grouped into different sectors, where each sector may have underlying causes of a different nature. Generic sectors are used wherever possible when constructing causal chains, for simplicity. It is usually possible to aggregate underlying causes into the following generic sectors:

- Urbanisation
- Tourism
- Agriculture
- Fisheries
- Industry
- Mining
- Transportation (including harbours)
- Energy production
- Aquaculture.

Finally, root causes for environmental problems are identified. Root causes (or drivers) are usually cross-cutting to transboundary problems, and their direct and underlying causes and can typically be divided into the following categories:

- Population pressure
- Poverty and inequality
- Inappropriate governance
- Inadequate knowledge and awareness
- Inadequate financial resources.

1.3 REPORT STRUCTURE

This report is structured as follows:

Following this introductory chapter, Chapter 2 provides an overview of the WIO region, describing the key features of its coastal marine environment, the socio-economic milieu, major marine pollution hotspots (from land-based activities) and the major marine circulation systems that play an important role in the transport and fate of pollutants.

Chapter 3 deals with the major transboundary marine pollution problems identified (defined here as problems common to the countries of the WIO region) that are a result of land-based activities, as well as their potential impacts. Supporting scientific information on such impacts in the WIO region is also provided, where readily available.

Root cause analyses (or problem trees) for the major transboundary marine pollution problems are presented and discussed in Chapter 4, including an evaluation of the direct causes, underlying sectors and root causes.

Chapter 5 provides an overview of legal frameworks and institutional set-ups in the WIO region, with specific reference to issues related to marine pollution. This chapter was largely extracted from the Governance Analysis that was conducted as part of the TDA, as well as information contained in the national status reports (Anon. Mauritius, 2009, Mong *et al.* 2009, Anon Mozambique 2007, Munga *et al.* 2007, Mohammed *et al.* 2008, Abdallah *et al.* 2006, Antoine *et al.* 2008, Weerts *et al.*, 2009).

The final chapter (Chapter 6) provides recommendations for consideration in the SAP and NPAs, specifically with regard to addressing the problem of marine pollution.

2. OVERVIEW OF WESTERN INDIAN OCEAN REGION

2.1 COASTAL AND MARINE ENVIRONMENT

The WIO region is made up of Comoros, France (La Reunion), Kenya, Madagascar, Mauritius, Mozambique, Seychelles, Somalia, South Africa and Tanzania. These mainland and islands countries have a combined coastline exceeding 15,000 km (UNOPS 2008).

2.1.1 Oceanography

The oceanographic characteristics of the WIO within the context of this assessment can best be described in terms of (a) ocean circulation patterns; (b) key physico-chemical parameters (salinity, temperature and oxygen); and (c) primary productivity (Kanagev *et al.* 2009).

Ocean surface circulation in the WIO region (Figure 1) is primarily wind-driven, and is an important feature that strongly influences the distribution of marine organisms, availability of nutrients and the transport and fate of pollutants. The prevailing wind regimes in the WIO region can be divided into two distinct systems; the monsoon regime that dominates the Somali Current Large Marine Ecosystem, and the subtropical high-pressure system that dominates the southern region (the Agulhas Current Large Marine Ecosystem) (Beckley 1998, Okemwa 1998). The Northeast Monsoon is characterised by north-easterly winds over the tropics and northern subtropics (Ngusaru 1997), and affects the climate of the Northwest Indian Ocean from November to March. It has winds of moderate strength, with dry terrestrially-derived air blowing from Arabia to Madagascar (Weller *et al.* 1998). In contrast, during the Southwest Monsoon (June to October) the wind direction reverses and winds tend to be much stronger, with an intense windstream developing along the high Eastern African highlands (Ethiopian highlands, Kenya highlands, highlands of northern and southern Tanzania, etc.) (Ngusaru 1997, Slingo *et al.* 2005).

During the Northeast Monsoon, the North Equatorial Current flows westward, turns south at the coast of Somalia, and returns east as the Equatorial Countercurrent between 2° and 10° S. During the Southwest Monsoon, the North Equatorial Current reverses its flow and becomes the strong east-flowing Monsoon Current. Part of the South Equatorial Current turns north along the coast of Somalia to become the strong Somali Current. A pronounced front, a phenomenon unique to the Indian Ocean at 10° S, marks the limit of the monsoon influence (Kanagev *et al.* 2009).

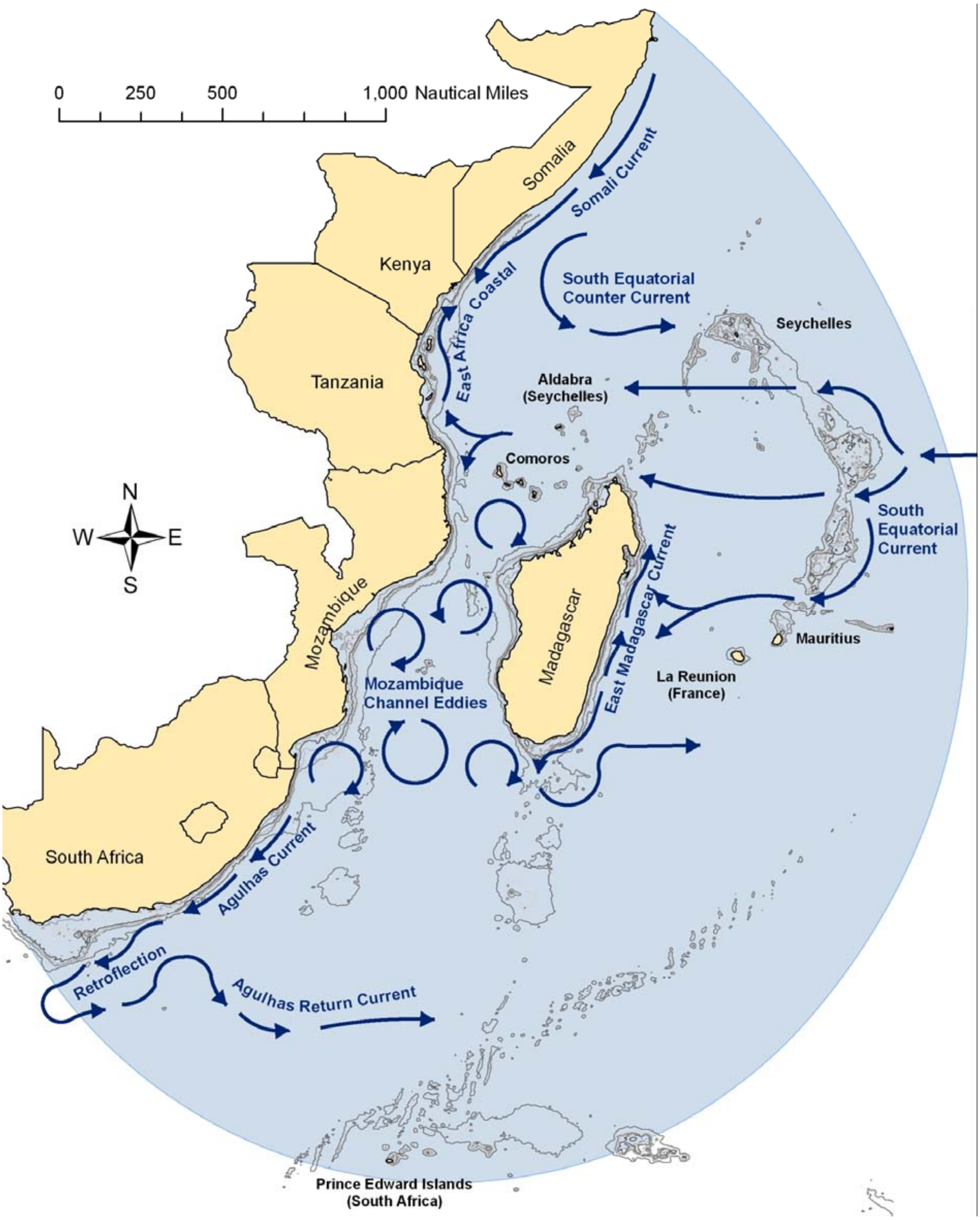

Figure 1: Schematic illustration of surface ocean currents in the Western Indian Ocean (courtesy of UNDP/GEF ASCLME Project)

The Somali Current reverses direction with season (American Meteorological Society 2000) and is the western boundary current of the Northwest Indian Ocean when flowing northwards along the East African coast. During the Northeast Monsoon, the Somali Current flows south, meeting the north-flowing East African Coastal Current which originates from the South Equatorial Current (Okemwa 1998, Horrill *et al.* 2000, American Meteorological Society 2000). The East African Coastal Current's geographical extent is seasonally determined and its interaction with the Somali Current shifts southward as the monsoon progresses (Horrill *et al.* 2000). By the time the Southwest Monsoon peaks in August, the Somali Current is established as a continuous current running from the East African Coastal Current to the East Arabian Current (American Meteorological Society 2000).

South of the monsoon region, there is a steady subtropical anti-cyclonic gyre, consisting of the west-flowing South Equatorial Current between 10° and 20° S, which divides as it reaches Madagascar (Kanagev *et al.* 2009, Lutjeharms 2006). One branch passes to the north of Madagascar and turns south as a series of slow-moving gyres or eddies that constitute the Mozambique Current between mainland Africa and Madagascar (Lutjeharms 2006). These drift southward along the shelf edge (Schouten *et al.* 2002) and can cause minor upwelling. The other branch, the East Madagascar Current, turns south to the east of Madagascar and then curves back to the east as the South Indian Current at about 40° to 45° S (Kanagev *et al.* 2009, Lutjeharms 2006). A strong, narrow, western boundary current, the Agulhas Current, is generated by this current and the Southwest Indian Ocean sub-gyre, with little inflow from the Mozambique Current (Lutjeharms 2006). The Agulhas Current flows along South Africa before turning east and joining the Antarctic Circumpolar Current south of 45° S. It generates periodic gyres between its western boundary and mainland which are responsible for minor upwelling (Lutjeharms 2006).

The current system at the eastern boundary of the ocean is not as well developed, but the West Australian Current flowing north from the South Indian Current closes the gyre to a certain extent. The Agulhas Current extends down to about 1200 meters and the Somali Current to about 800 meters. Other currents do not penetrate farther than 300 meters. Below the influence of the surface currents, water movement is sluggish and irregular, and is derived from a number of oceanic sources apart from the Indian Ocean. These cold, dense layers creep slowly northward from their source in the Antarctic Circumpolar region, becoming nearly anoxic (oxygen-deficient) en route.

The WIO region displays all three tidal types, namely diurnal, semi-diurnal and mixed, with the semi-diurnal (i.e. twice daily) type being the most widespread. Semi-diurnal tides prevail on the coast of eastern Africa as far north as the Equator (Hamilton and Brakel 1984). Tides are mixed in the northern region particularly towards the Arabian Sea (Sheppard 2000). Tidal ranges vary considerably. Mauritius, for example, has a spring tidal range of only 0.5 meters, while, along the eastern Africa coast, the spring tidal range is of the order of 3-4 meters (Alusa and Ogallo 1992, Hamilton and Brakel 1984, Kanagev *et al.* 2009).

The WIO region is a tropical area where the air temperature at sea level rarely falls below 20°C and seawater temperature is usually between 20 and 30°C. Seasonal upwelling occurs in some parts of the region. During the Southwest Monsoon, upwelling occurs off the Somali and Arabian coasts (Bakun *et al.* 1998, Kanagev *et al.* 2009). It is most intense between 5° and 11° N, with replacement of warmer surface water by water of about 14 °C.

The WIO region is subject to large variations in salinity as a result of high seasonal and annual variability in rainfall and evaporation rates. Sea surface salinity is also affected as by anomalous anticyclonic winds blowing in the Southeast Indian Ocean and preventing the export of saltier water from the WIO region. Overall, the salinity of WIO surface waters varies between 32 and 37 ppt, but with large local differences. High surface salinity (greater than 35 ppt) is also found in the Southern Hemisphere subtropical zone between 25° and 35° S, while a low salinity zone stretches along the hydrological boundary of 10° S from Indonesia to Madagascar.

The WIO region, particularly areas around the Agulhas and Somali Currents, is generally considered to be oligotrophic, characterised by low nutrient and phytoplankton concentrations. However, higher productivity is associated with surface upwelling areas, e.g. areas along the northern Somalia coast (McClanahan 1988, Mengesha *et al.* 1999). The flow of the South Equatorial Current delivers high levels of nutrients to the central and northern Mascarene Plateau regions, which may be responsible for higher levels of productivity in these areas (New *et al.* 2005). Nutrients and primary productivity in the surface waters of the Somali Current are generally low, except during seasonal upwelling (during the Southwest Monsoon) when colder nutrient-rich waters are introduced to the Somali and Arabian coasts.

2.2.1 Important coastal ecologies

The main ecological habitats of the WIO region are seagrass beds, mangrove forests and coral reefs. Estuaries could also be considered; these are complex systems that comprise numerous habitats and gradients in physico-chemical conditions and are better considered here as domains (along with nearshore and offshore, for example). Furthermore, consideration of seagrass beds and mangroves allows the two most sensitive estuarine habitat types to be included in this assessment.

(a) *Seagrasses*

Seagrass beds are a predominant feature throughout the shallow waters of the WIO region, and host a wide diversity of marine organisms, ranging from algae and invertebrates through to the vertebrate classes. Larger animals, including threatened species like marine turtles and dugongs, depend on seagrasses as a source of food (Richmond 2002). Seagrasses are continuously degraded either by direct disturbance and removal, or indirectly from impacts of land-based activities. This clearly has knock-on effects on other biota dependent on seagrasses. Key taxa within seagrass habitats are bacteria, fungi, algae, polychaetes, bivalves, gastropods, echinoderms (urchins, star fish and sea cucumbers), crustaceans (shrimp, prawns, crabs, isopods, and amphipods), fish, marine turtles and dugongs.

Seagrasses are marine angiosperms that cover large areas, called seagrass meadows or beds. These plants are the only true marine vascular plants. Seagrasses occur on soft substrates (sandy or muddy sediments) in intertidal and subtidal areas. They are usually found in estuarine and sheltered marine waters (den Hartog 1979, Richmond 2002) and create highly productive ecosystems that serve key functions (Duarte 2002). They are important habitats and nursery areas for numerous organisms including crustaceans, echinoderms, molluscs and fish. Other organisms such as macroalgae, epiphytes, fungi, sea anemones and a few sponge species are often associated with seagrasses. Seagrasses are a vital source of food for invertebrates and fishes, as well as for dugongs and marine turtles (Orth *et al*. 1984, Duarte 2002). Other functions of seagrass ecosystems include:

- Provision of oxygen to waters and sediments
- Sediment stabilization
- Shoreline protection
- Trapping and cycling of nutrients.

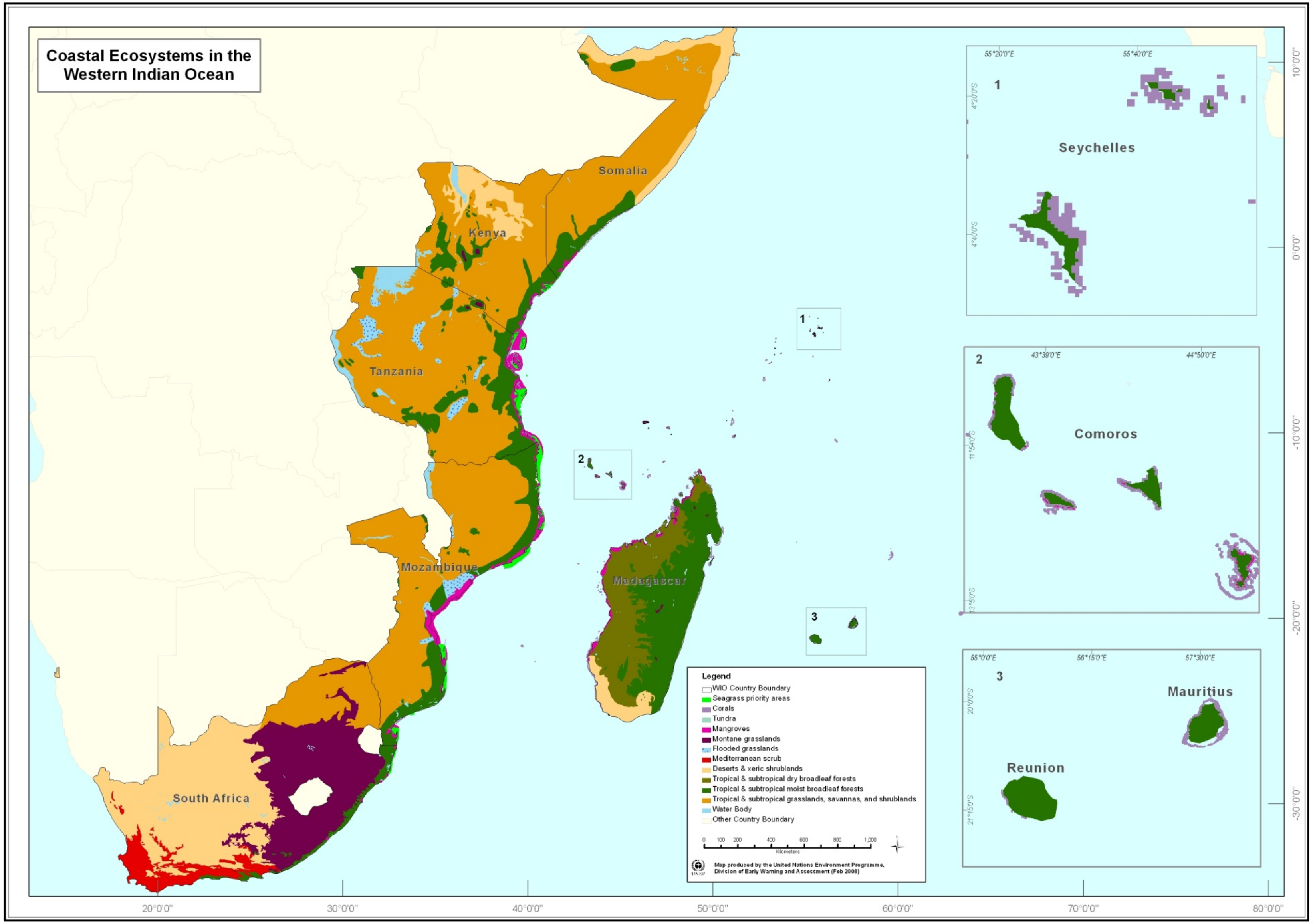

Figure 2: Distribution ofcoastal habitats within the Western Indian Ocean region

Twelve seagrass species, comprising about a fifth of the world's total, occur in the WIO region (Bandeira and Bjork 2001; Gulström *et al*. 2002). These species are divided into three families namely, *Zostera capensis* of the Zosteraceae; *Thalassia hepmrichii*, *Halophila ovalis*, *H. minor*, *H. stipulacea* and *Enhalus acoroides*, all Hydrocharitaceae, and *Cymodocea rotundata*, *C. serrulata*, *Halodule uninervis*, *H. wrightii*, *Syringodium isoetifolium* and *Thalassodendron ciliatum* of the Cymodoceaceae family. Kenya, Tanzania and Mozambique support the highest diversity of seagrasses (see Table 1). *Ruppia maritima*, recently defined as a seagrass (Short *et al*. 2001), is also a dominant species in the south-eastern Africa (Colloty 2000).

Table 1 Seagrasses species in WIO counties

Species	Comoros	Kenya	Madagascar	Mauritius	Mozambique	Seychelles	Somalia	South Africa	Tanzania
Zostera capensis		√			√			√	√
Thalassia hemprichii	√	√	√		√	√	√	√	√
Thallassodendron ciliatum	√	√	√	√	√	√			√
Syringodim isoetifolium	√	√		√	√	√	√		√
Halodule wrightii	√	√	√	√	√		√		√
Halodule uninervis	√	√	√	√	√	√	√		√
Halphila stipulacea	√	√	√	√	√	√	√		√
Halphila minor		√			√				√
Halophila ovalis	√	√	√	√	√		√	√	√
Enhalus acoroides		√			√	√			√
Cymodocea serrulata	√	√	√	√	√	√	√	√	√
Cymodocea rotundata	√	√	√		√	√	√	√	√
Ruppia maritima								√	

Sources: Bandeira 2000, Colloty 2000, Bandeira and Bjork 2001, Bandeira and Gell 2003; Ochieng and Erftemeijer 2003, Database of Marine Organisms of Mauritius 2007.

The principal locations of seagrass beds in WIO countries are shown in Table 2.

Table 2: Important sites of seagrass beds in the WIO mainland and area covered

Country	Key location	Area (km^2)
Kenya	Gazi Bay	8.00
	Diane-Chale Lagoon	4.50
Tanzania	Chwaka Bay (Zanzibar)	100.00
Mozambique	Inhaca Island and Maputo Bay	80.00
	Mecúfi-Pemba	30.00
	Quirimbas Archipelago	45.00
South Africa	St. Lucia estuary	1.81

(b) Mangroves

Mangroves forests in the WIO region are species-rich habitats that support major fisheries, particularly in the estuaries of Mozambique, Tanzania and Kenya. Ten species of mangroves occur in the WIO region, with the most extensive forests located along the Mozambican coastline (Richmond 2002, Figure 2). Despite the ecological value of mangroves, these habitats are facing severe degradation from human activities. Key taxa that typically associate with mangroves are bacteria, fungi, algae, polychaetes, bivalves, gastropods, crustaceans (shrimp, prawns, crabs, isopods, amphipods), fish, marine turtles and dugongs.

Mangroves are woody trees that grow along sheltered shores and within estuarine and brackish waters of tropical and subtropical regions (Abuodha and Kairo 2001). They thrive in sedimentary lagoons, bays, estuaries and tidal creeks, and have adapted unique physiological and morphological characteristics to survive in environments with high salinity, wave action and anaerobic soils. Such adaptations include aerial roots for gaseous exchange, lateral roots for extra anchorage, tidal dispersal of propagules, rapid canopy growth and efficient nutrient uptake (Alongi 2002). Mangrove forests are extremely productive ecosystems that support complex food webs consisting of both terrestrial and aquatic organisms, and are vital spawning, nursery and feeding grounds for numerous invertebrates, fish, reptiles and birds (Abuodha and Kairo 2001, de Boer 2002). As mangrove sediment is continuously submerged and eroded by wave action, the root system of mangroves provides a habitat for epiphytic communities such as macroalgae and bacteria. In addition to these functions, mangrove systems also provide other ecosystem goods and services, including:

- Visual amenity and shoreline aesthetics
- Shoreline protection by mangrove tree and root structure, which reduces severe wave action and erosion
- Sediment trapping which reduces the turbidity of coastal waters
- Nutrient uptake, fixation, trapping and turnover.

Mangrove forests occur on approximately two-thirds of tropical shorelines worldwide (Sumich 1992) covering over 18 million hectares in 112 different countries. In the WIO region, they occur from the coast of South Africa to southern Somalia (Table 3).

Table 3: Area of mangrove forests in the WIO region (Sources: FAO 2005, Republic of Mauritius, Ministry of Environment and NDU 2007)

Country	Area (ha)	Localities of highest occurrences
Comoros	2,600	Grande Comoro, Moheli
Kenya	51,600	Lamu Archipelago, Tana Delta
Madagascar	314,000	West coast at Mahajanga Bay, Nosy Be, and Hahavavy
Mauritius	23	Mathurin Bay, Rodrigues
Mozambique	390,500	Zambezi Delta
Seychelles	1,900	Aldabra Atoll
Somalia	7,500	Juba/Shebele Estuary
South Africa	667	St Lucia, Mhlathuze Estuary
Tanzania	164,200	Rufiji Delta, Tanga, Kilwa , Pangani

The total area of mangroves in the WIO is estimated to be 10,000 km^2 (Spalding et al., 1997), representing about 5.0 % of the total global mangrove coverage. The best developed mangroves in the region are found in the deltas of the Rufiji River (Tanzania), the Tana River (Kenya), the Zambezi and

Limpopo Rivers (Mozambique) and along the west coast of Madagascar at Mahajanga, Nosy Bé and Hahavavy.

In the WIO region, nine species of mangroves are commonly encountered, with the most common species being *Rhizophora mucronata* and *Ceriops tagal*. The most common mangrove-associated tree species occurring within the mangrove ecosystem are *Barringtonia asiatica, Barringtonia racemosa* and *Pemphis acidula* (Beentje and Bandeira 2007).

(c) Coral reefs

Extensive and highly productive coral reefs fringe over 1500 km of the WIO region coastline (Figure 2). Besides the massive bleaching event in 1998 which caused the extinction of some species, coral reefs are negatively impacted by direct and indirect anthropogenic activities. Typical fauna and flora that inhabit coral reefs are macro- and micro-algae, tunicates, sponges, polychaetes, bivalves, gastropods, echinoderms (urchins, star fish and sea cucumbers), crustaceans (prawns, crabs, lobsters, isopods, amphipods) and fish.

Coral reefs are shallow subtidal ecosystems found in tropical and subtropical oceans (McClanahan 2002). They are formed by the calcification activities of coralline algae and scleractinian corals, which create a calcareous skeleton using chemical reactions (Richmond 2002). These living structures thrive in shallow and nutrient-limited waters to depths of 20 to 30 meters (McClanahan 2002).

Coral reefs serve dual roles as key producers of biomass in these environments, and their skeletons provide structural habitat for a diverse range of algae, soft corals, sponges, invertebrates, fish and turtles. Besides providing a unique habitat for biota, coral reefs protect the shoreline from strong wave action, provide construction materials and support local subsistence and tourism.

The eastern coast of Africa has a string of coral reefs that covers over 1500 km of the WIO region coastline. There are four main types of coral reefs. The most common type found in the WIO is the fringing reef, which is generally associated with shallow lagoons. Patch reefs, atolls and barrier reefs also occur (Table 4).

Table 4: Area of coral reefs in the WIO region (sources: Richmond 2002, UNEP/GPA and WIOMSA 2004a&b, Obura 2005)

COUNTRY	AREA OF CORAL REEF (km^2)	LOCALITIES OF HIGHEST OCCURRENCES
Comoros	430	Fringing and patch reefs around the island
Kenya	630	Northern and southern coasts of the country
Madagascar	2,230	Fringing and patch reefs around the island and the barrier reef, Grande Recife
Mauritius	870	Mostly fringing reef with some small barrier reef in the south east. Mahebourg barrier reef of Mauritius and patch reefs around the island
Mozambique	1,860	Quirimbas, Bazaruto, Inhaca, Inhambane
Seychelles	1,690	Fringing and patch reefs around the island
South Africa	<50	Fringing and patch reefs in Sodwana, St Lucia and Aliwal Shoal and Leadsman Shoal
Tanzania	3,580	Fringing reefs in Tanga, Pemba, Unguja, Mafia and patch reefs in the Zanzibar channel

Corals of the genera *Acropora* were the most abundant and diverse genus found in the WIO region. However, since the 1998 bleaching event, the geographic range of *Acropora* has become limited to southern Tanzania and northern Mozambique. *Millepora*, a once dominant genus in shallow coral communities throughout the WIO region, has also experienced a decline in these waters and is now represented in some regions by dead skeletons only. Previously dominant genera are now being replaced by those that are less vulnerable to bleaching, such as *Porites* (Obura 2005). Other genera commonly found throughout the WIO region include *Astreopora*, *Alveopora*, *Cyphastrea*, *Echinopora*, *Favia*, *Favites*, *Galaxea*, *Goniastrea*, *Goniopora*, *Hydnophora*, *Leptoria*, *Montipora*, *Oxypora*, *Pavona*, *Platygyra* and *Pocillopora* (Fagoonee 1990, Obura 2005).

2.2 SOCIO-ECONOMIC OVERVIEW

The countries in the WIO region (including Réunion) had a combined population of 178 million in 2007 (Table 5). In some of the WIO countries, significant percentages of the national population live on the coast. The opportunities created by urbanisation, availability of ports and harbours and various coast-specific development have attracted high concentrations of people in some areas. According to World Bank (2009) projections, the annual population growth rate in the region range from 0.4 % in South Africa to 2.6 % in Madagascar. The proportion of population (2000) in the 25-km coastal strip varies substantially between countries, from 6.1% in Kenya and 13.6 % in Tanzania to 100% in the small island states.

Table 5: Country size, total population size versus coastal populations in WIO Ocean countries (Gössling 2006, World Bank 2009)

COUNTRY	SIZE OF LAND AREA (km^2)	POPULATION x 10^6 (2007)	% POPULATION LIVING ALONG COAST (2000)		
			<25 km	<75 km	<100 km
Comoros	2,170	0.63	100	100	100
Kenya	582,650	37.53	6.1	7.5	8
Madagascar	587,040	19.67	23.2	45	55
Mauritius	2,040	1.26	100	100	100
Mozambique	801,590	21.37	32.7	52.1	59
Reunion	2,517	0.76	100	100	100
Seychelles	455	0.09	100	100	100
Somalia	637,657	8.70	30.5	52.7	55
South Africa	1,219,912	47.60	23.4	35.9	39
Tanzania	945,087	40.43	13.6	17.3	21

The WIO countries are at various stages of economic growth, with considerable differences in the Gross Domestic Product (GDP) and per capita income in each country (Table 6).

Table 6: Estimated Gross Domestic Product (GDP) and Gross National Income (GNI) per capita for countries of the WIO region (World Bank 2009)

COUNTRY	GDP (USD billions) (2007)	GNI PER CAPITA (USD) (2007)
Comoros	0.45	1,150
Kenya	29.51	1,540
Madagascar	7.33	920
Mauritius	6.36	11,390
Mozambique	7.75	690
Seychelles	4.6	15,450
Somalia	0.73	-
South Africa	-	9,560
Tanzania	277.6	1,200

The socio-economic characteristics of the WIO region are largely dictated by availability and patterns of natural resources utilization. A significant percentage of coastal communities in the WIO region depend on nearby coastal and marine resources for their livelihood and income generation. The main forms of land and sea use are fisheries, tourism, agriculture, industry, forestry, shipping and ports, mining, conservation, urbanisation and infrastructure.

2.3 MARINE POLLUTION HOTSPOTS

Land-based sources of marine pollution in the WIO region are primarily associated with urban areas and river discharges from larger catchments into the sea. Hotspots of land-based sources of marine pollution in the WIO region, as identified in the African Process Reports and the WIO-LaB Draft Monitoring Framework Report for the Western Indian Ocean, are highlighted in Figure 3. At present, urban centres in the WIO region are still several hundred kilometres apart, creating distinct hotspots. However, it is likely that rapid urbanisation in the region will result in the so-called 'strip development' of coastal areas, which happens when smaller coastal towns and suburban areas eventually join up with main cities, creating larger continuous urban zones along the coastline (Ruwa 2006).

The transport and fate of land-based pollution is strongly influenced by ocean currents. Unlike enclosed or semi-enclosed marine water bodies such as the Baltic or Mediterranean, the coastal region of the Western Indian Ocean is much more exposed with less chance of land-based sources of marine pollution causing transboundary impacts. However, considering the ocean circulation patterns in the area (Figure 1) transboundary impacts cannot be ruled out.

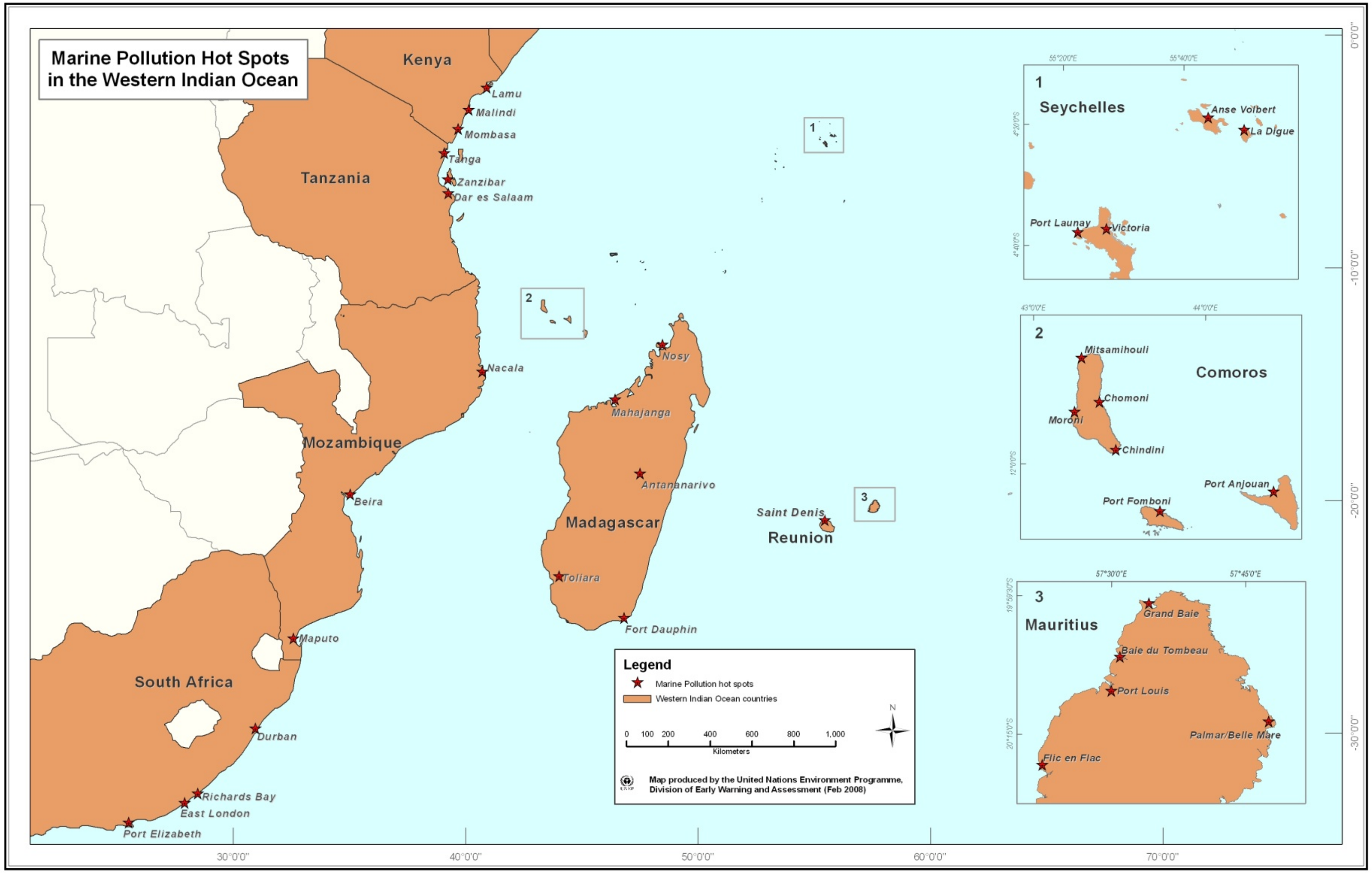

Figure 3: 'Hotspots' of land-based sources of marine pollution in the WIO region as identified in the African Process Reports and the WIO-LaB Monitoring Programme

At the 4th meeting of the Regional Working Group on Water, Sediment and Biota Quality Monitoring and Assessment in the WIO Region, held in Dar es Salaam, Tanzania on 23-25 June 2009, it was recognised that hotspots of land-based sources of marine pollution in the WIO region could be classified into different groupings based on the severity of pollution and the significance of impact. A categorisation framework was proposed and evaluation criteria developed, as presented below:

Severity of pollution ► Significance of impact ▼	1 Frequent non-compliance with environmental quality targets	2 Seasonal non-compliance with environmental quality targets	3 Occasional non-compliance with environmental quality targets
1 High	Hotspot Category 1	Hotspot Category 1	Hotspot Category 2
2 Medium	Hotspot Category 1	Hotspot Category 2	Hotspot Category 3
3 Low	Hotspot Category 2	Hotspot Category 3	Hotspot Category 3

An additional category, Hotspot Category 4, describes potential or emerging hotspots, which meet the following criteria:

- Compliance with environmental quality targets at present, but there are emerging issues that pose potential risk to sensitive ecosystems or beneficial uses, and/or
- Insufficient data at present, but there are emerging issues that pose potential risk to sensitive ecosystems or beneficial uses.

Workshop delegates (national representatives) used this system, taking into account recent results of WIO-LaB water and sediment quality monitoring programmes, to assess the validity of previous designations of pollution hotspots and categorise these hotspots. The updated categorisations are provided in Table 7, together with information on the main pollution types contributing to the categorisation. Evaluation templates completed by national representatives are given in Annex 3, and provide greater detail on how existing hotspots were validated and new ones identified.

Table 7: Categories of pollution hotspots in the WIO region, based on severity of pollution and significance of impact

COUNTRY	LOCATION	SEVERITY	SIGNIFICANCE	HOTSPOT CATEGORY	Pollution type		
					Microbiological	Metal	Nutrient
Comoros	Port Famboni			4	X	X	X
	Chindini beach			4	X		
	Chomoni beach			4			
	Mitsamihouli	3	1	2	X	X	X
	Port Moroni	1	2	1	X	X	X
	Port International de Mustamudu	1	1	1	X	X	X
Kenya	Mombasa inshore waters	1	1	1	X	X	X
	Lamu inshore waters	1	2	1	X	X	X
	Malindi Bay and Sabaki Estuary	1	1-2	1	X	X	X
	Diani	2	2	2	X	X	X
Madagascar	Nosy Be	1	1	1	X	X	X
	Mahajanga	1	1	1	X	X	X
	Toliera	1	1	1	X		X

COUNTRY	LOCATION	SEVERITY	SIGNIFICANCE	HOTSPOT CATEGORY	Pollution type		
					Microbiological	Metal	Nutrient
	Bay de Diego	2	1	1		X	X
	Port of Tamatave	2	2	2		X	
	Port Dauphin	2	2	2	X	X	
Mauritius	Palmar	2	1	1	X		X
	Pointe aux Sables to Baie du Tombeau	2	1	1	X		X
	Grand Baie	3	3	3	X		X
	Flic and Flac			4	X		X
Mozambique	Maputo Bay	1	1	1	X	X	X
	Beira			4	X		X
	Nacala Bay			4	X		X
	Pemba Bay			4	X		
	Incomati Estuary			4			X
Seychelles	Port Victoria	2	2	2	X	X	X
	Anse Volbert		2	4	X		
	La Digue		2	3	X		
	Beau Vallon Bay	2	2	2	X		X
	Mahé East Coast	3	2	3	X	X	X
South Africa	Richards Bay	3	3	3		X	
	Durban	2	1	1	X		
	East London			4	X		X
	Port Elizabeth			4	X	X	
	Eastern Cape and KwaZulu-Natal estuaries (and adjacent coastal areas)			4	X		X
Tanzania	Dar es Salaam	1	1	1	X	X	X
	Tanga	2	1	1	X		X
	Zanzibar	1	1	1	X		X

3. TRANSBOUNDARY PROBLEMS AND THEIR IMPACTS

Transboundary pollution problems are those arsing when pollution originating in one country impacts the coastal and marine areas of another. While direct impacts are easily understood, it should also be noted that land-based sources of marine pollution can significantly contribute to transboundary issues in an indirect way. For example, land-based activities may affect one or more life stages of migrating marine organisms, thus influencing the distribution and abundance of these organisms in a neighbouring country or region. For the purposes of the WIO-LaB project, transboundary problems were also considered also to include land-based marine pollution issues that are common to countries in the WIO region, even though they might not necessarily result in direct transboundary impacts in the true sense of the word.

The Draft National Pollution Status Reports prepared by participating countries in the WIO region identified five priority transboundary problems (including problems that are common to countries of the WIO region) that are linked to marine pollution and deterioration of coastal water quality as a result of land-based activities (Mong *et al.* 2009, Anon Mozambique 2007, Anon Mauritius 2009, Munga *et al.* 2007, Mohammed *et al.* 2008, Abdallah *et al.* 2006, Weerts *et al.* 2009):

- Microbial contamination
- High suspended solids
- Chemical pollution
- Marine litter (including solid waste)
- Eutrophication (or nutrient over-enrichment).

Initial prioritisation of transboundary problems was undertaken by regional stakeholders and experts at the Regional Consultative Workshop on the preparation of the TDA in Nairobi, Kenya (April 2007). The primary method applied for this exercise was a multi-criteria analysis undertaken by over 40 experts from various disciplines and representing all the project countries, based on a set of six criteria, which can be divided into two general categories:

- *Scope* of the problem:
  - Transboundary nature of the problem (i.e. geographical scope)
  - Scale of benefits of resolving problem
  - Feasibility of finding solutions to the problem
- *Severity* of the problem:
  - Environmental impact of the problem
  - Socio-economic impact of the problem
  - Macro-economic consequences of the problem

Following detailed analysis of the transboundary problems, their prioritisation was further refined by the Scientific and Technical Review Workshop of the TDA (held in Mombasa in August 2008), where the various problems and causes were analysed through a step-wise prioritisation exercise. Summary results are given in Table 8. A detailed overview and description of the methods and criteria used for prioritisation, and results are presented in Annex 2.

Table 8: Summary of prioritisation of transboundary marine pollution problems for the mainland countries and island states (H = high, M = medium, L = low) (see Annex 2 for details)

PROBLEMS	SEVERITY	SCOPE	OVERALL RATING
Microbial contamination	H	H	H
High suspended solids	H	H	H
Chemical pollution	M	L	L
Marine litter and debris	L	L	L
Eutrophication	L	L	L

Each of the identified priority transboundary problems, as well as associated environmental impacts and socio-economic consequences, are assessed in this chapter. Analysis of water and sediment quality data from WIO-LaB-funded monitoring programmes is included to render the assessment as up-to-date as possible. These data are presented graphically in Annex 3.

3.1 MICROBIAL CONTAMINATION

Microbial contamination refers to the presence of pathogenic organisms (protozoa, bacteria and viruses) of either human or animal origin in the aquatic environment that can pose health risks to humans. Risks to human health associated with microbial contamination of coastal water are unclear. Many sources reported that human diseases in coastal areas are mainly water-borne and associated with poor water quality. These include diseases such as dysentery, cholera and diarrhoea. However, these reports seldom distinguish between the exact sources, i.e. whether diseases are a result of ingesting contaminated drinking (fresh) water or associated with contaminated coastal water (e.g. from contact during recreation). The former is probably the most dominant source of water-borne diseases, although contaminated recreational water certainly contributes to the problem.

In the WIO region, microbial contamination of coastal waters is typically associated with inappropriate disposal of municipal wastewater (including sewage), contaminated surface and sub-surface runoff from urban areas, contaminated runoff from agricultural areas used for livestock rearing, and industrial effluents (mainly from food processing industries). The problem tree for microbial contamination in the WIO region, specifically linked to land-based activities, is provided in Figure 4. Stemming from the above, key sectors contributing to microbial contamination are urbanisation and tourism, agriculture, industry and transportation (referring to waste disposal facilities in harbours and ports).

Microbial contamination can have severe socio-economic consequences in coastal waters, such as:

- Human health risks associated with contact recreation or ingestion of contaminated seafood, and
- Reduced quality of seafood cultured or harvested in a particular area.

These consequences affect stakeholders across society, from local communities to tourists, and industrial and aquaculture operations, all of which utilise the marine environment for recreation and the collection and culture of seafood.

Loss, or potential loss, of the recreational value of coastal waters, due to unacceptable levels of faecal bacteria (typically used as indicators of microbial contamination), is evident throughout the coastal zone of the WIO region. Areas of concern are usually near larger urban centres where poorly treated or untreated waste and wastewater is problematic. In many areas the situation is exacerbated by unacceptable aesthetics and bad odours, also a consequence of inappropriate waste and wastewater management.

3.1.1 Madagascar

Studies conducted around Taolagnaro measured *E. coli* counts as high as 13300 counts/100 ml in coastal waters. The high levels of faecal contamination were attributed to defecation on the beaches as well as inappropriate treatment of municipal wastewater (Mong *et al.* 2009). Between 1993 and 1998, eighteen cases of human illness caused by ingestion of contaminated seafood were reported (Mong *et al.* 2009). These included illness resulting from eating marine turtles (seven cases), sharks (eight cases), fish (one case) and molluscs (two cases), although the causal link to microbial contamination was not always clear. Recent (2007) data collected for the purposes of the WIO-LaB water and sediment quality monitoring programme confirm that microbial pollution is an ongoing problem in some Madagascan coastal areas. High counts of enterococci and total coliforms were reported from Mahajanga and Nosy Bé.

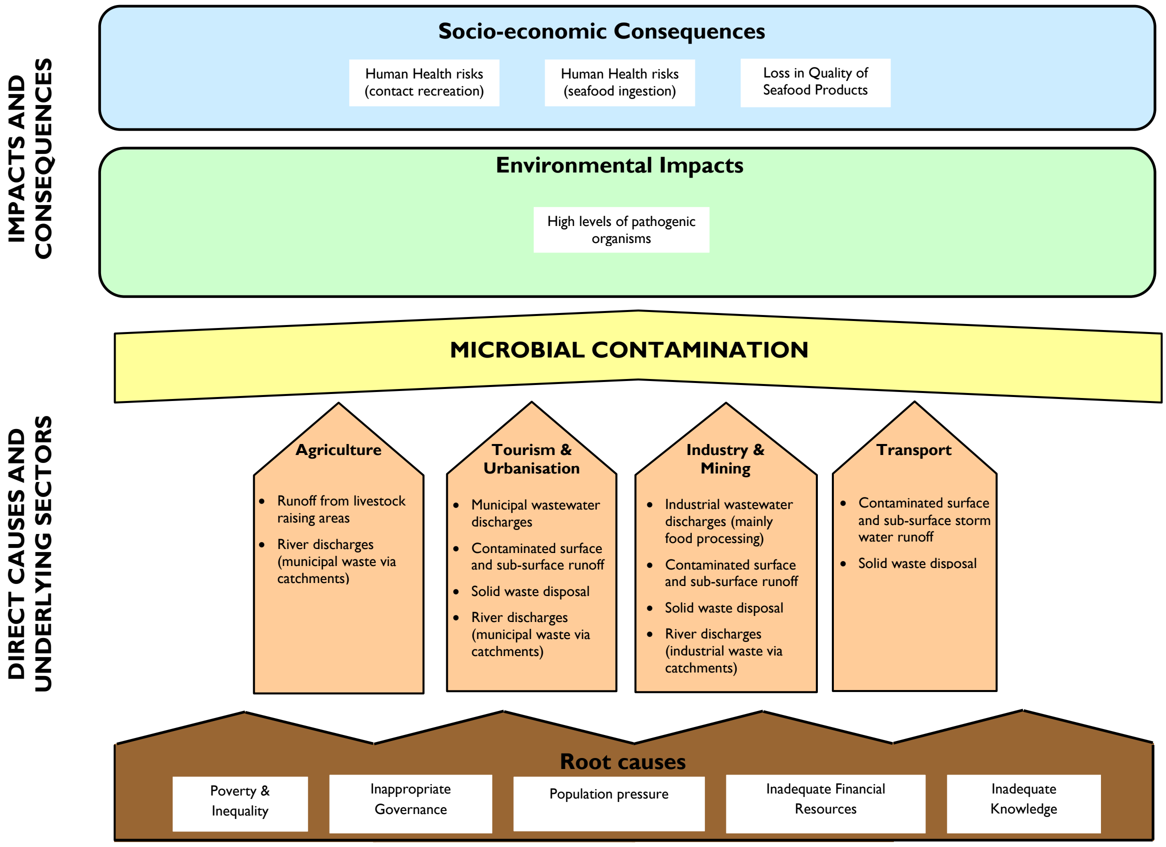

Figure 4: Problem tree: Microbiological contamination

3.1.2 Mozambique

In Maputo Bay, microbial contamination has been recorded in shellfish. The bacteria *Vibrio parahaemolyticus* and *V. mimicus* have been found in clams at the Incomati River mouth and near Matola in the Maputo estuary. *Vibrio* spp. are the main cause of severe gastro-intestinal illnesses (Fernandes 1996). High faecal coliform counts were also detected at several locations, including the area near the Infulene River mouth where values exceeded 2400 counts/100 ml. Such high contamination results from inadequate treatment of sewage. There is only one sewage treatment plant in Mozambique, located in Maputo City, which treats only about 50% of the city's sewage. Areas near the entrance of the Maputo estuary (Miramar) are not considered safe for swimming. Faecal contamination has also been recorded in Beira Bay and Nacala Bay, although levels were lower than those recorded for Maputo Bay (Fernandes 1995).

3.1.3 Mauritius

Along the coast of Mauritius, total and faecal coliforms are monitored monthly at public beaches at Flic en Flac, Albion, Pointe aux Sables, Trou aux Biches, Mon Choisy, Le Goulet, Grand Baie and Blue Bay. The Ministry of Fisheries reported in 2004 that waters at most beaches were within recommended guidelines for contact recreation in Mauritius (counts of total coliforms < 1000 per 100 ml and faecal coliforms < 200 per 100 ml). Exceptions were noted at some areas in Pointe aux Sables near Port Louis (Dulymamode *et al.* 2006). Good water quality was confirmed by quarterly monitoring of waters in 2007 through the WIO-LaB project. The highest levels of faecal and total coliforms were recorded at Pointe aux Sables.

3.1.4 Kenya

Studies conducted in Mombasa showed that microbial pollution levels in aquatic environments near urban centres were several orders of magnitude higher than in aquatic environments in rural areas (Table 9) (Mwanguni 2002).This was confirmed by quality monitoring undertaken in 2007 as part of the WIO-LaB project. High levels of microbial contamination were recorded in the Kilindini/Port Reitz creek area and, to a lesser extent, the Sabaki estuary/Malindi Bay complex, compared with Funzi Bay. Over 50% of all reported diseases in Kenya have been attributed to poor water quality associated with inadequate wastewater management, although no distinction has been made between effects from drinking contaminated water and coastal recreational (Mwanguni 2002).

Table 9: Average faecal coliforms and *E. coli* counts measured in urban and rural coastal waters in Kenya (Mwanguni 2002)

AREA		MIROBIOLOGICAL COUNTS/100 ml	
		Faecal coliforms	*E. coli*
Urban	Tudor Creek	1,703	12.8
	Kilindini Creek	1,525	690
	Mtwapa Creek	1,400	55
	Bamburi Marine Park	70	19
Rural (Ungwana Bay)	Kipini	19	4
	Sadani	13	4
	Tana	10	3
	Kilifi	12	2
Rural (Ngomeni Bay)	Mambrui	16	3

3.1.5 Seychelles

In the Seychelles, effluent from wastewater treatment plants discharged directly into the ocean was found to contain total coliform counts between 2000 and 5000 per 100 ml, far above the stipulated standards of 500 per 100 ml (Antoine *et al.* 2008). During a monitoring survey conducted during 2007, high microbial counts were recorded at Beau Vallon Bay during the rainy season. These were mostly associated with runoff from non-point sources such as rivers and small streams (Antoine *et al.* 2008).

In Seychelles outbreaks of water- and insect-borne diseases usually occur during the rainy season and are mainly associated with defective on-site wastewater disposal systems.

3.1.6 South Africa

Since about 1985, the design of offshore sewage outfalls in South Africa has followed the receiving water quality objectives approach where effluent quantities and composition must be within limits that meet site-specific Environmental Quality Objectives, as recommended in the South African Water Quality Guidelines for Coastal Marine Waters. Generally, long-term environmental monitoring programmes at these outfalls have indicated no detrimental impact related to chemical and microbiological contamination on the marine environment or its beneficial uses. Of greater concern is the rapid increase in discharges to less dynamic and sensitive areas such as surf zones and estuaries, where effluents from malfunctioning or overloaded treatment facilities are adversely affecting the marine environment and its beneficial use, albeit in a localised manner (RSA DWAF 2004a,b,c).

In Cape Town (South Africa) an extensive monitoring programme for microbiological contamination (using *E. coli* as an indicator organism) is conducted by the local municipality. In 2005 approximately 80% of stations sampled complied with the recommended South African water quality guidelines for contact recreation. The stations that did not comply (*E. coli* exceeded 200 counts/100ml in 80% of samples in one, and 2000 counts/100 ml in 95% of samples in the other) were in highly developed and urbanised sections of the coastline (City of Cape Town 2005).

3.1.7 Tanzania

In Zanzibar, high total and faecal coliform levels have been reported in certain coastal areas (e.g. Stone Town), prompting health concerns and warnings of health risks to swimmers. Similarly, some beaches on the mainland in Dar es Salaam (e.g. Ocean Road and Banda beaches) have been closed for swimming and other recreational activities due to microbial contamination (Mohammed *et al.* 2008). WIO-LaB monitoring conducted in 2007 showed contamination of waters around Dar es Salaam as well as Stone Town.

Considering the root causes of microbial contamination, particularly population pressure, poverty and inequality, it is likely that the problem will intensify in future, posing even greater socio-economic risks to society, unless the different sectors that contribute to the problem take measures to address it.

3.2 HIGH SUSPENDED SOLIDS

High concentrations of suspended solid loads enter WIO coastal waters from land-based sources. These sources include municipal and industrial wastewater discharges, river discharges and surface runoff, particularly during the rainy seasons. Dredging activities (usually associated with ports and harbours) can also contribute significantly to this transboundary problem.

Key sectors contributing to high suspended solid loading in the marine environment are agriculture (linked to soil erosion in river basins/catchments), industry (particularly those discharging effluents containing high suspended solid loads/sediments) and transportation (primarily linked to dredging activities). The urban sector (e.g. local municipalities) also contributes, through inappropriate disposal of municipal waste, while aquaculture may contribute to the problem through disposal of waste containing high suspended solids (Figure 5).

Key environmental impacts linked to high suspended solid loads are:

- Smothering of benthic biota, clogging of gills and feeding apparatus of marine organisms
- Chronic and acute effects on marine biota
- Modification of marine biota species composition
- Discolouration of coastal waters.

The consequences associated with the problem affect stakeholders across society, from local communities to large international tourism concerns. Aquaculture and agro-processing industries are also affected. The social and economic consequences of increased suspended solids in coastal waters include:

- Loss of aesthetic value
- Loss of recreational, commercial and/or artisanal fisheries resources and revenue
- Reduction in quality of seafood.

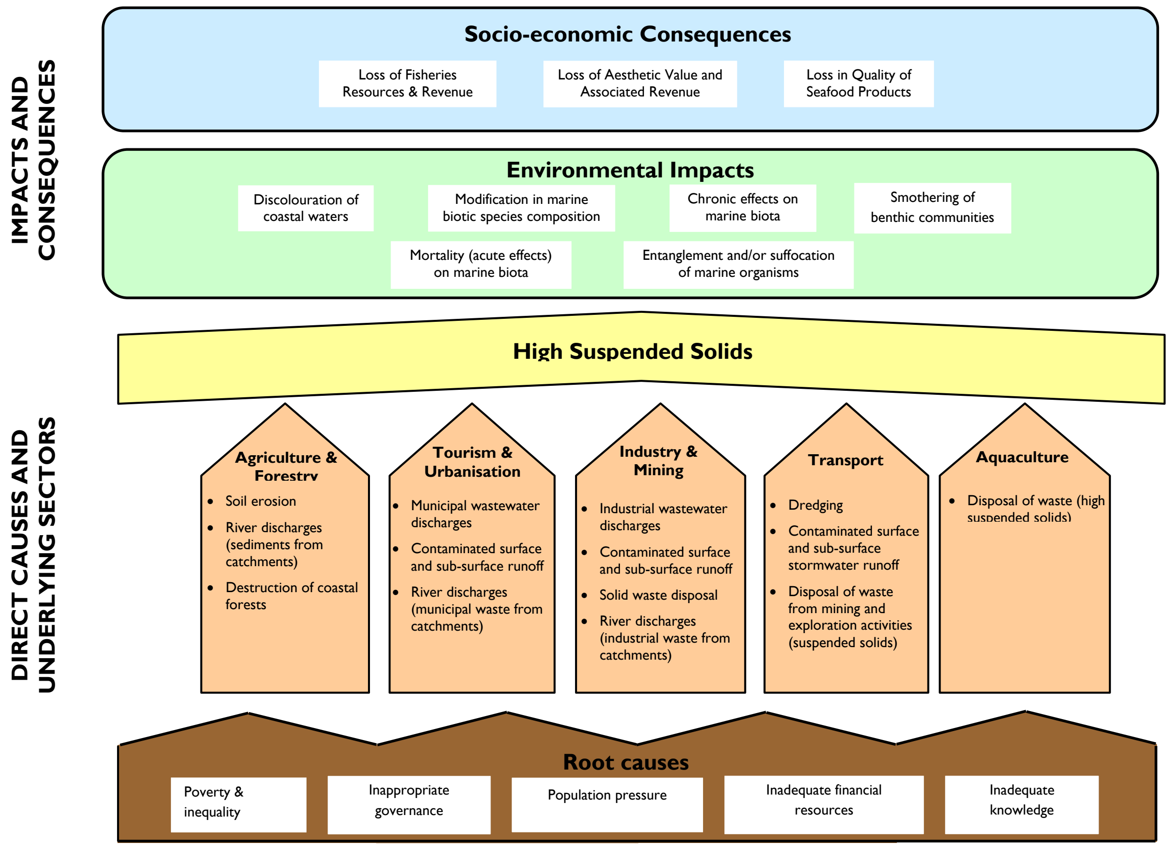

Figure 5: Problem tree: High suspended solids

3.2.1 Kenya

In Kenya, sediment loading has been found to affect the coral reefs in the Malindi National Marine Park and Reserve (McClanahan and Obura 1997, Kazungu *et al.* 2002, Kitheka *et al.* 2003a). A decrease in the number of seagrass species has also been reported. In 1972, four endemic seagrass species were recorded in Malindi Bay but only two species remained in 1992 (Wakibia 1995). The decrease occurred in an area experiencing heavy siltation. The loss of seagrass beds due to sediment loading may have negative impacts on fisheries, as these habitats are important for numerous fish species (Kazungu *et al.* 2002).

Heavy sedimentation in Mwache Estuary (located in the upper reaches of Port-Reitz Creek) has led to degradation of a large expanse of mangrove forest located in the estuary (Kitheka *et al.* 2003b). High sediment loads in the Athi-Sabaki and Tana estuaries have led to very high turbidity of waters in Ungwana Bay (Kitheka *et al.* 2003a,b, Kitheka *et al.* 2005). Sedimentation has resulted in significant impacts on mangrove areas, smothering the root systems of trees and causing die-back of these forests (Kitheka, *et al.* 2005).

Sediment deposition and beach accretion (e.g. in Malindi Bay) have resulted in the loss of beach frontage from some hotel and resort developments in Kenya, with a consequent loss of tourism revenue and employment (Kazungu *et al.* 2002, Kitheka *et al.* 2003a, b). The Port of Mombasa requires regular dredging of the navigational channel to maintain the depth required for shipping activities. The associated costs of dredging are another socio-economic consequence of high suspended solids in the Kenyan coastal waters (Kazungu *et al.* 2002). Finally, discoloration of coral reef waters impairs their productivity and results in a reduction in their aesthetic value, rendering them less attractive for tourism.

3.2.2 Madagascar

In Madagascar, sediment loads from river catchments are recognised as a major pollution concern. Discharge of suspended solids from the Toliara Water Basin has been estimated at approximately 6 million tones per year (Musyoki and Mwandotto 1999 cited in Payet and Obura 2004). Sedimentation has resulted in significant impact on mangrove areas, smothering the root systems of trees and causing die-back of these forests (Mong *et al.* 2009).

3.2.3 Mauritius

In Mauritius, high sedimentation and associated high turbidity have been reported in the lagoon at Rodrigues and in Grand Baie, resulting in modification of these ecosystems (Resource Analysis-EDC 1999). In Grand Baie, increased suspended sediment was mainly associated with household wastewater discharges, while in Rodrigues it resulted mostly from soil erosion from agricultural areas in the highlands. Here, some of the bays are completely silted and channels have been constructed to facilitate the movement of boats. A 2006 Mauritius Pollution Status Report (Anon Mauritius 2009) noted that sedimentation has also caused damage to the coral ecosystem (e.g. by smothering), thereby affecting artisanal fishing.

3.2.4 Mozambique

In Mozambique poor land-use practices, including deforestation of coastal and hinterland areas, are the main contributors to sedimentation in coastal environments. As a result, more frequent dredging of the Maputo and Beira harbours is needed. Surveys from 10 years ago showed that between 1.2×10^6 m^3 and 2.5×10^6 m^3 of sediments need to be dredged annually from the ports of Maputo and Beira respectively (FAO 1999).

3.2.5 Seychelles

In the Seychelles around the main islands of Mahé, Praslin and La Digue, sediment discharge has contributed significantly (~10%) to coral bleaching, together with other factors such as global warming (~70%) (Jones *et al*. 2002).

3.2.6 Recommendations on sediment loading

Impacts associated with sediment loading have been recorded in the WIO region. Increasing agricultural activities and inappropriate farming practices have increased the risk of soil erosion. Furthermore, increasing urbanisation and the associated municipal waste and industrial activities in the coastal zone will exacerbate sedimentation, unless the sectors contributing to this problem implement mitigating measures through better legislation and regulation, better land-use practices, and widespread public education and awareness.

3.3 Chemical Pollution

Chemical pollution refers to the adverse effects of chemical contaminants released into the coastal environment from land-based human activities. Chemical contaminants are defined here as compounds that are toxic, persistent and/or bio-accumulating. These can be grouped in three broad categories: heavy metals, hydrocarbons and persistent organic compounds (e.g. pesticides). Sources in the WIO region are typically linked to agrochemical discharges (e.g. persistent organic pollutants), dredging in ports and harbours (thereby releasing sediment-bound heavy metals and hydrocarbons), atmospheric emissions (containing heavy metals) and leachates from solid waste dump sites. The key sectors contributing to chemical pollution of coastal marine waters in the WIO region include industry (disposal of toxic substances in wastewaters), agriculture (persistent organic pollutants) and transportation (dredging activities in ports and harbours). The urban sector (through traffic emissions) and energy production (from burning of fossil fuels) also plays a role, albeit to a lesser extent. Major industries contributing to chemical pollution in the WIO region include manufacturing, textiles, tanneries, paper and pulp mills, breweries, chemical, cement, sugar and fertiliser factories and oil refineries. Inappropriate utilisation, storage and dumping of agrochemicals are of increasing concern. Furthermore, accidental spills of oil or chemicals in harbour areas or along transport routes near the coast are another potential cause of chemical pollution. The problem tree for chemical pollution is shown in Figure 6.

Specific environmental impacts linked to chemical pollution include:

- Discolouration of coastal waters
- Chronic effects (e.g. effects on growth and reproduction) on marine biota
- Mortalities (acute effects) of marine biota
- Modification of species compositions in marine biological communities.

The consequences associated with chemical pollution which poses risks to human health affect stakeholders across society, from local communities to large tourist developments. Commercial and artisanal fisheries, as well as aquaculture and seafood production industries, may also be affected. Socio-economic consequences include:

- Loss of artisanal and/or commercial fisheries
- Reduction in quality of seafood products cultured or harvested from a particular area

- Human health risks associated with contact recreation or ingestion of contaminated seafood.

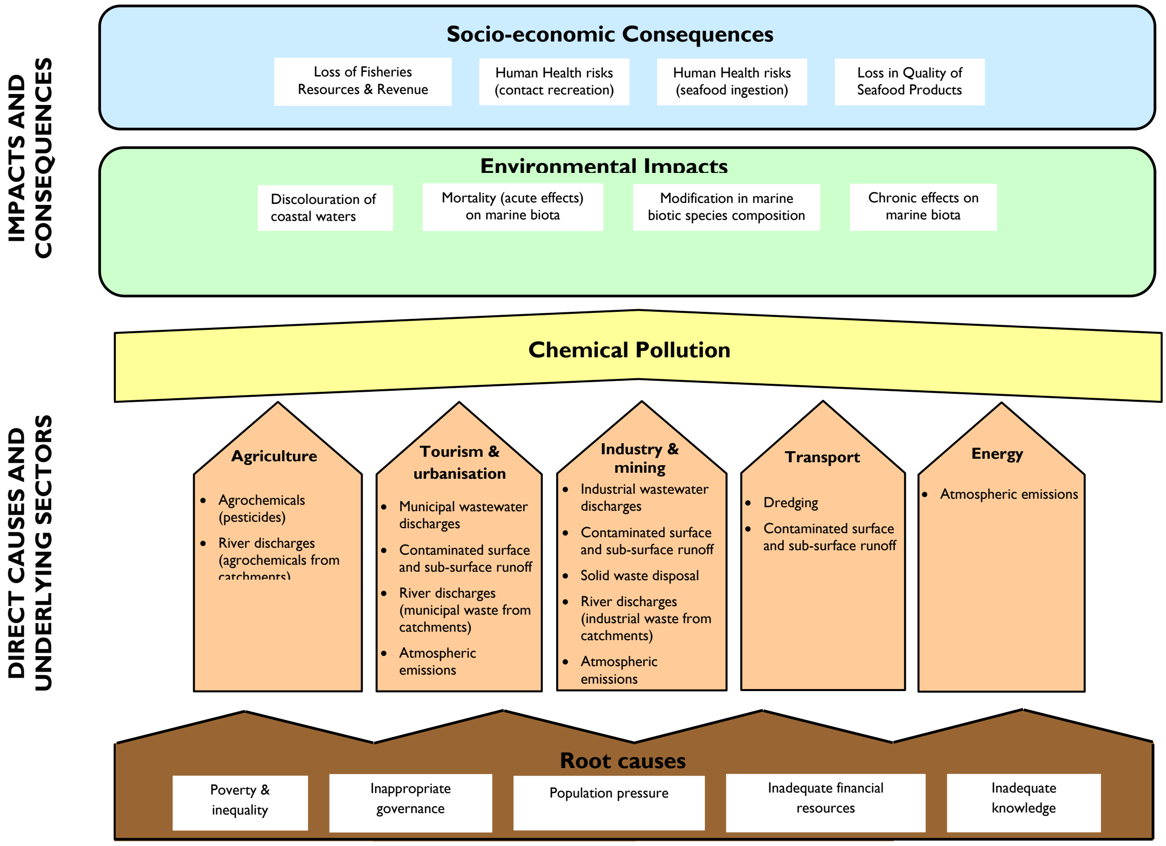

Figure 6: Problem tree: Chemical pollution

3.3.1 Kenya

Signs of chemical pollution have been recorded in various coastal areas in the WIO region. Studies conducted in the Kilindini and Makupa Creeks (Mombasa, Kenya) revealed elevated levels of heavy metals (copper, cadmium, iron and zinc), although these levels were considered to be substantially lower than those recorded in other polluted coastal areas (Kamau 2001). Other studies in Kenya (Makupa and Tudor Creeks) revealed that overall lead and cadmium concentrations in the water column were low. A few incidents of elevated levels in sediment and some fish species were recorded, but levels of lead and cadmium in most of the fish species analysed were generally within acceptable limits (FAO/WHO 1986). Monitoring conducted as part of the WIO-LaB project in 2007 in the Sabaki estuary/Malindi Bay complex and Kilindini/Port Reitz Creek returned concentrations of cadmium, copper, lead and zinc in sediments well above recommended WIO guidelines (United Nations Environment Programme/Nairobi Convention Secretariat and CSIR 2009, see Annex A).

Extensive mangrove forests in Mombasa and Maputo have been destroyed by oil spills (Munga 1993, Richmond 2002). Spillage from the British tanker *Cavalier* caused considerable damage and destruction of mangrove forests in Mombasa in 1972. Since then, this coastline has been subjected to five other severe spills. Such spillage has resulted in mangrove dieback, especially in Mida Creek where the effects of oil spills were still evident 10 years after the last oil spill incident (Abuodha and Kairo 2001). The main effects of oiling on mangrove ecosystems are complete smothering of estuarine vegetation and organisms (Abuodha and Kairo 2001). Seagrass habitats are similarly affected and studies in Kenya have indicated cases of complete smothering of these benthic plants, as well as their associated organisms (Abuodha and Kairo 2001). To exacerbate the problem, dispersants which are commonly used to clean up oil spills contain toxic solvents which penetrate the protective waxy cuticles of seagrass blades. This affects the biological functioning of cellular membranes and chloroplasts, thereby causing plant loss and as well as harmful effects in other benthic biota (Ellison and Farnsworth 1996, Abuodha and Kairo 2001).

3.3.2 Madagascar

Monitoring of pollution hotspots (Mahajanga and Nosy-Bé) in Madagascar as part of the WIO-LaB project in 2007 indicated that population pressure and associated landuse activities were one of the main drivers of pollution. Heavy metals in sediments were the highest reported for the WIO region (Annex A). The highest levels were generally reported in closest proximity to sewage outfall points (Mong 2008).

3.3.3 Mozambique

Studies conducted in Mozambique have shown the presence of heavy metals, particularly lead, in the Port of Maputo from discharges of the Matola and Maputo Rivers, as well as in Nacala Bay (Fernandes 1995, Anon Mozambique 2007). Common pesticide residues identified in Mozambique were 2,4,5-TCB, p,p'-DDT, p,p'-DDE, p,p'-DDD, lindane and HCB. Though DDT is officially banned in Mozambique, it is still used, as it is in neighbouring countries (Massinga and Hatton 1997). Analysis of pollutants sorbed to plastic pellets however, indicates comparatively low concentrations of DDTs compared with elsewhere in the world (Ogata *et al*. 2009). However, very high concentrations of HCH, likely from the use of the pesticide lindane, were recorded (Ogata *et al*. 2009).

3.3.4 Mauritius

In Mauritius various industries, such as steel mills, galvanizing, electroplating and battery factories, historically released their wastes directly into rivers (Grand River North West and St. Louis River) which empty into marine systems. Estuarine habitats such as Tombeau Bay and Poudre d'Or Estuary have been exposed to such untreated industrial wastes since the 1980s (Ramessur 2002). Heavy metals, particularly chromium (from textile industries), zinc and lead (from industrial effluent, sewage sludge and landfill leaches) are potentially problematic (Ramessur 2002).

Despite this, coastal systems in Mauritius appear relatively unpolluted compared with more industrialised countries (Ramessur 2004, Anon Mauritius 2007). Heavy metals (copper, zinc, lead, cadmium, mercury) and the pesticides atrazine, diuron and hexazinone were not detected in water samples taken from the river mouths at Grand River North West, Pointe Roches Noires, Grand River South East, Mahebourg, l'Escalier, Baie du Cap, Tamarin and Rivière Lataniers, and chromium, lead and zinc in sediments were well below contamination levels quoted by Van Veen and Stortelder (1988, 24% clay and 10% organic matter). There are however, indications of elevated levels of zinc and lead in urban estuaries, and this is cause for growing concern (Ramessur 2004).

3.3.5 South Africa

In South Africa, municipal and industrial wastewater discharges, including discharges into the marine environment, are regulated and licensed. This appears to have had some positive influence in sustaining acceptable environmental quality and in controlling chemical pollutants. This is reflected in monitoring and assessment studies conducted in and around the offshore outfalls (CSIR 2004, McClurg *et al.* 2007). Monitoring of such outfalls off Durban gives little indication of contamination by organic pollutants from municipal and industrial sources (CSIR 2004, McClurg *et al.* 2007).

Inputs of persistent organic pollutants into coastal waters from agriculture (e.g. pesticides) have not been quantified in South Africa, although pesticides have been detected in fatty tissues of seals and dolphins along the South African (and Namibian) coast (Vetter *et al.* 1999). In general, the levels were not considered to represent a serious pollution problem. A recent study involving analysis of pollutants sorbed to plastic pellets from South Africa's east coast indicates very high concentrations of HCH (relative to elsewhere in the world (Ogata *et al*. 2009). The likely source is the use of the pesticide lindane (Ogata *et al*. 2009).

Studies investigating heavy metal accumulation in Cape Town revealed that the coast is generally in a clean condition, except in localised areas such as the Port of Cape Town (Brown 2005, CSIR 2006a,b). Similarly, outfalls monitoring off Durban gives little indication of contamination by heavy metals from municipal and industrial sources (CSIR 2004, McClurg *et al.* 2007, see Annex A). The fairly good state of the environment is also reflected in the results of a Mussel Watch Programme conducted along South Africa's west coast. Results for cadmium, lead, zinc and mercury do reflect inter-annual variations but, as yet, no clear long-term (increasing) trends seem to be apparent (Figure 7).

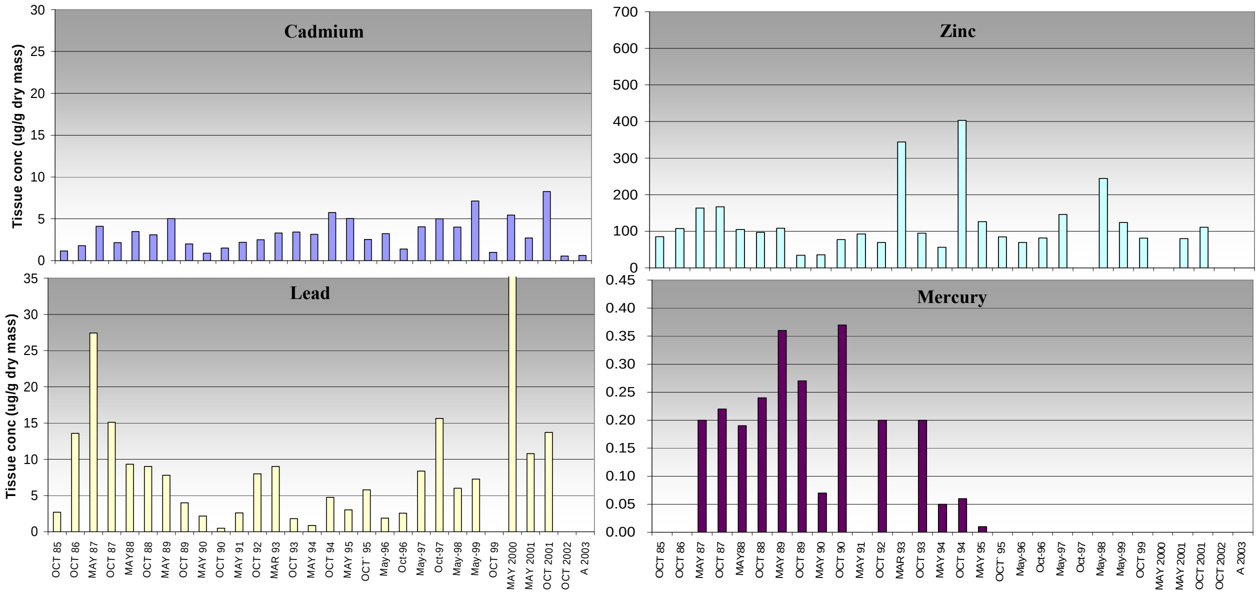

Figure 7: Heavy metal concentrations (µg/g dry mass) measured in mussel tissue along the South African coast (Cape Town) (1985 – 2003) (Source: G Kieviets, Department of Environmental Affairs and Tourism, Marine and Coastal Management, South Africa)

3.3.6 Tanzania

Chemical pollution in Dar es Salaam (Tanzania) is regarded to be a serious problem. Significant amounts of some heavy metals were found in mangrove sediments and associated biota near the city (Mremi and Machiwa 2003). Sediment samples from the Msimbazi and Mtoni mangrove areas, which are located within the city, had higher levels of heavy metals (up to three-fold) compared to samples from mangrove forests some distance from the city at Mbweni, clearly indicating anthropogenic input to be a cause (Table 10). Monitoring conducted as part of the WIO-LaB project in 2007 also indicated that some areas around Dar es Salaam had concentrations of copper in sediments well above the guideline value recommended for the WIO region (United Nations Environment Programme/Nairobi Convention Secretariat and CSIR 2009, see Annex 3).

Table 10: **Average concentration (mg/kg dry weight) of heavy metals in mangrove sediment and biota in the Dar es Salaam area (Mremi and Machiwa 2003), as well as the recommended environmental quality targets (EQTs) for sediments in the WIO (United Nations Environment Programme/Nairobi Convention Secretariat and CSIR 2009)**

HEAVY METAL	RECOMMENDED EQTs (Sediments)	MBWENI		MSIMBAZI		MTONI	
		Sediment	Crab	Sediment	Crab	Sediment	Crab
Copper	18.7	10.7	24.7	31.6	36.2	17.9	39.3
Chromium	52.3	10.1	30.0	31.7	30.0	27.1	30.0
Lead	30.2	27.8	15.0	37.5	14.3	36.8	44.1

Ferletta *et al.* (1996) conducted baseline studies on the accumulation of heavy metals in algae as indicators of pollution in marine water in Dar es Salaam and Zanzibar. A significant increase in heavy metal concentrations was noted from 1989 and 1994 (Table 11). A ten-fold increase in heavy metal content in several algal species was reported over a period of just seven years (Ferletta *et al*. 1996). Another study showed that macroalgae collected from Chapwani and Changuu Islands off Zanzibar had significant levels of aluminium and cadmium with the suggested source of these contaminants being the various industries in nearby Stone Town (Engdahl *et al.* 1998).

Table 11: **Comparison of heavy metal concentrations (µg/g dry weight) measured in algae in 1989 (Wekwe et al. 1989) and 1994 (Ferletta et al. 1996) in Dar es Salaam and near Zanzibar**

HEAVY METAL	ALGAE	DAR ES SALAAM (OYSTER BAY)		MDUDYA ISLAND (near Zanzibar)	
		1989	1994	1989	1994
Cadmium	*Padina tetrastromatica*	0.12	2.3	0.14	2.6
Chromium		1.5	6.6	1.5	4.6
Copper		1.0	5.0	1.0	8.4
Iron		1190	613	1189	278
Manganese		58.5	nd	58.6	nd
Nickel		0.38	6.5	0.38	6.5
lead		2.15	6.10	2.17	10.10
Zinc		33.4	104.6	34.0	13.4
Cadmium	*Ulva* sp.	0.3	3.3	0.3	nd
Chromium		0.8	5.5	0.8	nd
Copper		7.0	7.9	7.0	nd
Iron		230	412	230	nd
Manganese		3.5	24	3.6	nd
Nickel		0.9	7.8	0.9	nd
lead		1.6	13.3	1.6	nd
Zinc		28	39.9	27.9	nd

nd - not detected

An analysis of heavy metals in sediments in the inner area of Dar es Salaam harbour (Machiwa 2000) also revealed an accumulation of certain heavy metals, notably chromium and copper (see Table 12). The harbour receives large quantities of industrial waste from the city of Dar es Salaam.

Another study on marine sediments and biota along the coastline of Dar es Salaam (Mwevura *et al.* 2002) concluded that organochlorine pesticide levels in sediments might cause adverse effects on humans consuming biota directly exposed to the sediments. Biota living in the water column however, showed levels that were significantly below the FAO/WHO maximum acceptable for fish and seafood (200 mg/kg fresh weight, FAO/WHO 1986) and were safe for human consumption. Dieldrin and total DDT measured in sediments around Dar es Salaam in 2007 as part of WIO-LaB monitoring were below guideline values recommended for the WIO region (United Nations Environment Programme/Nairobi Convention Secretariat and CSIR 2009, see Annex 3).

Table 12: Average concentration (mg/kg dry mass) of total heavy metals measured in sediments of harbours and estuaries in the WIO region (Sources: Machiwa 2000, Anon Mauritius 2007), as well as the recommended environmental quality targets (EQTs) for sediments in the WIO (United Nations Environment Programme/Nairobi Convention Secretariat and CSIR 2009)

STUDY AREA	AVERAGE HEAVY METAL CONCENTRATION (mg/kg)				
	Chromium	Copper	Mercury	Lead	Zinc
Recommended EQTs (sediments)	52.3	18.7	0.13	30.2	124
Dar es Salaam harbour	33	28	0.1	21	68
Mauritius west coast estuaries	225	-	-	27	107

Although several scientific studies conducted in coastal areas in the WIO region revealed elevated levels of chemical pollutants, most likely attributable to land-based sources, uncertainties remain regarding the geographical spread of chemical contamination, as most of the studies were not designed to reflect the spatial extent of the pollution. Furthermore, scientific data on environmental impacts or socio-economic consequences directly linked to chemical pollution have not been collected in the region.

3.3.7 Recommendations on chemical pollution

Industrialization in the WIO region remains slow relative to other parts of the world, but it is increasing rapidly. Recent history has shown that rapid development often takes place without proper environmental impact assessments or legislative controls, leading to increased pressure on the environment. Commercial agricultural activities are also increasing in countries of the WIO region, as is the use of agrochemicals. Thus, chemical pollution from these sectors is likely to intensify unless better legislation and regulation is implemented, along with awareness-raising and education on best practices. Despite insufficient data, the risk of chemical pollution of coastal waters from land-based activities should not be ignored. There is a need for timely intervention by industry managers, farmers and the government authorities responsible for regulating these activities.

3.4 Marine Litter (Including Solid Waste)

Marine litter pollution refers to the introduction of solid waste material (which either floats or sinks) into water bodies and their surroundings. Inappropriate disposal of solid waste represents a serious problem in most of the coastal urban centres in the WIO region, although quantitative data are limited. Important land-based sources of litter are waste from urban centres (particularly ports, industrial and commercial areas and informal settlements) and that discharged into marine environments via rivers (transporting solid waste from adjacent catchments). The main sectors contributing litter in marine environments include the urban and tourisms sectors, industry and transport. Litter pollution arises mainly because of inappropriate facilities for the disposal of solid waste, as shown in the problem tree presented in Figure 8.

Major environmental impacts of litter are ingestion by marine organisms, or entanglement resulting in loss of biodiversity (UNEP and WIOMSA 2008). Socio-economic consequences include:

- Loss of aesthetic value of coastal areas, and
- Risks to human heath through contact with contaminated waste products (e.g. medical waste).

The consequences associated with marine litter affect stakeholders across society, from local communities to large tourist developments, affecting the aesthetic value of coastal areas and posing risks to human health.

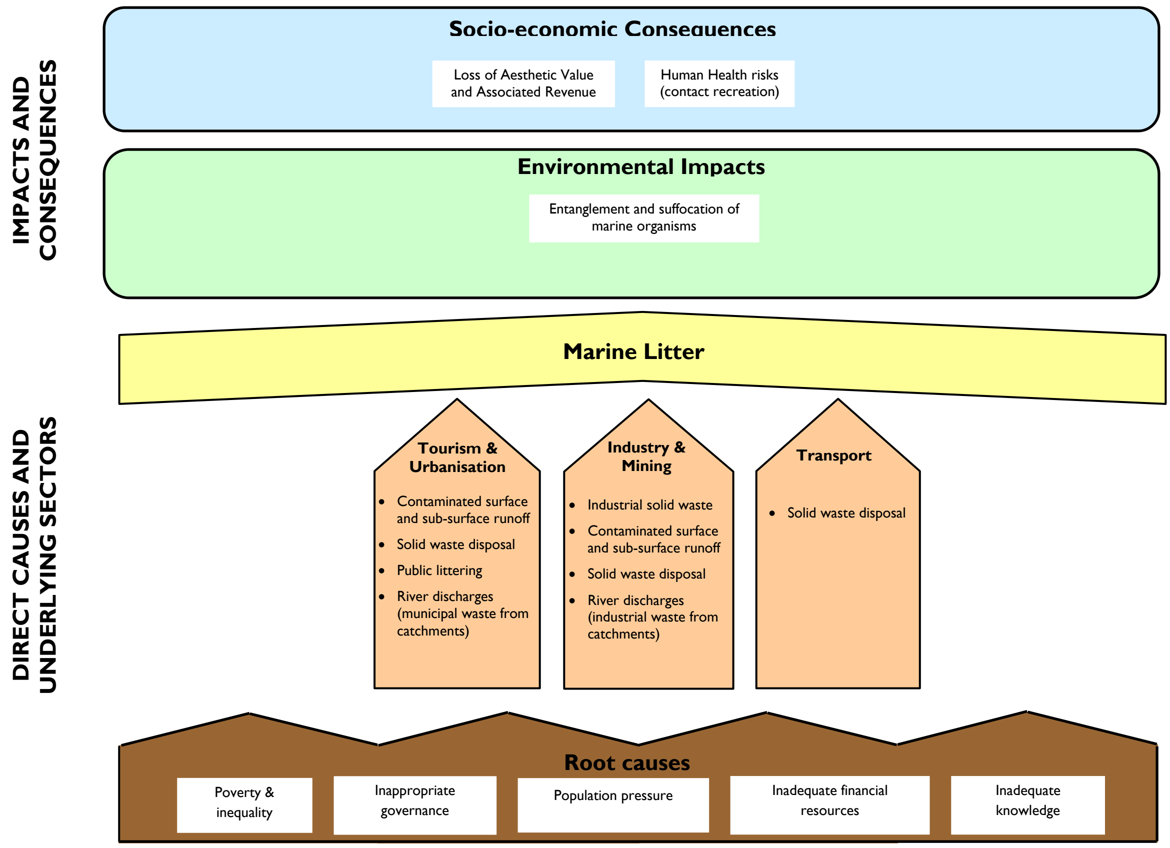

Figure 8: Problem tree: Marine litter

Environmental impacts and socio-economic consequences of marine litter are largely inferred and not adequately assessed or quantified in the WIO region, other than in South Africa (UNEP and WIOMSA 2008). However, the synopsis given in South Africa's national marine litter reports is applicable to the entire region (UNEP and WIOMSA 2008). It finds that "litter has numerous impacts on marine ecosystems, as well as direct and indirect impacts on humans. The main ecological impacts of floating litter are that it is ingested by, or entangles, marine organisms. Off South Africa, levels of ingestion and, perhaps to a lesser extent, entanglement, are on a par with the highest recorded elsewhere in the world. There are some encouraging developments (e.g. the reduction in virgin [pre-processed] plastic pellets ingested by seabirds), but overall the situation remains unacceptable, with several threatened species affected. Floating marine litter may play a role in rafting invasive organisms to these remote systems, with potentially serious biological and commercial impacts. Litter that sinks to the seabed may impede gas exchange in bottom sediments or become entangled around sessile organisms, increasing their drag and, in shallow depths, their risk of being dislodged or washed off during large storm swells."

National marine litter reports from Kenya, Madagascar and Tanzania indicate that medical and sewage wastes can impact human health. This urgent matter appears to be receiving attention from the respective governments in partnership with aid agencies. Medical wastes are obviously a priority source of marine litter to eliminate (UNEP and WIOMSA 2008).

The impact of marine litter on the aesthetic quality of coastal areas in the WIO region is demonstrable. Quantities of litter are negatively correlated with the popularity of the beaches used for recreation, and litter discourages tourism (UNEP and WIOMSA 2008). Economic and aesthetic impacts include reduced amenity value (e.g. beach use drops as litter levels increase); ever-growing investment in formal beach cleaning programmes; risk of flooding due to blocked drains; disabling or damaging vessels; and negative impacts on commercial fisheries. Most of these impacts have not been quantified in economic terms. Taking some of the root causes of marine litter in the WIO region into account, particularly population growth pressure, poverty and inequality, it is likely that this problem will intensify in future, posing even greater socio-economic risks to society, and unless those responsible in the different polluting sectors intervene, serious impacts on tourism development will result. As economies develop and expand and infrastructure improves, the demand for some waste products has emerged. For example in Dar es Salaam, the demand for empty plastic mineral water bottles for recycling in China has resulted in their removal from local waste dumps, roadsides and beaches (Richmond, M. *pers comm*. cited in UNEP and WIOMSA 2008). The trend in Seychelles has been to ban take-away boxes, plastic bags and PET bottles, and recycle plastic bottles. Grills have been placed on most river outlets to trap litter. Additionally, marine litter in port areas and on all major beaches is collected.

3.5 EUTROPHICATION

Eutrophication refers to artificially enhanced primary production (e.g. algal and phytoplankton growth) and elevated organic matter loading in coastal waters due to the increased availability or supply of nutrients, usually as a result of inappropriate disposal of municipal wastewater or nutrient-enriched agricultural return flows. Wastewater with a high organic content (with high biological or chemical oxygen demand, BOD or COD) or wastewater containing high levels of inorganic nutrients (e.g. nitrogen and phosphate) typically contributes to eutrophication. While eutrophication in the true sense of the word hardly ever occurs in the WIO region, harmful or nuisance algal blooms resulting from nutrient enrichment are problematic in some areas.

The key sectors potentially contributing to eutrophication and algal blooms in coastal waters include the urban sectors (municipalities responsible for waste disposal), industries (generating high BOD and nutrient loads in their wastewater) and agriculture (with inappropriate use and disposal of fertilisers), as shown in the eutrophication problem tree (see Figure 9).

Environmental impacts of eutrophication/algal blooms include:

- Nuisance or harmful algal blooms affecting both aesthetics and biodiversity
- Discolouration of coastal waters, affecting light-dependent benthic species
- Smothering of benthic communities (e.g. during die off of algal blooms)
- Mortalities of marine biota (e.g. caused by anoxic conditions generated on decomposition of organic matter)
- Modification of species compositions in marine biological communities.

A broad range of stakeholders are potentially affected by eutrophication/algal blooms, from local communities to larger sectors such as fisheries, aquaculture and tourism. Socio-economic consequences include:

- Loss of aesthetic value,
- Risks to human health from contact recreation and ingestion of contaminated seafood, and
- Loss of artisanal and/or commercial fisheries and aquaculture.

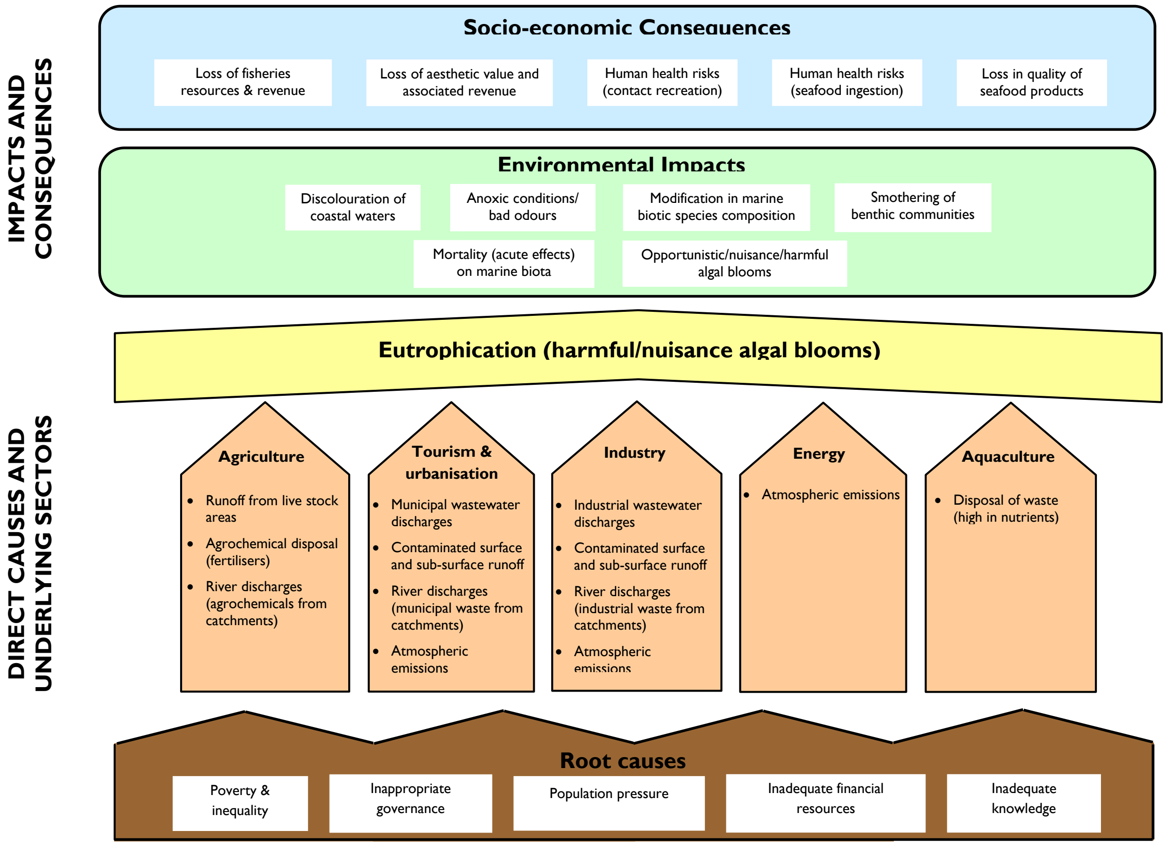

Figure 9: Problem tree: Eutrophication

Human population growth in WIO countries, particularly in coastal regions, has increased the volume of discharged sewage and domestic wastes (Richmond 2002, UNEP/GPA and WIOMSA 2004a). There is some evidence of anthropogenic sources of nutrient enrichment impacting coastal ecosystems through harmful or nuisance algal growth.

3.5.1 Kenya

Along the Kenya coast, Uku (1995, 2005) and Uku and Björk (2005) reported an abundant growth of epiphytic algae on seagrass and the dominance of the green algae (*Ulva* and *Enteromorpha* sp.) in areas adjacent to dense tourism development, where epiphytic cover reaches up to 69% in the more developed areas.

3.5.2 Mauritius

Nuisance algal growth, affecting the recreational (aesthetic) value of coastal resources has also been reported in Mauritius where, for example, high nitrate concentrations introduced into lagoon systems through agricultural return flows have been associated with algal proliferation in the lagoons of Belle Mare/Palmar. As a result, many hotels have had to remove algal deposits from the shoreline on a weekly basis (Dulymamode *et al.* 2002). At Flic en Flac, black anoxic sands, smelling of hydrogen sulphide, have been observed at the low water mark and are associated with organic enrichment from wastewater discharges (Prayag *et al.* 1995).

Also in Mauritius, domestic sewage released to coastal waters from urban areas and poorly planned housing developments on reclaimed wetlands is a cause of eutrophication/algal blooms that lead to the smothering of coral reefs. Algal blooms are observed annually at Trou aux Biches and isolated cases have been reported at Bain des Dames near Port Louis. High levels of nitrate and phosphate and associated proliferation of algal growth have been recorded at both Belle Mare and Flic en Flac (Prayag *et al.* 1995, Botte 2001). Nutrient enrichment of lagoon waters also results in increased algal growth over corals, affecting their biology and the coral reef ecosystem as a whole (Botte 2001). In 1990 the coastal waters and ecosystems of Port Louis (Mauritius) suffered from severe eutrophication as a result of nutrient-enriched runoff and sewage effluent, as did seagrass beds in Bain des Dames and Point Moyenne (Ramessur 2002). Eutrophication, algal blooms and smothering of corals found in shallow lagoons in Mauritius are common, particularly in Port Louis, where coral mortality is prevalent (Ramessur 2002). High concentrations of phosphates were reported from Mauritius (relative to other WIO countries) from sampling conducted as part of the WIO-LaB project (see Annex 3).

3.5.3 Seychelles

Jones *et al.* (2002) identified eutrophication/algal blooms as a major issue in some of the sensitive areas around the coast of the Seychelles, although the report did not include any quantified scientific evidence of this.

3.5.4 South Africa

Along the South African coast, estuarine systems typically act as nutrient-purifying systems, where nutrients from catchments are absorbed, resulting in cleaner water entering the sea. Excessive weed growth or phytoplankton blooms in estuaries provides evidence for this nutrient removal (Snow *et al.* 2000, Taljaard *et al.* 2000). This is particularly evident during low flow periods (dry seasons) when river runoff entering the estuaries may have high nutrients levels due to agricultural irrigation return flows. High nutrients levels in estuaries can also result from longer residence times within the estuaries, for example during weak neap tides when tidal exchange is reduced (Taljaard *et al.* 2006). Urban estuaries on the KwaZulu-Natal coast are increasingly showing signs of excess nutrient and organic loading from surface drainage and, possibly, malfunctioning sewage reticulation systems. This has contributed to recent fish kills in several estuaries in the eThekwini municipality and the Port of Durban.

3.5.5 Tanzania

In the Tanga area of Tanzania, proliferation of macroalgae has been reported in coastal waters due to nutrient loading from municipal wastewater and industrial discharges, particularly from a fertiliser factory (see Munissi 1998). Munissi (2000) also demonstrated the association of *Ulva* spp. and *Enteromorpha* spp. with nutrient input from sewage pipes.

In Zanzibar, eutrophication/algal blooms, associated with the release of inorganic nutrients from domestic sewage, has been identified as one of the main causes for a decrease in coral-reef-building algae (Björk *et al.* 1995). Coralline algae are sensitive to phosphate and are disappearing from phosphate-rich areas (Björk *et al.* 1996).

3.5.6 Recommendations on eutrophication

There is good evidence of impacts associated with nutrient enrichment from land-based activities in the WIO region. The problem is mainly confined to sheltered environments such as estuaries, creeks and ports, where weak water circulation limits the assimilative capacity for nutrient and biodegradable organic matter. However, with the rapid increase in coastal urbanisation (and associated generation of municipal waste) as well as the projected increase in commercial agricultural and industrial activities in the region, nutrient loads to the marine environment could increase markedly over the coming years. This may challenge the assimilative capacity of wider coastal regions in the WIO, and the problem therefore needs to be addressed.

3.6 SUMMARY OF TRANSBOUNDARY IMPACTS

In summary, Table 13 provides an overview of the key impacts that can be associated with each of the priority transboundary problems discussed in this chapter.

Table 13: Overview of key impacts associated with the major transboundary marine pollution problems identified for the WIO region

TRANSBOUNDARY PROBLEM					ENVIRONMENTAL IMPACTS
Microbial contamination	Eutrophication	Marine litter	Suspended solids	Chemical pollution	
	√		√	√	Modification in species composition in marine biological communities
	√		√		Smothering of benthic communities
		√	√		Entanglement/suffocation of marine organisms
			√	√	Chronic effects on marine biota
	√		√	√	Mortality (acute effects) on marine biota
	√				Opportunistic/nuisance/harmful/toxic algal blooms
	√		√	√	Discoloration of coastal waters
	√				Anoxic conditions/bad odours
√					High levels of pathogenic organisms
					SOCIO-ECONOMIC CONSEQUENCES
	√	√	√		Loss of aesthetic value
√	√	√		√	Human health risk through contact recreation
√	√			√	Human health risk through ingestion of contaminated seafood
√	√		√	√	Loss in quality of seafood products
	√		√	√	Loss of fisheries resources and revenue

4. CAUSAL CHAIN ANALYSIS

4.1 DIRECT CAUSES AND UNDERLYING SECTORS

Transboundary problems and associated impacts of marine pollution from land-based sources in the WIO region can be attributed to a number of direct causes and underlying sectors. There can be several causes for a particular marine pollution problem and, on the other hand, a single direct cause can result in several different problems. This is illustrated in the summary of the main direct causes (linked to land-based activities) of key marine pollution problems (Table 14). The direct causes (in terms of land-based sources) can be divided into a number of key underlying sectors, namely:

- Urbanisation and tourism
- Agriculture and forestry
- Industry and mining
- Transportation (including harbours)
- Energy production
- Aquaculture.

Activities within each of these sectors are further explored in the following sections. From the overview below, it may be concluded that the main sectors contributing to the transboundary pollution problems in the WIO region are urbanisation, agriculture and industry, all of which have cross-cutting impacts. Aquaculture, tourism, mining, transportation and energy-generation and consumption are associated with specific types of pollution.

4.1.1 Urbanisation and tourism

Of increasing concern in the countries of the WIO region is the rapid and often uncontrolled urbanisation and tourism development occurring in coastal areas. Uncontrolled urbanisation results in increases in municipal wastewater, municipal solid waste and atmospheric emissions (e.g. from fossil fuel burning and vehicular traffic), which are often not properly managed or controlled, thereby contributing to many of the priority transboundary marine pollution problems seen in the region (Table 14).

Table 14: An overview of direct causes and underlying sectors linked to transboundary marine pollution problems related to land-based activities

TRANSBOUNDARY PROBLEM					DIRECT CAUSE	UNDERLYING SECTOR
Microbial contamination	Eutrophication	Marine litter	Suspended solids	Chemical Pollution		
√	√		√		Disposal of untreated or under-treated municipal wastewater	Urbanisation, Tourism
√	√		√	√	Industries discharging untreated or under-treated wastewater	Industry
			√	√	Dredging activities	Transportation

TRANSBOUNDARY PROBLEM					DIRECT CAUSE	UNDERLYING SECTOR
Microbial contamination	Eutrophication	Marine litter	Suspended solids	Chemical Pollution		
√	√		√	√	Waste from coastal mining and exploration activities	Mining
√	√	√	√	√	Contaminated surface and sub-surface runoff (e.g. from municipal, industrial and agricultural areas, as well as from accidental spills)	Urbanisation, Tourism, Industry, Mining, Transportation, Agriculture
			√		Destruction of coastal forests contributing to high suspended solid loads	Forestry
√	√	√	√	√	River discharges transporting high suspended solid loads (as a result of soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchments	Agriculture, Urbanisation, Industry
	√			√	Leaking and leaching of agrochemicals (fertilisers and pesticides) from inadequate storage facilities, dumping or return-flows	Agriculture
√	√				Runoff from livestock-rearing areas	Agriculture
	√			√	Atmospheric emissions (e.g. incineration of waste, vehicle and industrial emissions and wood/coal burning)	Industry, Urbanisation, Tourism, Energy production
√		√		√	Inadequate collection, treatment and disposal of solid waste	Urbanisation, Tourism, Industry, Transportation
		√			Public littering on beaches and in areas where litter can be transported into coastal areas	Urbanisation, Tourism
	√		√		Waste products from aquaculture farms that are high in nutrients and suspended solid loads	Aquaculture

(a) Municipal wastewater

Untreated sewage from sanitary facilities (septic tanks, pit latrines and malfunctioning wastewater treatment plants) is a major source of marine water quality degradation in many of the countries in the WIO region (Anon. Mauritius, 2009, Mong *et al.* 2009, Anon Mozambique 2007, Munga *et al.* 2007, Mohammed *et al.* 2008, Abdallah *et al.* 2006, Antoine *et al.* 2008, Weerts *et al.*, 2009). Available information on municipal wastewater loads in coastal areas in the WIO region varies from one country to another, with some countries having detailed information on waste loads and others having very limited and often only qualitative information. The level of treatment of municipal (or domestic) wastewater, as well as the type of treatment (or lack thereof) also differs from country to country (UNEP/Nairobi Convention Secretariat and WIOMSA, 2009, see Table 15).

Table 15: Indication of level of treatment of municipal (or domestic) wastewater in different countries of the WIO region

COUNTRY	PERCENTAGE OF POPULATION			
	Central sewer systems	Septic tanks & soak-aways	Pit latrines	No/other system
Comoros (WHO and UNICEF 2000, WHO 2003)	0.3%	5.3%	94.4%	-
Kenya (major coastal towns)	12%	17%	71%	-
Madagascar (Mong 2007, UNEP 2007)	-	11%	70%	19%
Mauritius	25%	73%	2%	
Mozambique (Mozambique Demographic and Health Survey 2003)	5.4%	24.6%	70%	-
Seychelles (Montano 2007)	7.5%	87.6%	3.6%	1.3%
South Africa[a] (25 coastal municipalities) (derived from Statistics South Africa 2008)	47%	4%	18%	31%[b]
Tanzania (large coastal towns - Tanzania mainland and Zanzibar)	2.8%	9.8%	81.5%	5.9%

a *Western Indian Ocean provinces of Eastern Cape and KwaZulu-Natal (population of 25 coastal municipalities).*
b. *Includes 14.5% of the population that uses dry and chemical toilets*

Available data on estimated volumes and loads of selected pollutants associated with municipal wastewater in coastal areas of the WIO region are provided in Tables 16 and 17.

Table 16: Estimated volumes of municipal wastewater generated in coastal areas of the WIO region (and potentially entering the coastal zone)

COUNTRY	ESTIMATED VOLUME (m^3/day)
Comoros	168[a]
Kenya (Mwaguni 2002; UNEP/Nairobi Convention Secretariat and WIOMSA, 2009)	145,500
Madagascar (Mong, 2007; UNEP/Nairobi Convention Secretariat and WIOMSA, 2009)	176,000
Mauritius (Radhay 2007)	100,000
Mozambique	29,149[c]
Seychelles	4,922 (10,372[b])
South Africa[d]	255,000 (offshore, preliminary treatment) 46,300 (surf zone, secondary treatment) 31,500 (estuaries, secondary treatment)
Tanzania (Tanzania mainland and Islands)	37,912

a. *Assuming 0.8% of population is sewered with an estimated 20 kl/capita/yr (UNEP 1982)*
b. *Volume of wastewater to be collected and treated after planned extension of systems*
c. *Assuming 15% of population is sewered with an estimated 20 kl/capita/yr (UNEP 1982)*
d. *Western Indian Ocean region, i.e. Provinces of Eastern Cape and KwaZulu-Natal (RSA DWAF 2004a,b,c)*

Table 17: Estimated loads of organic material (BOD), suspended solids and nutrients generated from municipal wastewater in coastal areas of the WIO region

COUNTRY	ESTIMATED LOADS (tons/year)[a]			
	BOD	*SUSPENDED SOLIDS*	*NITROGEN*	*PHOSPHOROUS*
Comoros	489	1,063	212	26
Kenya	2,744	3,889	802	97
Madagascar	2,962	6,869	1,417	172
Mauritius	598	1,388	286	35
Mozambique	1,137	1,203	108	26
Seychelles	541	1,254	259	31
South Africa[b]	39,502	30,478	4,518	2,259
Tanzania	21,741	50,413	10,398	1,260

a. Loads from septic tanks calculated as per WHO (1982) unless otherwise stated

b. Western Indian Ocean areas, i.e. Provinces of Eastern Cape and KwaZulu-Natal (estimated concentrations for raw sewage provided in WRC (1990) with secondary treatment concentrations derived from percentage removal estimated in WHO (1982)

To varying levels, municipal wastewater enters marine environments through seepage or rivers in all of the countries of the WIO region. Microbial contaminants, nutrients and suspended solids are the main pollutants in untreated municipal wastewater. The highest concentrations of these pollutants are therefore found close to the major cities in the region, although in many rural coastal areas low-level sewage contamination from defecation on beaches is common.

From the above analysis, it may be concluded that the highest pollutant loads entering the WIO originate from the mainland states (mainly South Africa and Tanzania) and Madagascar. This is not surprising considering the size of the coastal cities in these countries. However, in the case of South Africa, about 74% of the municipal wastewater is discharged to the offshore marine environment through properly designed marine outfalls where the quantity and composition of the effluent must be within limits that meet site-specific environmental quality objectives (RSA DWAF 2004a,b,c). In terms of wastewater volumes, countries with well developed water-borne sewerage reticulation systems obviously discharge relatively more wastewater than those whose wastewater is dealt with by offline systems (pit latrines, septic tanks and soak-away pits). The example in this case is Mauritius, which generates equal or more wastewater than most (much larger) mainland states, but whose pollution loads (BOD, nitrate, phosphate and suspended solids) are much lower.

(b) Solid waste disposal (contributing to marine litter)

Information and data on the quantities of solid waste disposed in coastal areas of the WIO region varies considerably from country to country (UNEP and WIOMSA 2008). Marine litter has been researched in South Africa for over two decades and there is information on the abundance, distribution and trends of different types of litter found around the coast. The sources of the litter are inferred rather than demonstrated, but it is obvious that most of it originates from littering and inappropriate waste disposal on land. Seychelles has a good waste management system in place and contributes almost no marine litter. Mauritius also shows the ability to contain solid wastes. Mozambique, similarly, contributes very little to the marine litter load. This is because it has a very poor transport infrastructure and the vast majority (about 70%) of the population lives in poor rural areas with limited access to products with plastic packaging. Additionally, informal recycling of most salvageable products is commonplace. These factors have kept solid waste loads that may contribute to marine litter under control thus far, but this situation may change (UNEP and WIOMSA 2008).

In Tanzania, Madagascar and Kenya there is relatively little information on the quantities, types and characteristics of solid waste that contribute to marine litter. It is, however, known that large quantities of litter from urban areas reach the sea. The main reason for the littering is that none of these countries has an adequate solid waste management system in place (UNEP and WIOMSA 2008).

A feature common to all WIO-region countries is that most land-based sources of solid waste are associated with urban centres, particularly informal settlements and industrial and commercial areas, and that wastewater runoff is the main distributor via rivers, streams and stormwater drains. According to Lane (2007), the major land-based sources of marine litter are:

- Solid waste dump sites (legal and illegal) located on the coast or on river banks
- Surface water runoff (from stormwater drains and untreated municipal wastewater)
- River discharge and flood waters
- Industrial wastewater discharges
- Public litter on beaches and other coastal areas.

The major sources of solid waste contributing to marine litter in each of the countries of the WIO region are presented in Table 18.

Table 18: Summary of major sources of marine litter in the countries of the WIO region (Source: UNEP and WIOMSA 2008, unless otherwise referenced)

COUNTRY	MAJOR SOURCES
Comoros	Of concern is waste from hospitals, including compresses, syringes, braiding, packaging, plastic, glass and human waste discharged in open dumpsites, usually in the vicinity of the hospitals (Abdallah *et al.* 2006).
Kenya	The major sources of marine litter are reported to be beach recreation (66%), shipping (14%), dumping and surface runoff from urban areas.
Madagascar	The major sources are dumping on the beach and surface runoff from urban/industrial areas (including medical and household wastes) and other areas with crude land dumping practices. There are also reported to be numerous shipwrecks that contribute substantially to marine litter, occurring particularly during the annual cyclone period.
Mauritius	Marine litter arises chiefly from beach recreation, surface runoff from urban areas and from rivers. The volume of ship-generated garbage is far smaller than land-generated volumes.
Mozambique	Beach users, garbage from shipping, fishing gear, road users and urban stormwater runoff are the major sources of litter.
Seychelles	Most litter is from water runoff from rivers and storm drains (despite daily cleaning), from port wastes and particularly from public eating spots or picnic areas. Data are not available for litter generated by the fishing industry.
South Africa	The major source of marine litter is surface runoff from urban areas (via rivers and storm drains), confirmed by (a) litter deposition being greatest in the rainy season (winter in the Cape) and higher levels close to urban areas; and (b) the high proportion of South African-made articles (96%) in stranded litter. Commercial, industrial and low income residential areas produce most litter. Ship-generated waste in South Africa is trivial compared to land-based litter sources. Some litter comes across the South Atlantic in the West Wind Drift from Argentina, Uruguay and Brazil. Marine litter on uninhabited oceanic islands derives from local and foreign fisheries, and distant continents.
Tanzania	The major source of marine litter arises from uncontrolled disposal of solid wastes in unplanned settlements where, for example, about 70% of Dar es Salaam's population live. Most litter is from surface runoff, illegal dumping into river valleys and drainage from crude, open dump sites located near the beach and rivers. Marine litter also arises from fishing and shipping, as the important economic city of Dar es Salaam has a moderate-sized port and fishing is a major activity amongst the coastal communities. The latter are presumed to contribute a significant quantity of gear, boats, traps and plastic bottles as marine litter.

(c) Atmospheric emissions

Activities linked to urbanisation, tourism and subsistence agriculture that contribute to marine pollution through atmospheric emissions include:

- Fossil fuel fires: a large majority of coastal communities in the WIO region use fossil fuel for their domestic energy needs (this is therefore also an issue linked to the energy-production sector),
- Traffic emissions: motor vehicles emissions can contribute significantly to atmospheric pollution, and
- Forest burning for land clearing: urban development adds pressure on land for growth.

Atmospheric pollutants can also originate from solid waste dump sites and burning of waste. Rotting processes cause odour problems and methane gas emissions, while burning of wastes (including plastics) generates smoke which is aesthetically unpleasant and contains pollutants such as particulate matter and noxious gases.

Data on the atmospheric emissions (e.g. suspended solids, nitrogen, trace metals and hydrocarbons) that specifically contribute to marine pollution are lacking for the entire WIO region. In Mauritius, South Africa and Tanzania, atmospheric emissions are monitored in some of the coastal centres (see Anon Mauritius 2009, Weerts *et al.* 2009, Mohammed *et al.* 2008), but this fails to provide insights into the actual loads being deposited into the marine environment.

Based on the rapid increase in urbanisation and tourism development, particularly within the main urban centres of the WIO region, it can be expected that pollutant loads from atmospheric emissions (e.g. nitrogen, trace metals and hydrocarbons) have increased markedly over the past years. This requires further quantification and assessment.

4.1.2 Agriculture and forestry

Agriculture is the backbone of the economy in most countries in the WIO region and is central to the alleviation of poverty and revenue generation. Agricultural activities contribute mainly to marine pollution in that they produce elevated levels of four types of pollutant: suspended solids (the result of erosion due to inappropriate land-use practices); inorganic nutrients (excessive use of fertilisers); pesticides (persistent organic pollutants); and microbial contaminants (typically associated with runoff from livestock rearing areas). Slash-and-burn clearing for subsistence agriculture adds to the atmospheric pollution in some countries. Pollutants from agricultural activities usually enter the marine environment through river discharges, although agricultural activities adjacent to coastal areas can directly contaminate coastal waters through surface or sub-surface runoff.

Agrochemical pollutant loads in river discharges to the sea (i.e. the main route through which pollutants enters the marine environment) have not been quantified for the majority of the countries in the WIO region. Volumes of sale or application of agricultural fertilisers and pesticides have often been used as a proxy for the extent of pollutant inputs from agricultural activities. However, such information can be misleading, particularly for the mainland states, as data are either quoted for the entire countries (therefore overestimating the coastal pollution loads) or only for certain catchments or coastal districts (possibly underestimating coastal pollutant loads) (UNEP 1998b). The physical effects of soil erosion in river basins and the subsequent impacts related to suspended-solid loading and siltation in coastal systems are currently of greater concern than agrochemical pollution in most countries throughout the region. Impacts from soil erosion are most notable along the coasts of Kenya and Madagascar (UNEP 1998b).

Agricultural activities in countries of the WIO region are increasing and are becoming more mechanised and commercial. This increases soil erosion and the use of agro-chemicals. Even without substantial scientific evidence of existing impacts, it can be expected that marine pollution associated with agricultural activities will increase in coming years, unless appropriate environmentally sustainable agricultural practices are promoted within the basins of large rivers discharging into the WIO.

(a) Comoros

In the Comoros agricultural production occupies approximately 67% of land and accounts for 98% of export revenue. The main export crops include vanilla, ylang-ylang and cloves. Cereals, rice, potatoes, fruits and legumes are also grown for local consumption. As a general rule, the use of pesticides and fertilisers for market gardening is limited. The total quantity of pesticides used between 1991 and 1993 was approximately 70,000 kg. Steep slopes and continuous cultivation without provision of fallow fields has led to the impoverishment of the soil and incidents of serious soil erosion, and subsequent siltation of coral reefs. Agricultural runoff is also considered to have led to the pollution of groundwater, although there are no data on which an accurate assessment of the problem can be made. Almost all organic waste coming from the agricultural practices is reintroduced into the soil to improve fertility (Abdallah *et al.* 2006).

(b) Kenya

Although Kenya's coastal region is important for the production of vegetables, tropical fruit and for livestock, these activities make up only a small proportion of the land-use. Thus, apart from the two large commercial sisal farms (which also rear livestock) located 30-60 km north of Mombasa, agricultural activities at the coast are mostly subsistence. Agricultural chemicals and fertilisers are used by some of the larger farms in Mombasa, Kilifi, and Lamu. Potential sources of persistent organic pollutants that are used, although still on small scale, include organochlorine insecticides, organophosphorous, carbamates and pyrethroids (for food crops) and herbicides such as 2,4-diamine and 2,4,5-triamine. However, the use of agrochemicals (e.g. pesticides and fertilisers) is increasingly replacing traditional farming methods, even on the smaller farms (UNEP/GEF 2002).

Livestock rearing is thought to be the major source of pollution from agricultural activities in Kenya. The combined BOD load from livestock wastes in the districts of Mombasa, Kwale, Kilifi and Lamu has been estimated to be 1855 tons. In Kilifi district agricultural activities contribute significantly to marine pollution, with large livestock farms such as Vipingo Estate Ltd, Kilifi Plantations Ltd and the Agricultural Development Corporation farm in Malindi, situated along the coast. For example, the combined nitrogen and phosphorous loading to the coastal environment from the Kilifi Plantations Ltd and Vipingo Estate Ltd farms was estimated at 92.5 and 5.3 tons/year, respectively. These farms manage low-density pasture units, where livestock waste is used as manure. Some of the busiest slaughterhouses in the area are also located on the farms, further contributing to marine pollution (e.g. through microbiological contamination and nutrient enrichment). In Kwale district mainly dairy cattle are kept along the coastline (UNEP/GEF 2002).

River discharges are the main route through which suspended solids and agrochemicals reach coastal areas, particularly during the rainy season. The Tana and Athi rivers drain hinterland agricultural areas, carrying significant quantities of nutrients into their estuaries. Studies conducted by Barasa *et al.* (2007) revealed residues of organochlorines in coastal sediments, reflecting the usage of aldrin, dieldrin, lindane and endosulfan (Table 19). The use of p,p'-DDT was banned in 1997 following the

Stockholm Convention on POPs, and their presence in coastal sediments indicates the persistent nature of these type of compounds, and/or their continued use.

Table 19: Mean pesticide residue concentrations reported for coastal sediments of Kenya (Barasa *et al.* 2007), as well as the recommended environmental targets (EQTs) for sediments in the WIO (United Nations Environment Programme/Nairobi Convention Secretariat and CSIR 2009)

PESTICIDE	RECOMMENDED EQT (sediments)	MEAN RESIDUE CONCENTRATION (µg/kg dry mass)			
		Sabaki	Kilifi	Mombasa	Ramisi
Aldrin	-	4.83	6.76	7.39	21.4
Lindane	-	Below detection	Below detection	7.55	13.4
Endosulfan	-	2.94	6.77	7.34	9.71
Dieldrin	0.72	22.7	11.8	5.85	9.33
p,p'DDT	3.89	7.04	10.8	3.55	12.2
p,p'DDE	2.2	3.19	7.50	0.95	3.85
p,p'DDD	-	4.94	10.5	2.82	6.13

Poor agricultural practices along the major river basins and on steep slopes enhance soil erosion, resulting in the transportation of high loads of suspended sediments through river discharges into the sea, causing siltation in estuaries, adjacent beaches and mangroves. This caused shadowing and/or smothering of coral reefs and seagrass beds (Munga *et al.* 2006).

Solute and sediment transport modelling studies to assess the fate of pesticide residues and nutrients from agricultural activities have been conducted for the Mombasa coastal region (Munga *et al.* 2006) and nutrient loads from the Sabaki River were reported by Ohowa (1996) (Table 20).

Table 20: Estimated nutrients load introduced to coastal areas in Kenya (Ohowa 1996, Mwashote *et al.* 1998, KWS Netherlands Wetland Project 1998)

COASTAL REGION/RIVER	GROUNDWATER DISCHARGE (tons/year)	
	Nitrogen	Phosphate
Nyali (south coast)	1.8	-
Diani (south coast)	0.4	-
Mida Creek	780	1.6
Sabaki River	415	840

(c) Madagascar

In Madagascar, cattle rearing and rice production are the main agricultural activities, although small areas of intensive production of sugar cane and cotton are located in the southwest and northwest of the country, where the greatest quantities of fertilisers and pesticides are applied. The application of fertilisers in intensive agricultural areas was reported to be as high as 163 kg/ha in 1990, and has been linked to localised algal blooms and reduced fish catches in lagoons, and particularly around the reef at Toliara (Mong *et al.* 2009). However, no research has been reported to date to prove cause and effect (UNEP/GEF 2002).

The clearing of forests for agricultural purposes in Madagascar is of concern, as it causes serious erosion. Rivers transport high sediment loads to the coast, which smother sensitive coastal habitats, including coral-reefs, particularly on the west coast. The major causes of erosion are bush-fires, harvesting of forests for production of charcoal and clear-felling for agriculture purposes. Little is being done in the way of reforestation to reduce soil erosion. Although algal blooms have been observed in Madagascan coastal waters, it is not clear if this is as a result of agricultural activities. To date, algal blooms around coastal urban centres have generally been associated with inorganic nutrients derived from domestic-sewage pollution (UNEP/GEF 2002). Atmospheric pollution associated with the burning of sugar cane fields prior to harvesting is of concern, particularly in Nosy Bé, Ambilobe, Namakia and Brickaville (Mong *et al.* 2009).

(d) Mauritius

Until the late seventies, agriculture was the main foreign exchange earner in Mauritius. It was also the largest sector in terms of output and employment. The area under cultivation in Mauritius (90,100 ha) represents about 48% of the island. Sugarcane cultivation occupies about 77,000 ha, about 90% of the arable land. The rest of the agricultural land is used for tea, tobacco and food crops. The main food crops cultivated are onion, tomato, chilli and eggplants (UNEP/GEF 2002, Anon Mauritius 2009). Despite a decrease in agricultural activities, the island has a long history of pesticides use. Considering the import figures of agrochemicals as a proxy for potential impacts on the coastal environment, this appears to be significant. Approximately 1,153 tons of pesticides are imported annually, out of which 59% are herbicides, 31 % insecticides and 8% fungicides. The vast majority of the country's 35,000 small scale farmers use hand sprayers, resulting in wastage and spillage of the pesticides. In addition, plant growth regulators and fruit and cane ripeners are increasingly being used. Some agrochemical importers are also still selling banned pesticides on the island. However, over the past decade there has been a systematic conversion of agricultural lands to industrial and urban development, with agricultural land decreasing by approximately 5,500 ha. Associated with this has been a reduction in the use of agrochemicals. For example 61,266 tons of fertiliser was used in Mauritius in 2004. This was about 3.5% lower than the 63,507 tons used in 2003 (Anon Mauritius 2009).

(e) Mozambique

In Mozambique most agricultural activity takes place along or close to the main river basins. River discharges are the main pathways through which suspended solids and agrochemicals enter coastal environments. Rivers around which intensive agricultural activity takes place include the Monapo (in Nampula Province), the Zambezi (which are also impacted by agricultural activity in Zimbabwe and Zambia), the Pungoé (with tobacco plantations in Zimbabwe), the Limpopo and the Incomati (with intensive farming in South Africa) and the Umbeluzi (impacted by sugar cane farming in Swaziland) (Massinga and Hatton 1997). Despite this, the present contribution of Mozambique’s farming to the pollution of coastal waters is considered to be negligible, considering that mechanised farming in the country occupies only 8% of the total cropland. However, increased foreign investment after the war is resulting in an increase in agriculture activity. Although DDT is officially banned in Mozambique, it is still being used in the country and neighbouring regions. Common pesticide residues identified are 2,4,5 TCB, pp DDD, pp DDT, pp DDE, Lindane and HCB (Massinga and Hatton 1997).

(e) Seychelles

Pollution from agricultural activities has not been properly assessed in the Seychelles. However, agriculture does not represent a significant proportion of land-use on the island (4% of the total area) or of the GDP. Agricultural activity only takes place on a local scale, often for household use (UNEP/GEF 2002).

(f) South Africa

No data on pollutant loads entering the marine environment from agricultural activities are readily obtainable for South Africa. River discharges from intensive agricultural areas are, however, considered to be the main transport mechanism by which agricultural pollutants enter the marine environment. For example, the Gamtoos River, associated with intensive agriculture, introduces high nutrient loads to its estuary, causing eutrophication (Snow *et al.* 2000). Water quality is monitored in many of South Africa's rivers as part of a national monitoring programme (RSA DWAF 2007), but monitoring points are typically located far upstream in catchments, and are generally not representative of the loads that ultimately enter estuaries or the marine environment. Estimated nutrients loads (nitrogen plus phosphorous) entering the estuaries of a number of rivers along the South African coast are provided in Table 21. These nutrients are mainly derived from agricultural activities in the catchments (Taljaard *et al.* 2006).

Table 21: Estimated nutrient loads entering the marine environment from selected rivers in South Africa (mainly nitrogen and phosphorous associated with agricultural activities in the catchments, Taljaard *et al.* 2006)

RIVER	ESTIMATED NUTRIENT LOAD (tons/yr)
Orange (west coast)	150
Breede (south coast)	250
Thukela (east coast)	860

(h) Tanzania

Agriculture employs about 80% of Tanzania's population, and accounts for about half of the country's GDP. Most agriculture in Tanzania occurs in river valleys and floodplains. However, the extent of agricultural pollution has not been evaluated. To control pests, diseases and improve yields, the agricultural industry in Tanzania uses a range of agrochemicals, many of them imported. The pesticides commonly used in Tanzania include aldrin, dieldrin, lindane, endosulfan and heptachlor. Poor storage and transportation of such chemicals may result in accidental spills into freshwater and marine systems (UNEP/GEF 2002).

In Zanzibar, agricultural activities are still artisanal, dominated by the cultivation of food crops rather than cash crops. These food crops include banana, cassava, yams, sweet potatoes, rice, millet and maize. Sugarcane is cultivated in the northern district. The use of fertilisers and pesticides has remained relatively low. Fertilisers are used mainly in rice and sugarcane cultivation. The supply of the chemicals is often erratic and because of this their use has been severely curtailed. For example, use of fertiliser dropped from 2,800 tons in 1988 to 406 tons in 1996 (Ministry of Agriculture, Zanzibar). According to the Zanzibar livestock census of 1993, there are about 73,000 domestic animals on the island. Most of these animals are taken to communal dips, to protect them against diseases. These dips dispose an estimated 300,000 litres of waste annually (Mohammed *et al*. 2008). Given that the majority of smallholdings do their own dipping/spraying, the amount of waste produced through livestock rearing may be much greater (UNEP/GEF 2002).

The destruction of coastal forests also contributes to high suspend solid loading in coastal areas, although no quantitative data are currently available for the WIO region.

4.1.3 Industry and mining

Major industries and mining activities situated within coastal areas of the WIO region include:

- Textile industries
- Tanneries
- Paper and pulp mills
- Breweries
- Chemical factories including production of agrochemicals and pharmaceuticals
- Cement factories
- Sugar refineries
- Food processing industries (e.g. fish factories and slaughterhouses)
- Fertiliser factories
- Oil refineries
- Oil and gas exploration (an emerging activity).

These industries and mining activities contribute to transboundary marine pollution problems through inappropriate disposal of liquid wastewater, solid waste or atmospheric emissions. An overview of the industries and mining activities and their potential contribution to transboundary marine pollution problems is presented in Table 22. Coastal mining activities in the WIO largely comprise the extraction and baking of coral rock, and mineral mining and refining. These activities contribute to the deterioration of water and sediment quality through the disposal of solid waste, suspended solids and chemical pollution. However, no quantitative information on the contribution of these activities to marine pollution is available for the region.

Table 22: Overview of key industries and their potential contribution to transboundary marine pollution problems in the WIO region

INDUSTRY TYPE	TRANSBOUNDARY PROBLEM				
	Microbial contaminants	Eutrophication (nutrients)	Marine litter (solid waste)	Suspended solids	Chemical pollution
Manufacturing			X		X
Textile factories		X		X	X
Sisal processing		X	X	X	
Tanneries		X	X	X	X
Paper and pulp		X	X	X	
Breweries		X	X	X	
Chemical factories		X		X	X
Cement factories			X	X	
Sugar production		X	X	X	X
Food processing (including fish)	X	X	X	X	
Fertiliser factories		X		X	X
Oil refinery				X	X
Oil and gas exploration				X	X

(a) Comoros

In the Comoros, processing industries associated with agricultural and livestock production (including food processing) account for 85% (14.41 tons per annum) and 92% of the BOD and suspended solid load, respectively (Abdallah *et al.* 2006). However, the loads of BOD, suspended solids and solid waste produced by such industries are considered to be small in comparison with domestic waste loads.

(b) Kenya

In the coastal areas of Kenya, most industrial activity is situated in the Mombasa, Kilifi and Lamu districts. Very few industries treat their wastewater, which is discharged either to municipal sewers or stormwater drains. Due to the proximity of industrial areas to natural drainage systems, most of the pollution generated on Mombasa Island and the surrounding mainland shores ends up in the creeks around Mombasa. The solid wastes from industries are of unknown composition and quantity, but are likely to include hazardous components (Mwaguni and Munga 1997). The petroleum refinery at Changamwe produces hazardous sludge containing toxic substances such as hydrocarbons and heavy metals, which is dispersed on agricultural land within the refinery grounds. Large quantities of solid waste are produced by cashew-nut- and sisal-processing factories, producing about 15,330 and 8,400 tons/year respectively. The sisal-processing industry also discharges considerable quantities of liquid waste directly into the sea, thereby introducing a significant BOD load.

(c) Madagascar

Most industrial activities in Madagascar are situated in coastal urban centres, mainly near the ports of Antsiranana, Ambilbe, Mahajanga, Tolagnaro and Toamasina. The exception is the textile industry, which is primarily located inland at Antananarivo. Coastal industrial activities are focused on seafood processing, sugar extraction, oil and soap production, breweries, tanneries and sisal production (Mong *et al.* 2009). The majority of these industries do not treat their waste. Where there is some treatment, it is limited to coagulation and decanting, or to decanting only prior to discharge into a treatment system or directly into the sea (Mong *et al.*, 2009, UNEP/Nairobi Convention Secretariat and WIOMSA, 2009a.). Compared to municipal waste, however, the pollution load from industry in Madagascar is considered to be relatively small.

(d) Mauritius

In Mauritius, about 10 million cubic metres of industrial wastewater is produced annually. Most is discharged to treatment plants from industries that include sugar production (the largest contributor), textiles (e.g. dye houses), breweries and food processing plants (Anon Mauritius 2009). Plaine Lauzun, Vacoas-Phoenix and Coromandel are the main industrial zones in Mauritius. The Coromandel industrial zone, comprising mostly of dye houses and soap and food processing industries, directs wastewater to Mt Jaquot Wastewater Treatment Plant prior to discharge through a 600-m-long marine outfall into Pointe aux Sables lagoon. Industries in Plaine Lauzun and Vacoas-Phoenix discharge wastewater directly to the St Martin wastewater treatment plant. Other major wastewater treatment plants are located at Grand Baie and Baie du Tombeau. The estimated pollution load from the 31 major industries located in Mauritius introduces 1,117 tons of BOD, 17 tons of nitrogen, 81 tons of total phosphorous and 23 tons of suspended solids into the marine environment annually (source: Mauritius Wastewater Management Authority).

(e) Mozambique

Most industrial facilities in Mozambique are located in the coastal urban centres of Maputo, Matola and Beira, and include textile, paper and tyre factories, as well as a brewery. Most of these industries discharge untreated wastewater into the Infulene River that drains into Maputo Bay (Anon Mozambique 2007). The total number of industrial units listed for Maputo increased from eleven in 1982, to 29 in 1992 and 137 in 1996. These industries produced a total of 79,388 tons of BOD in 1996, as well as an unknown quantity of waste containing heavy metals such as mercury, lead, chromium, manganese, nickel and zinc (Anon Mozambique 2007).

(f) Seychelles

Major industrial sources of marine pollution in the Seychelles are food processing and chemical industries. Food processing industries dealing with agriculture and livestock products account for 71.6% and 88.7% respectively, of the BOD and suspended solid loads introduced to the coastal waters (Radegonde 1997). Other major contributions are from fish-processing and canning industries, which account for 17.7% and 6.7% of the BOD and suspended solid loads respectively. In Seychelles, industrial waste accounts for only 17.5% of the total BOD load discharged into the environment, with 72% derived from stormwater runoff and municipal wastewater. Fifty six percent of the suspended solid load was reported to be derived from industrial waste, with the remainder coming from municipal sources.

(g) South Africa

In South Africa, industrial wastewater disposal into the WIO region occurs mainly in the larger urban centres along the east coast (e.g. Port Elizabeth, East London, Durban and Richards Bay), where an estimated 308,100 m^3/day of industrial wastewater is discharged to the sea. Most of this effluent is discharged to the offshore environment through properly designed marine outfalls that are subject to regular environmental monitoring and assessment studies (RSA DWAF 2004a,b,c, CSIR 2004, Taljaard *et al.* 2006, McClurg *et al.* 2007) (Table 23).

Table 23: Estimated volume for industrial wastewater (point sources) discharged directly into the marine environment of South Africa (RSA DWAF 2004a,b,c)

<table>
<tr><th rowspan="2">URBAN CENTRE</th><th colspan="6">ESTIMATED VOLUME* (m^3/day)</th></tr>
<tr><th>Food (fish) processing</th><th>Oil refinery</th><th>Chemical</th><th>Paper & pulp</th><th>Fertiliser</th><th>Textile</th></tr>
<tr><td>Port Elizabeth</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td></tr>
<tr><td>East London</td><td>-</td><td>-</td><td>-</td><td>-</td><td>-</td><td>1,800</td></tr>
<tr><td>Durban</td><td>-</td><td>-</td><td>9,700</td><td>87,000</td><td>-</td><td>3,600</td></tr>
<tr><td>Richards Bay</td><td>-</td><td>-</td><td colspan="3">120,000 (combined)
86,000 (gypsum)</td><td>-</td></tr>
</table>

(h) Tanzania

Although the level of industrialisation in Tanzania is considered to be relatively low, disposal of untreated industrial waste causes localised pollution. About 80% of the industries in Tanzania, including food-processing industries (agro-industries), chemical factories, breweries, soap and steel manufacturing plants, are located in the coastal city of Dar es Salaam where most of the industries discharge their wastewater into the Msimbazi and Mzinga Creeks (Mgana and Mahongo 1997, 2002). Industrial wastewater discharge contributes an estimated 2,715 tons/year of BOD and 15,454 tons/year of suspended solids to the marine environment. This is equivalent to 19% of the total BOD and 55% of the total suspended solid loads for the city, respectively. Breweries account for most of the BOD and suspended solids, while nutrient loads (nitrogen and phosphorus) originate mainly from slaughterhouses (Table 24).

Table 24: Estimated pollutant loads from industrial activities into the Msimbazi Creek (Dar es Salaam)

INDUSTRY TYPE	ESTIMATED LOAD (kg/year)				
	BOD	Suspended solids	Oil	Nitrogen	Phosphorous
Food processing (breweries)	1,117.3	433.8	-	-	-
Food processing (slaughterhouses)	53.6	59.9	18.8	6.3	0.5
Textile	50.4	20.7	-	-	-

About 43% of the major industries surveyed in Dar es Salaam emit atmospheric pollution. The cement industry at Wazo Hill is the principal atmospheric polluter, emitting approximately 2,831 tons of air-borne particulate material per year. If Wazo Hill is representative, the same levels of atmospheric pollution may be expected from the cement factories located elsewhere in the region, e.g. Maputo, Bamburi (Mombasa) and Kaloleni (Kilifi).

In Zanzibar industrial activities are mainly concentrated in the Saateni, Maruhubi and Mtoni areas, and include mainly food processing (slaughter houses, dairy products and beverages) and chemical (soap production) industries, generating around 15 tons of BOD and 16 tons of suspended solid loads per year (Table 25).

Table 25: Estimated pollutant loads from industrial activities on Zanzibar

INDUSTRY TYPE	ESTIMATED LOAD (kg/year)				
	BOD	Suspended solids	Oil	Nitrogen	Phosphorous
Food processing (slaughterhouses)	13,512	12,611.2	4,729.2	1,576.4	112.6
Food processing (dairy)	7,885.4	2,505.6	-	461.0	101.1
Food processing (soft drinks)	303	101	-	-	-
Food processing (coconut oil)	44.3	43.8	50.0	-	-
Chemical (soap production)	3,256	814	18.5	-	-

4.1.4 Transportation

Almost all of the large urban centres within the WIO region have large commercial ports and harbours. Activities such as ship maintenance and repair, disposal of garbage and dredging contribute to transboundary marine pollution. Furthermore, industrial zones are often located in close proximity to the major ports and harbours. Pollution issues that have been identified for ports and harbours in different countries are highlighted in Table 26.

In the Comoros the harbour at Mutsamudu is located near a river and as a result of continued sedimentation it is becoming shallower, reducing its capacity to accommodate larger ships and vessels (Abdallah *et al.* 2006).

Kilindini Harbour in Mombasa is the major Kenyan port, managed by the Kenya Ports Authority. It is a natural harbour and is strategically positioned to serve a number of east and central African countries including Rwanda, Uganda, Burundi, Tanzania, Zaire and Sudan. The location of the port has attracted many industries to Mombasa. The port area is, however, subjected to environmental perturbation due to shipping and other marine and land-based activities. Periodic dredging in the port and its approach channels for maintenance and expansion causes the suspension of considerable quantities of particulate material and associated chemicals (e.g. nutrients, heavy metals, persistent organic contaminants, etc.) (Munga *et al.* 2006).

Madagascar has numerous harbour facilities along its coast, as maritime transportation is very important for the island. In general, the sources of marine pollution linked to harbours are as a result of spillage of pollutants (e.g. chemical products and oil) during cargo handling, lack of facilities to handle garbage, oil residues and wastewater from vessels, and lack of facilities and infrastructure to remove wrecks (Mong *et al*. 2009).

Table 26: Major ports in the countries of the WIO region and reported marine pollution issues

COUNTRY	PORT/HARBOUR	MAJOR ISSUES
Comoros	Mutsamudu	Located near a river and is becoming shallower as a result of continued sedimentation, reducing its capacity to accommodate larger ships and vessels (Abdallah *et al.* 2006).
Kenya	Kilindini (Mombasa)	The port area is subjected to environmental perturbation due to shipping and other marine- and land-based activities. Periodic dredging in the port and approach channels for maintenance and expansion of facilities re-suspends considerable quantities of particulate material and associated pollutants (e.g. nutrients, heavy metals, persistent organic pollutants, etc.) (Munga *et al.* 2006).
Madagascar	Antsiranana, Mahajanga, Toamasina and Toliara	According to Mong *et al.* (2009), marine pollution linked to harbours is derived from spillage of pollutants during loading and offloading, lack of facilities to handle garbage, oil residues and wastewater from vessels and lack of facilities to remove wrecks.
Mauritius	Port Louis	Dredging is undertaken on an *ad hoc* basis for maintenance of existing channels as well as for port development (Anon Mauritius 2009).
Mozambique	Maputo, Beira and Nacala and several small ports e.g. Inhambane, Quelimane, Pebane, Angoche and Pemba	No specific issues have been listed, but major issues are most likely associated with dredging and spills. Waste management in Maputo harbour is a major issue (solid waste enters the port through streams/surface runoff during rainy seasons) (Anon Mozambique 2007).
Seychelles	Port Victoria	Dredging, land-reclamation, waste from rivers and fishing vessels, food processing plants (cannery) (Antoine *et al.* 2008).
South Africa	Port Elizabeth, Ngqura, Richards Bay, Durban and East London	Contribution to marine pollution through poor operational practices and dredging activities (Clark *et al.* 2002).
Tanzania	Dar es Salaam, Tanga, Mtwara and Zanzibar	Heavy metal and organophosphate levels in sediments are of concern, while other issues are mostly associated with dredging operations and chemical spills. There are also waste management problems (Mohammed *et al.* 2008).

Port Louis, the only port in Mauritius, has undergone substantial development to cater for increasing maritime activity accompanying economic development of the country. Dredging is undertaken on an ad-hoc basis in existing channels for maintenance purposes, as well as for strategic port development (Anon Mauritius 2009).

There are three large ports in Mozambique (Maputo, Beira and Nacala) and several smaller ones (Inhambane, Quelimane, Pebane, Angoche and Pemba). These handle cargo to and from Swaziland, South Africa, Zimbabwe, Zambia, Malawi and Congo. Waste management around these ports is a source of concern (Anon Mozambique 2007).

There are four commercial ports along the WIO coast of South Africa. These are controlled by Transnet National Ports Authority and are situated at Port Elizabeth, East London, Durban and Richards Bay. These ports are not only conduits for trade between South Africa and its partners in Africa, but also function as hubs for traffic emanating from, and destined for Europe, Asia, the Americas and the east and west coasts of Africa. In 2008, South African ports handled close to 13,000 vessels, over 185 million tons of cargo and 3.9 million containers (TNPA 2008). The Port of Ngqura has been developed as a new deep-water port 20 km east of Port Elizabeth, together with an adjacent Industrial Development Zone. This is South Africa's primary location for major new industrial investments in the coastal zone. The new port is intended to provide development impetus in the Eastern Cape Province and is anticipated to make South Africa the hub of north-south and south-south sea traffic. Furthermore, major upgrades are currently underway at several of the other major national ports to increase handling capacity and absorb the rapid increase in commercial traffic. Although these ports and harbours have triggered extensive industrial and urban development in South Africa (and continue to do so) they have also contributed to land-based sources of marine pollution through poor operational practices and dredging activities.

Dar es Salaam, Tanga, Mtwara and Zanzibar are the major ports along the Tanzanian coast, with smaller ports situated at Kilwa, Lindi and Mafia. The port at Dar es Salaam is the largest and also serves the neighbouring countries of Rwanda, Burundi, Democratic Republic of the Congo, Malawi, Zambia, Zimbabwe, and Uganda. Heavy metal and organophosphate levels in port sediments are of concern, as are other pollution issues such as dredging operations, chemical spills and waste management problems (Mohammed *et al*. 2008).

4.1.5 Energy production

The energy production sector influences marine water quality mainly through thermal discharges of cooling water, atmospheric emissions from combustion of oil, gas, or coal from power generation installations, and atmospheric emissions associated with burning of fuels (e.g. wood, charcoal and paraffin) for domestic cooking. Pollutant loads from these activities have not been properly quantified for the WIO region, and further investigation is needed before conclusive statements can be made in terms of their contribution to marine pollution.

4.1.6 Aquaculture

The WIO has good aquaculture potential. However aquaculture activities are currently largely limited to the farming of crustaceans (e.g. shrimp, prawns and crabs) and seaweed in the Seychelles, Madagascar, Mozambique (crustaceans) and Tanzania (seaweed) (WIOMSA 2007). Although aquaculture is still poorly developed in the region, it is an emerging sector that could have deleterious effects on coastal water quality, in terms of organic/nutrient pollution from uneaten feed or waste products (e.g. faeces), cleaning fluids and antibiotics in the feeds, and suspended solids from cleaning of ponds.

4.2 IMPORTANT ROOT CAUSES

The root causes (or drivers) of pollution problems are usually cross-cutting to transboundary problems and their direct and underlying causes, and can typically be divided into the following categories:

- Population pressure
- Poverty and inequality
- Inappropriate governance
- Inadequate knowledge and awareness
- Inadequate financial resources.

These root causes are largely cross-cutting to all key marine pollution transboundary problems identified in Chapter 2, as can be seen from the causal chain analyses.

4.2.1 Population pressure

Population growth is a fundamental root cause threatening marine resources in coastal areas of the WIO region because it brings about an increase in demand for goods and services, and the natural resources needed to sustain livelihoods. Rapid urbanisation with associated changes in lifestyles characterised by high consumption rates has resulted in increased generation of waste. All of the countries in the WIO region have experienced rapid population growth and urbanisation in coastal areas, particularly in the larger coastal centres.

As indicated in Chapter 2.2, the countries in the WIO region had a combined population of 178 million in 2007, of which a significant percentage lives along the coast (Table 5). Urbanisation and availability of ports and harbours (including opportunities created by various development processes) have attracted high concentrations of people in some coastal areas. The annual population growth rate in the region in 2007 ranged from 0.4 % in South Africa to 2.6 % in Madagascar (World Bank 2009). The proportion of coastal population (in 2000) in the 25 km strip varied substantially between countries, from a low 6.1% in Kenya and 13.6 % in Tanzania to 100% in the small island developing states.

The increase in population and demographic changes have been a significant factor in the increased demand for land for housing and associated infrastructure development (e.g. sanitation and waste management). Rapidly changing lifestyles, including increasing and changing consumption patterns and rising expectations, are a major root cause of the pressure on ecosystems (Jones *et al.* 2002). Populations along the coast are not evenly distributed, but are mostly associated with larger urban coastal centres. Sanitation and solid waste management are two specific issues related to population growth that pose potential risks to the coastal and marine environment, and which, if not adequately provided for, can result in severe pollution impacts.

4.2.2 Poverty and inequality

The WIO region is characterised by some of the highest levels of poverty in the world, as seen from the estimated per capita income in the different countries (Table 6). Consequently, lack of adequate resources is one of the main reasons for insufficient or unsuitable sanitation and solid waste disposal facilities in many of the WIO countries. Alleviating poverty is a major challenge, requiring transparency, progressive development, management of land and water resources, education on effective technologies for both commercial and subsistence farming, and policies for food security. Education, healthcare and empowerment of people are essential elements for poverty alleviation.

4.2.3 Governance

Governance concerns the values, policies, laws and institutions by which issues are addressed, and it defines the fundamental goals, the institutional processes and the structures that are the basis for planning and decision-making. Management, on the other hand, is the process by which human and material resources are harnessed to achieve a known goal within a known institutional structure. Thus, governance sets the stage within which management occurs (UNEP 2006).

Based on the assessment of governance of marine pollution in the WIO region (Chapter 5) the level of efficiency varies from one country to another. In many of the countries some of the important building blocks for effective governance are not in place.

4.2.4 Knowledge and awareness

The empowerment of people in society and allowing them to play an active role in effective governance and management of natural resources (including marine resources) is an important factor in alleviating poverty. Knowledge is a key pillar for people's empowerment. However, within the countries of the WIO region many people do not have access to appropriate knowledge on matters such as:

- Environmental impacts and socio-economic consequences of human activities that, in many instances, are affecting their quality of life
- Technologies to prevent or minimize impacts on the environment and the goods and services that it provides. For example, appropriate agricultural practices, technologies for municipal wastewater treatment, solid waste treatment and disposal
- Existing policies and institutional structures that provide (often legally) enforceable ways of preventing or mitigating impacts on the environment and socio-economic well-being of people.

4.2.5 Financial resources

The lack of financial resources to implement and enforce appropriate technologies and practices so as to prevent or minimise environmental impacts and/or socio-economic consequences of human activities in the marine environment is a concern in many countries of the WIO region. Furthermore, the lack of political commitment, in many instances, to address issues of environmental concern (including marine pollution) is reflected in the low priority given to such issues in the policies and budget allocations of countries in the region. Evidently, the socio-economic consequences of environmental degradation have also not been properly communicated to politicians and other decision-makers. With this knowledge, policy makers might allocate environmental issues a higher priority.

5. LEGISLATIVE FRAMEWORKS AND INSTITUTIONAL SET-UP

An overview of legal frameworks and institutional set-ups in different WIO countries (with specific reference to issues affecting marine pollution) is useful in a pollution synthesis report, and is provided in this chapter.

5.1 COMOROS

The Comoros has ratified, *inter alia*, the Nairobi Convention. Government is decentralised, which means that each of the three islands that make up the Comoros has its own ministries and departments. Although there appears to be some legislation governing the environment, the legislation is not applied properly due to a lack of both financial and dedicated human resources (Abdallah *et al.* 2006).

5.2 KENYA

Kenya is party to several international conventions, including the Law of the Sea Convention, the Biodiversity Convention and the Nairobi Convention. The management of the coastal environment and resources is governed by various pieces of legislation covering different sectors and issues. No single policy document has been prepared specifically on the conservation, development or management of the coastal zone. The National Environment Action Plan identifies 77 statutes relating to the management and conservation of the environment, most of which apply to the marine and coastal environment. In recent years several initiatives have been undertaken to review some of Kenya's laws, including a number related to the management of the coastal zone. Legislation related to coastal areas has, however, not always been adequately enforced by the relevant authorised institutions. This is due to a number of reasons, including as poor or weak administrative structures, generally low levels of active and participative awareness among the majority of the population, and preference for short term gains at the expense of more sustainable alternatives in policy making and planning. Gaps and overlaps in institutional responsibilities make enforcement of legislation difficult. Furthermore some of the enforcing agencies do not have the necessary resources to enforce regulations adequately and follow-up on complaints and violations (Munga *et al.* 2006).

5.3 MADAGASCAR

In Madagascar the Ministry of the Environment currently coordinates all the activities relating to the environment, with different environmental components assigned to the sectoral ministries. The Malagasy legislation regarding pollution is very fragmented and does not specifically address marine pollution (Mong *et al.* 2009).

5.4 MAURITIUS

In Mauritius the Water Resources Unit is responsible for the assessment, development, management and conservation of water resources. It is the nodal organization concerned with water resources management, and it liaises with other institutions such as the Central Water Authority (mainly responsible for water supply) the Irrigation Authority (responsible for the supply of irrigation water), the Wastewater Management Authority (responsible for the collection, conveyance and treatment of domestic and industrial wastewater) and the Central Electricity Board (a large water consumer for hydro-electric power generation). As part of the development strategy of Mauritius, various policies have been developed covering land-use, freshwater management, wastewater management, coastal development and port management. The policies are implemented through relevant primary and secondary legislation (Anon Mauritius 2007). Shortcomings (inadequate response to pollution problems) in institutional capacity, policy and regulatory frameworks include the following:

- The responsibilities of a number of organisations involved in monitoring of the environment are often not clearly defined, leading to duplication or overlap of work and projects,

- In spite of land-based pollution having a major impact on the environment (including the coastal environment), there is no systematic study or long-term national environmental monitoring programme to determine the extent of such impact,
- Acts are fragmented, with the relevant provisions being dispersed across a number of different Acts and regulations, often giving rise to jurisdictional overlaps, and
- Enforcement of laws is inadequate, mainly due to a shortage of resources and capacity in government departments, low levels of awareness on the laws themselves, and overlapping responsibility for enforcement.

5.5 MOZAMBIQUE

In Mozambique the key institutions responsible for policy making, monitoring and control of water pollution include the Ministry for Coordination of Environmental Affairs (MICOA), the Ministry of Health, the National Directorate of Waters and regional water authorities. Decree No. 76 of 1998 established the Regulation of the Environmental Impact Assessment Process administered by MICOA (Anon, Mozambique 2007). The main constraints related to institutional capacity, policy and regulatory frameworks are:

- Ineffective coordination among the institutions,
- Shortage of financial resources to carry out the planned projects and action plans,
- Insufficient expertise and training facilities, and
- Low environmental awareness in the society.

5.6 SEYCHELLES

Seychelles has a number of national institutions established with the aim of ensuring the protection of the environment, including the coastal marine environment. The key such institution is the Department of Environment, established within the Ministry of Environment and Natural Resources with the responsibility of setting up, enacting and implementing policies and legislation related to the protection of the environment. Other relevant national institutions include the Environment Management Plan of Seychelles (EMPS) Steering Committee, Seychelles Bureau of Standards and the Department of Health. There are no specific policies and strategies adopted and implemented by the government of Seychelles to manage water pollution in the coastal zone. However, one of the guiding principles of the EMPS is to maintain basic ecological integrity and control pollution. Amongst several other acts, the Environment Protection Act 1994 is a key piece of legislation in Seychelles pertaining to the environment. This Act provides for the protection, preservation and improvement of the environment and for the control of hazards to human beings, other living organisms and property. The Act also provides for the coordination, implementation and enforcement of policies pursuant to the national objectives on environment protection. Shortcoming identified in institutional capacity, policy and regulatory frameworks include:

- Lack of a wastewater management policy,
- Lack of a legally binding land-use management plan,
- Inadequate technical human resources dedicated to respond to pollution problems,
- Insufficient and ineffective resources and tools (guidelines and procedures) for monitoring and enforcement, and

- Complicated decision-making and enforcement processes, as a result of a lack of clear definition of institutional and organisational responsibilities for waste management among the various ministries, departments and organizations.

5.7 SOUTH AFRICA

As a signatory to UNEP's Global Programme of Action for the Protection of the Marine Environment from Land-based Activities, South Africa adopted its National Programme of Action (NPA) in October 2008 (RSA DEAT 2008). The NPA aims to coordinate relevant national, provincial and local initiatives playing a role in the control of land-based activities that detrimentally impact the coastal marine environment. It further seeks to strengthen cooperative governance, to identify shortfalls in current efforts and to facilitate appropriate future initiatives. South Africa's greatest effort, particularly over the past 10 years, in combating marine pollution has been in the development of sound environmental policies and legislation. Currently, the disposal of land-derived wastewater is primarily governed under the National Water Act (NWA) (1998) by which municipal wastewater and industrial wastewater discharges (i.e. point discharges) are required to be authorised by licenses issued by the Department of Water and Environmental Affairs (DWEA). The development in 2004 of the Operational Policy for the Disposal of Land-derived Water Containing Waste to the Marine Environment of South Africa was an attempt to improve matters with regard to the management and control of land-based wastewater sources. Diffuse wastewater discharges (e.g. stormwater runoff, agricultural return flows, etc) still remain a challenging aspect, but a number of best practice guides have been developed by national government to assist with the management and control of such diffuse sources. Solid waste disposal by landfill is required to be authorised by a license issued by DWEA. To combat littering in the coastal environment, public involvement and awareness have been stimulated through clean-up initiatives, under the banner of Coastcare, a national programme that was established to assist with education and exchange of information about coastal issues. Atmospheric pollution in South Africa is governed under the National Environmental Management: Air Quality Act of 2004, also administered by DWEA. The quantity and quality of catchment (river) runoff is also governed by DWEA under the NWA (1998) which requires water resources to be classified and resource quality objectives be specified in order to protect aquatic ecosystems. In 2006, South Africa promulgated new Environmental Impact Assessment Regulations under the National Environmental Management Act (1998). Waste disposal activities are scheduled activities under these regulations and as such require an Environmental Impact Assessment.

While national government is largely responsible for establishing a sound legal framework, protocols and best practice guides, the control and management of land-based sources of marine pollution have largely been delegated to the regional (provincial) and local (municipality and local industries) levels. Existing institutional structures for coastal management in South Africa are still largely sectoral. Various government departments, to a greater or lesser degree, have established in-house systems pertaining to specific sectors. However, despite good environmental legislation, effective implementation remains a challenge due to shortage of skilled resources. This matter requires serious intervention on all levels to capitalise on the significant achievements made over the past 10 years. To this end, the new National Environmental Management: Integrated Coastal Management Act (2008) offers great opportunity in that the establishment of cross-sectoral national, provincial and municipal coastal management committees, to facilitate cooperative governance of the coastal marine environment, will soon become a mandatory requirement in South Africa.

5.8 TANZANIA

Under the Constitution of the United Republic of Tanzania of 1977, policies and laws pertaining to natural resource management, including coastal and marine resources, are established and implemented by the central government. Corresponding to the legislation, many sectoral-based ministries share coastal and marine resource planning, management and enforcement duties. These include the Ministries of Natural Resources and Tourism (with forest, fishery, tourist and park regulatory responsibilities), Lands and Human Settlement, Trade and Industry, Water, Agriculture and Cooperatives, Foreign Affairs and International Relations, Energy and Minerals, Communication and Transport, and Home Affairs. Zanzibar, although a part of Tanzania, has a unique legal status. In Zanzibar, the institution that has a leading role in both the planning and management of the coast is the Commission for Lands and Environment, which includes the Department of Environment, and the Department of Land and Surveys. A number of government policies adopted in the 1990s directly and substantially affect coastal and marine resources, although only a few make specific reference to such resources. Such policies constitute drafting instructions from the government for the laws established by parliament.

Both mainland Tanzania and Zanzibar have enacted pieces of legislation and mandated various institutions to facilitate and carry out their duty to protect and manage the country's environment, including the coastal and marine environment. In mainland Tanzania, there are several sectoral pieces of legislation relevant to the protection of marine and coastal environment. These cover sectors such as fisheries, agriculture, forestry, industry and trade, land-use planning, culture, marine transport, environment, energy and tourism. Tanzania, however, lacks a coherent policy that addresses the issue of pollution. Despite environmental regulations aimed at controlling pollution, there are serious problems with enforcement as a result of limited financial and human resources, lack of technological capacity and insufficient political support. Other factors include pressure on government from interest groups, as well as the practical challenges of enforcing environmental regulations (Mohammed *et al.* 2008).

6. RECOMMENDATIONS FOR THE STRATEGIC ACTION PLAN

Coastal marine environments of the WIO region are currently threatened by numerous anthropogenic activities which cause marine pollution, physical alteration and destruction of habitats, and modification of freshwater inflows. However, though critically important, land-based activities are not the only souces of threats to the coastal and marine environment. Others environmental threats emanate from the exploitation of living resources (e.g. fisheries), maritime transportation, dumping of waste at sea and climate change (Figure 10).

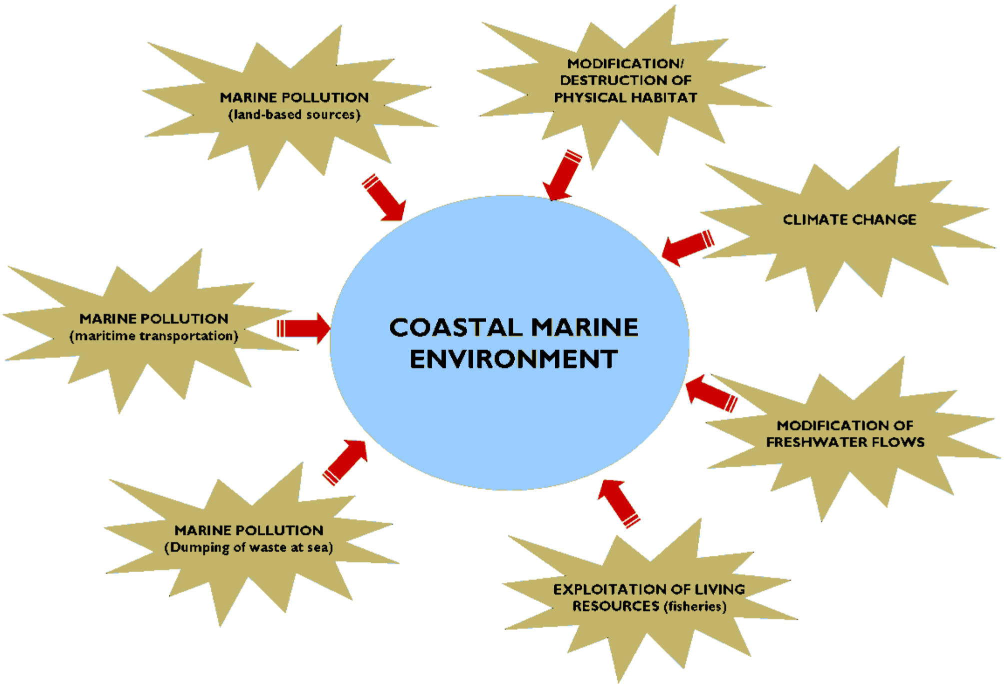

Figure 10: Schematic illustration of different activities threatening the coastal marine environment in the WIO region

Therefore, although the focus of the regional assessment is on *marine pollution from land-based activities,* other threats have to be considered in the integrated management of coastal and marine environments, so as to account for possible cumulative or synergistic impacts. The need for such integration should be acknowledged in the Strategic Action Plan (SAP) and countries' NPAs.

Based on the outcome of the regional assessment, recommendations for consideration in the SAP and NPAs, specifically with regard to marine pollution from land-based activities, are provided in Table 27. These are specifically related to *governance inadequacies*, *inadequate knowledge and awareness* and *inadequate financial resources* as root causes. The root causes of population pressure, poverty and inequality require much broader interventions, which are beyond the scope of this regional assessment on marine pollution.

Table 27: Recommendations for consideration in the SAP and NPAs in the WIO region, addressing specific root causes

ROOT CAUSE	RECOMMENDATIONS
Inappropriate governance	Develop specific management tools (e.g. regional best practice guidelines) and demonstrate best practice technologies and management approaches for: • Municipal and industrial wastewater and solid waste (including governance aspects such as holding product manufacturers responsible for the treatment and recycling of their packaging, applying the 'polluter pays' and 'cradle to grave' principles and introducing economic incentives for low-waste packaging) • Ports and harbours (including issues related to on- and offloading, disposal of waste from vessels, disposal of used oil and oil-related products, and contingency planning in cases of accidental spills) • Agricultural activities (including issues related to soil erosion, agrochemical application and livestock raising).
	Develop regional guidelines for setting ELVs and standards for different industry types based on a technology-based or EQO-based approach.
	Develop targeted investment plans and proposals for the establishment of appropriate wastewater and solid waste management infrastructure in priority hotspots of pollution, e.g. based on the above-mentioned guidelines and lessons learnt from demonstration projects.
	Establish sector-specific ELVs / standards for different industry types using a technology-based and/or EQO-based approach, and develop mechanisms to convert such scientifically set standards into legally enforceable mechanisms.
	Mainstream the above-mentioned guidelines and investment plans into national policies, strategies, legislation and budgets.
	Enforce legislation/regulations for industries to conduct EIA studies and regular audits to assess and evaluate potential impacts on the coastal and marine environment, in alignment with the overarching EQOs and sector-specific ELVs, and ensure that local-level (on the ground) mechanisms are in place to audit and enforce compliance (e.g. monitoring programmes, and incentive and penalty systems).
	Develop a register of municipal wastewater and solid waste management facilities for each of the countries (working towards a permitting system, particularly for central wastewater treatment facilities and landfills).
	Develop a register of manufacturing industries (working towards a permitting system for such facilities).
	Develop a register of agro-chemicals use (e.g. fertilisers, pesticides, herbicides, etc), specifying allowable products and dosages (working towards legally enforcing such specifications).
Inadequate knowledge and awareness	Develop and implement monitoring and assessment programmes to fill gaps in knowledge of priority pollutants (e.g. those identified in the national pollution status reports), including major sources of pollution and their driving forces, with special emphasis on the identified coastal hotspots of pollution.
	Develop and implement regional training programmes to build capacity in wastewater and solid waste management (in many instances focusing on local municipalities and harbour authorities).
	Develop and implement regional education and awareness programmes to inform all sectors of society (including the general public, politicians and managers) on their roles and responsibilities in the generation, collection, treatment and disposal of wastewater and solid waste, as well as the consequences of pollution on the environment and their socio-economic wellbeing.
	Develop and maintain a web-based regional information management system that includes information on best practice technologies, registers (listed above) as well as tools and guidelines for the selection of appropriate technology, institutional and policy frameworks and financial mechanisms.
Inadequate financial resources	Identify and establish sustainable financial mechanisms for investments in the field of wastewater and solid waste management, and cleaner production technologies (including the development of public-private partnerships).

ELV, Effluent limit value; EQO, Environmental quality objective; EIA, Environmental impact assessment

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ANNEX 1: Hotspot evaluation for participating WIO countries

Evaluation templates as completed by national representatives at the 4th meeting of the Regional Working Group on Water, Sediment and Biota Quality Monitoring and Assessment in the WIO region, Dar es Salaam, 23-25 June 2009

KENYA

Hotspot (previously identified): Malindi Bay and Sabaki Estuary
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Entire area
Major pollutants: Suspended particulate matter (especially sediments), debris (marine litter), heavy metals (lead, zinc), chlorinated pesticide residues, nutrients, microbial contaminants
Major sources of above pollutants: River discharge (suspended solids), municipality and hotels, farming upriver
Impact on beneficial uses and sensitive ecosystems (beneficial uses = both existing and potential future uses): Tourism, beaches, bathing, coral reefs (biodiversity in Marine Protected Area), artisanal fishing
How significant is this impact (high/medium/low): High
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes
If "Yes" above, list potential mitigation/management measures: Municipal wastewater management, solid waste management, enforcement of regulations (e.g. Environmental Management and Coordination Act [EMCA] regulations, municipal by-laws), promoting good agricultural practices

Hotspot (other and/or emerging): Diani
An existing or potential hot spot: Existing
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Diani tourist resort and Ukunda urban centre, issues of concern include shoreline erosion
Major pollutants: Nutrients, microbial contaminants
Major sources of above pollutants: Municipal sewage, solid waste, farming
Impact on beneficial uses and sensitive ecosystems (beneficial uses = both existing and potential future uses): Tourism, bathing, coral reef system, fishing
How significant is this impact (high/medium/low): Medium, with seasonal peaks
List potential mitigation/management measures: Wastewater management, solid waste management, good agricultural practices, enforcement of regulations

MADAGASCAR

Hotspot (previously identified): Nosy-Bé
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): The area surrounding the harbour is characterised by bays where major land-based activities are situated. These are potential sources of marine environment pollution. Discharges from port, industries, petroleum product depot and domestic wastewater point impact coral reef and mangroves ecosystems. Fish mortality occurred in the area a few years ago
Major pollutants: Up to now nutrients, heavy metals, *E. coli* and faecal streptococci, hydrocarbons, and (likely) pesticides owing to large plantation of sugar cane on the catchment area are the major pollutants
Major sources of above pollutants: Domestic wastewater, sugar cane and sea food industries, petroleum product depot, harbour activities, solid waste, power generator effluent, stormwater
Impact on beneficial uses and sensitive ecosystems (beneficial uses = both existing and potential future uses): Impacts on tourism, as the island is one the major tourist destinations in the country. Some impact on the coral reef ecosystem has been noted, through growth of opportunistic algae
How significant is this impact (high/medium/low): The impact is considered to be high, owing to the occurrence of fish mortality (twice). The island of Nosy-Bé will likely be impacted by offshore petroleum exploration
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes
If "Yes" above, list potential mitigation/management measures: An environmental platform was set up a few years ago and a public awareness campaign has been embarked upon. Recently a marine park to protect a small island around from tourism impact (solid waste, anchoring) was established. A National Pollution Management Strategy will be validated soon and will take into consideration the trend of degradation of the marine environment

Hotspot (previously identified): Majunga
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): The hot spot is located at the mouth of the River Betsiboka, which is the main source of sediment to the western coastal zone of Madagascar. It is a large bay where the harbour is situated, and the main receptor of municipal discharge of the city of Majunga
Major pollutants: According to monitoring results: nutrients, heavy metals, faecal coliforms and F. streptococci, hydrocarbons, suspended solids
Major sources of above pollutants: Domestic wastewater, textile industries, aquaculture, harbour activities, solid waste, power generator effluent, stormwater
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Impact on the fishing activities and industry and on the mangroves ecosystems. Majunga is developing its seaside tourism, which is highly dependent on the quality of the marine environment
How significant is this impact (high/medium/low): Due to the discharge from the River Betsiboba, it was noted that substantial heavy metals are accumulating in the bay. The impact of municipal wastewater with respect to coliforms and enterococci should also not be neglected. The coast of Mahajanga is the nearest site of the offshore activities.
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes
If "Yes" above, list potential mitigation/management measures: NGOs and the university are running composting activities using municipal solid waste. A National Pollution Management Strategy will be validated soon and will take into consideration the trend of degradation of the marine environment

Hotspot (previously identified): Bay of Toliara
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): The Bay of Toliara stretches along the city of Toliara and includes the port of the city. In the north the bay is the main receptor of the sediment transported by the River Fiherenana
Major pollutants: According to monitoring results the bay is mainly polluted by microbiological contaminants, sediment, nutrients, and likely heavy metals.
Major sources of above pollutants: Domestic wastewater, open defecation, seafood processing, and the River Fiherenana transporting heavy loads of sediment that degrade the coral reef ecosystem
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Impact on the tourism activities and also on the seafood industry. Due to the destruction of the Grand récif (Great reef) by the discharge of sediment, fishing has been affected and the consumption of seafood puts the population at high risk during hot season where toxic microalgae bloom.
How significant is this impact (high/medium/low): The impact is high and directly affects the population. Chronic food poisoning is being noted during the hot season
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes
If "Yes" above, list potential mitigation/management measures: There is a project (twinning project between the city of Toliara and Sandnes [Norway]) addressing the water, sanitation and solid waste issues within the city of Toliara. A National Pollution Management Strategy will be validated soon and will take into consideration the trend of degradation of marine environment.

Hotspot (previously identified): Bay of Fort-Dauphin
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): The area within the bay where the old port is situated
Major pollutants: Heavy metals, faecal coliforms and F. streptococci, hydrocarbons
Major sources of above pollutants: Domestic wastewater, power generator effluent storm water, wrecked ships.
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): While no sensitive ecosystem is located in the area, fishing is practiced by the population
How significant is this impact (high/medium/low): To date no significant impact has been noted except the presence of manganese in trophic webs (probably due to the presence of 40,000 t of manganese mineral in a wrecked ship named ''Welborn''). Potential impacts are expected from the ongoing ilmenite extraction project
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes
If "Yes" above, list potential mitigation/management measures: The ilmenite project has been subjected to Environmental Impact Assessment and is currently following its environmental management planning. The municipality, through bilateral cooperation funding, is building public toilets in order to reduce the open defecation practice. A National Pollution Management Strategy will be validated soon and will take into consideration the trend of degradation of marine environment.

Hotspot (other and/or emerging): Bay de Diego (extreme north of Madagascar)
An existing or potential hot spot: Potential hot spot
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): The entire bay, where lots of mainland based activities are located (harbour, seafood industry, salt production, fishing, navy military base, tourism)
Major pollutants: Suspected heavy metals, hydrocarbons, suspended solids, biodegradable organic material
Major sources of above pollutants: Industrial effluent, municipal wastewater, shipwrecks (~ 30), petroleum product depot, navy military base, stormwater
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Tourism, salt product and fishing activities
How significant is this impact (high/medium/low): Quite high (as indicated by fish mortality in 2004). A sensitive ecosystem (mangrove) and marine mammals (dugongs) found in the area
List potential mitigation/management measures: The city, with French financial support, is implementing a project to improve the sanitation of the city of Diego. The city, in particular its bay area, will benefit from the implementation of the National Pollution Management Strategy

Hotspot (other and/or emerging): Port of Tamatave
An existing or potential hot spot: Potential hot spot
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): The area surrounding the port is the zone of discharge and is influenced by land-based activities, including a major new mining project (extraction of cobalt and nickel), industry (seafood, edible oil), petroleum, municipal wastewater
Major pollutants: Suspected heavy metals, hydrocarbons, suspended solids, biodegradable organic material, microbiological
Major sources of above pollutants: Industrial effluent, municipal wastewater, shipwrecks (~ 30), petroleum product depot, navy military base, stormwater
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Tourism, fishing
How significant is this impact (high/medium/low): Potentially high due to existing sensitive ecosystem (fringing coral reef) and the discharge of sludge from the cobalt/nickel extraction *(to be validated)*
List potential mitigation/management measures: The new mineral project has been subjected to environmental impact assessment leading them to implement Environmental Management Planning. Implementation of the National Pollution Management Strategy will also benefit the area.

MAURITIUS

<u>Hotspot (previously identified)</u>: Palmar
<u>Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?):</u> Palmar is located on the eastern coast of Mauritius in Flacq district. It stretches from the Northern tip of Trou d'Eau Douce to Belle Mare. The surface area of the region is approximately 8 sq km. There are about eight hotels in the region.
<u>Major pollutants:</u> Nutrients: nitrate and phosphate
<u>Major sources of above pollutants:</u> Agriculture/Pig farm, possibly treated effluent used for irrigation in hotels premises
<u>Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses):</u> Impact is mainly on recreational activities in turn affecting hotel business
<u>How significant is this impact (high/medium/low):</u> High
<u>Do you still consider the above as a hotspot or potential hot spot (Yes/No):</u> Yes.
<u>If "Yes" above, list potential mitigation/management measures:</u> Relocation of farmers, using compost rather than inorganic fertilizers. Regular monitoring of treated effluent from the hotels

<u>Hotspot (previously identified)</u>: Pointe aux Sables to Baie du Tombeau (through Port Louis harbour)
<u>Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?):</u> The stretch starts from La Pointe in the South of Pointe aux Sables and comprises the estuary of Grand River North West, Sables Noir, Bain des Dames, Fisheries Post in Baie du Tombeau and Le Goulet Public beach
<u>Major pollutants:</u> Nitrates and phosphates and faecal coliforms
<u>Major sources of above pollutants:</u> Sewage runoff from certain unsewered areas, past discharge of treated effluent within the lagoon of Pointe aux Sables (prior to 2007) and Baie du Tombeau (prior to 2002)
<u>Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses):</u> Impact is on recreational activity at Sables Noir public beach (closed to swimming), seafood intended for human consumption
<u>How significant is this impact (high/medium/low):</u> High
<u>Do you still consider the above as a hotspot or potential hot spot (Yes/No):</u> Yes.
<u>If "Yes" above, list potential mitigation/management measures:</u> Extend sewerage coverage, prevent household discharge into the ocean, regular monitoring of sea water quality

Hotspot (previously identified): Grand Baie
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Grand Baie is situated in the north west of the island in Pamplemousses District. It has an approx surface area 8 sq km and it extends from Pereybere in the north to Pointe aux Cannoniers in the south
Major pollutants: Suspended solids, oil and grease
Major sources of above pollutants: Water sports, pleasure boat marina
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Highly touristic area thus the impact is on recreational activity
How significant is this impact (high/medium/low): Medium
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes.
If "Yes" above, list potential mitigation/management measures:

Hotspot (previously identified): Flic en Flac
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Flic en Flac is situated in the western district of Black River extending from Wolmar in the South to the Klondike hotel in the North. It has an approximate area of 8 sq km
Major pollutants: Suspended solids, nitrate, phosphate, faecal coliforms
Major sources of above pollutants: Restaurants, bungalows and hotels. The area is not sewered at present. Hotels used treated effluents to irrigate their gardens. Large sugar cane fields irrigated by water treated at St Martin treatment plant. Submarine groundwater discharge opposite Ocean restaurant (possibly)
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Highly touristic area and the impact is on recreational activity
How significant is this impact (high/medium/low): Low
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes.
If "Yes" above, list potential mitigation/management measures: The region can be sewered under the West Coast Sewerage project. Treated water from hotels should be regularly monitored

MOZAMBIQUE

Hotspot (previously identified): Maputo Bay, Beira Bay and Nacala Bay
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Maputo Bay: From the Port to Marine Club (5 km) Beira Bay: From the Port to Palmeiras, including Chiveve Creek (7 km) Nacala Bay:3 km
Major pollutants: Microbial pollutants, nitrates, phosphates, heavy metals
Major sources of above pollutants: Municipal sewage, industrial wastewaters, agricultural runoff, ship maintenance in port
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Recreation, fisheries, sensitive ecosystems (sea grass and corals)
How significant is this impact (high/medium/low): Maputo Bay: Recreation – High; Fisheries – Low; Seagrass – Low; Corals- Low Beira Bay: Recreation – Medium; Fisheries – Low; Seagrass – Low; Corals- Low Nacala Bay: Recreation – Low; Fisheries – Low; Seagrass – Low; Corals- Low
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Maputo: Yes Beira: Yes Nacala Bay: Yes
If "Yes" above, list potential mitigation/management measures: Municipal Wastewater Treatment facilities and collection systems, reception facilities in port (for sewage, litter and oil from the ships), environmental education, solid waste facilities, monitoring programmes

Hotspot (other and/or emerging): Pemba Bay and Incomati Estuary (Maputo)
An existing or potential hot spot: Potential
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Pemba Bay: From the port to municipal waste disposal Incomati Estuary (entire estuary)
Major pollutants: Pemba Bay : Microbial pollutants; nitrates; phosphates Incomati Estuary: Nitrates; phosphates
Major sources of above pollutants: Pemba Bay : Waste disposal Incomati Estuary: Agriculture runoff; sugar industry, sewage
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Pemba Bay: Fisheries, sensitive ecosystems Incomati Estuary: Fishery; health
How significant is this impact (high/medium/low): Pemba Bay: Fisheries - medium Incomati Estuary: medium
List potential mitigation/management measures: Pemba Bay: Close the waste disposal; barriers; controlling wells Incomati Estuary: On going study (UEM): physical, chemical and biological measurements, monitoring programmes

SEYCHELLES

Hotspot (previously identified): Port Victoria
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Port Victoria is the only sea port situated at the east coast of Mahé island with three main rivers flowing into it, namely St Louis, English and Moosa river. It is close to the St Anne Marine National Park
Major pollutants: Nutrients, dissolved oxygen, heavy metals (chromium, copper, lead and zinc), petroleum hydrocarbons (risk)
Major sources of above pollutants: Oxygen-depleting wastes, fish processing plant
Impact on beneficial uses and sensitive ecosystems (= both existing and potential future uses): Reduced water and sediment quality in the port and possibly beyond the boundary of St Anne Marine National Park which is popular tourist attraction.
How significant is this impact (high/medium/low): High
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes.
If "Yes" above, list potential mitigation/management measures: Avoid discharge of wastes into the port area, establish sewerage coverage, operate and maintain a wastewater treatment Plant, reuse treated effluent.

Hotspot (previously identified): Beau Vallon Bay
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Beau Vallon is a bay situated in the north of the main island and it receives pollution loads which are mainly of human nature
Major pollutants: Nutrients, microbiological parameters (*S. aureus*, Total coliforms and *E. coli*)
Major sources of above pollutants: Treated wastewater input from nearby hotels, and river inflows during the rainy season
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Eutrophication, harm to corals
How significant is this impact (high/medium/low): High
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes.
If "Yes" above, list potential mitigation/management measures: Establish/reinforce sewerage coverage, reforestation, undertake work to prevent soil erosion

Hotspot (previously identified): East Coast Industrial Zone
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Located along a stretch of 7km of land situated in the east coast of Mahé island. It is land reclaimed from the sea. The zone is adjacent to St Anne Marine National Park (similar to Port Victoria)
Major pollutants: Trace metals, nutrients
Major sources of above pollutants: Paint factory, garages, SWDS, wastewater from Wastewater Treatment Plant
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): May affect St Anne Marine National Park, eutrophication
How significant is this impact (high/medium/low): High
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes.
If "Yes" above, list potential mitigation/management measures: Regular monitoring of the effluent quality from factory and garages, proper operation and maintenance of the wastewater

treatment plant, regular monitoring of treated effluent from wastewater treatment plant

SOUTH AFRICA

Hotspot (previously identified):
Richards Bay

Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?):
Port: Some indication of very localised enrichment near one stormwater outlet. High chrome levels in sediments have been shown to be lithogenic. The port is well flushed and nutrients are not a problem.
Offshore outfalls: Gypsum accumulation has been problematic in the immediate vicinity of one of the outfalls (a diffusers problem). This alters physical habitat and is objectionable matter. Additional pipeline is now operational. Occasional elevated concentrations occur in immediate vicinity to the outfalls

Major pollutants:
Trace metals (port), gypsum (offshore)

Major sources of above pollutants:
Outfalls: Industrial wastewater

Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses):
None. Localised impact on a robust ecosystem a good distance offshore and away from swimming beaches

How significant is this impact (high/medium/low):
Low

Do you still consider the above as a hotspot or potential hot spot (Yes/No):
Yes.

If "Yes" above, list potential mitigation/management measures:

Hotspot (previously identified):
Durban

Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?):
Port: Fish kills have resulted from algal blooms in the upper reaches of the bay. Elevated trace metals are expected in this part of the bay as well.
Bathing beaches: Selected swimming beaches adjacent to rivers and stormwater inflows (e.g. Mlaas Canal, Mgeni River).
Offshore outfalls: Operating well within design capacity, localised organic enrichment in the immediate vicinity of one discharge

Major pollutants:
Port: Nutrients, toxic substances (probably trace metals and organic contaminants)
Bathing beaches: Microbiological
Offshore outfalls: Organic matter potentially with high BOD levels

Major sources of above pollutants:
Port: Contaminated stormwater from informal settlements and urban areas
Bathing beaches: Contaminated stormwater from informal settlements, overloaded wastewater treatment works and reticulation systems
Offshore outfalls: Sewage sludge

Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses):
Port: Recreational and subsistence fishing, estuarine nursery area.
Bathing beaches; Recreation and tourism.
Offshore outfalls: None. Localised impact on the ecosystem, not in a sensitive area, a distance offshore and away from swimming beaches.

How significant is this impact (high/medium/low):
Port: Medium
Bathing beaches: High
Offshore outfalls: Low

Do you still consider the above as a hotspot or potential hot spot (Yes/No):
Yes: Bathing beaches (potential, data need to be analysed)

If "Yes" above, list potential mitigation/management measures:
Wastewater treatment works (operation and maintenance) and reticulation systems, stormwater management programmes

Hotspot (other and/or emerging):
East London

<u>An existing or potential hot spot:</u> Existing
<u>Spatial scale (i.e. is the entire area a hotspot or only specific regions in the area?):</u> Inshore areas at and near Hood Point
<u>Major pollutants:</u> Organic matter, microbiological
<u>Major sources of above pollutants:</u> Inappropriately treated municipal wastewater discharged into the surf zone
<u>Impact on beneficial uses and sensitive ecosystems (beneficial uses = both existing and potential future uses):</u> Surf zone is a sensitive part of the ecosystem. Possible impacts on recreational use
<u>How significant is this impact (high/medium/low):</u> Unknown, potentially high
<u>List potential mitigation/management measures:</u> Improve effluent treatment and consider offshore outfall

<u>Hotspot</u> (other and/or emerging): Port Elizabeth
<u>An existing or potential hot spot:</u> Existing
<u>Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?):</u> Inshore area adjacent to Papenkuils outlet, extending to the port Port areas
<u>Major pollutants:</u> Toxic substances (trace metals and organic contaminants)
<u>Major sources of above pollutants:</u> Contaminated stormwater from urban runoff and industrial effluent discharge, overloaded wastewater treatment works and reticulation systems
<u>Impact on beneficial uses and sensitive ecosystems (beneficial uses = both existing and potential future uses):</u> Inshore area, localised sensitive areas in the surf zone, potential impact on aquaculture areas
<u>How significant is this impact (high/medium/low):</u> Medium
<u>List potential mitigation/management measures:</u> Planning, resourcing, training and maintenance of wastewater works, consider offshore outfall, stormwater management

<u>Hotspot</u> (other and/or emerging): Eastern Cape and KwaZulu-Natal estuaries (and adjacent coastal areas) (Risk area)
<u>An existing or potential hot spot:</u> Existing, and growing
<u>Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?):</u> Estuaries and inshore areas adjacent to: 1. coastal river, estuarine or surfzone discharges of municipal wastewater (there is increasing frequency of malfunctioning and overloading of these treatment works caused by lack of experience/resources and rapid increase in coastal populations), or 2. catchment areas with informal settlements not serviced by wastewater treatment works
<u>Major pollutants:</u> Nutrients, microbiological
<u>Major sources of above pollutants:</u> Malfunctioning and overloading of treatment works, inappropriately treated municipal wastewater, stormwater runoff, agricultural return water
<u>Impact on beneficial uses and sensitive ecosystems (ibeneficial uses = both existing and potential future uses):</u> Estuaries and surf zones are sensitive parts of the ecosystem. There is an increasing trend of elevated nutrient concentrations and microbial contamination in east coast estuaries. This is most evident in larger municipal areas. Ecosystem function is affected (eutrophication) and recreational use (tourism) is impacted by poor water quality in the estuaries themselves, or in the surf zones that they discharge into.
<u>How significant is this impact (high/medium/low):</u> Nutrients: Eutrophication of sensitive ecosystems (particularly estuaries) - High Bathing beaches: Recreation and tourism - High
<u>List potential mitigation/management measures:</u> Address problems with wastewater treatment works (operational, maintenance, wastewater volumes). Planning, resourcing,

training and maintenance of wastewater works, stormwater management plans

TANZANIA

Hotspot (previously identified): Dar es Salaam Harbour
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Microbial pollution widely spread but intensity varies depending on population density and/or the proximity of beach hotels, sewer outfalls, fish landings, storm water discharges, general surface runoff and ground water input
Major pollutants: Microbial, heavy metals
Major sources of above pollutants: Municipal wastewater discharged through streams and runoff, ground water input, sewer outfall, storm water drainage Heavy metals sources are mainly industrial effluents and municipal wastes Petroleum hydrocarbons/PAHs from harbour activities, including unloading of tankers Pesticides mainly from agricultural activities
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Aesthetic/recreational: Microbial pollution affects aesthetic value (and suitability for swimming) of Dar es Salaam waters close to the harbour as well as the quality of seafood and shellfish collected in the intertidal area at Ocean Road Beach
How significant is this impact (high/medium/low): Gastrointestinal diseases are common in some parts of Dar es Salaam. However, on a broader scale the impact is low.
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes
If "Yes" above, list potential mitigation/management measures: Wastewater management, including treatment of sewage, is critical in order to reduce microbial pollution; cleaner production by industries to be emphasized; institution of best practices in use of pesticides; improvement of handling of petroleum at unloading points also better control of shipping activities.

Hotspot (previously identified): Zanzibar (harbour and Stone Town)
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Zanzibar: Microbial pollution widespread but intensity varies depending on population density and/or the proximity to beach hotels, sewer outfalls, fish landing sites, storm water discharges, general surface runoff and ground water input
Major pollutants: Microbial
Major sources of above pollutants: Municipal wastewater discharged through streams and runoff, ground water input, sewer outfall, storm water drainage
Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Aesthetic/recreational: Microbial pollution affects aesthetic value (and suitability for swimming) of Zanzibar waters close to the harbour
How significant is this impact (high/medium/low): Low
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Yes
If "Yes" above, list potential mitigation/management measures: Wastewater management, including treatment of sewage, is critical in order to reduce microbial pollution

Hotspot (previously identified): Tanga municipality
Spatial scale (i.e. Is the entire area a hotspot or only specific regions in the area?): Tanga municipality: Microbial pollution widely spread but intensity varies depending on population density, storm water discharge, general surface runoff and ground water input
Major pollutants: Microbial
Major sources of above pollutants: Municipal wastewater discharged through streams and runoff, ground water input, storm water drainage

Impact on beneficial uses and sensitive ecosystems (i.e. beneficial uses = both existing and potential future uses): Aesthetic/recreational: Microbial pollution affects aesthetic value (and suitability from swimming) of Tanga waters close to the harbour
How significant is this impact (high/medium/low): Generally low
Do you still consider the above as a hotspot or potential hot spot (Yes/No): Unknown, owing to the absence of quantitative information
If "Yes" above, list potential mitigation/management measures: Wastewater management, including treatment of sewage, is critical in order to reduce microbial pollution; institution of best practices in use of agrochemicals; improvement in the handling of petroleum at unloading points; and control of shipping activities.

ANNEX 2: Criteria for the prioritisation of transboundary problems

LEVEL 1: Prioritisation of transboundary problems

Simple Rating Form:

	Severity	Scope	Overall rating
Problem 1			
Problem 2			
Problem 3			
Problem 4			
Problem 5			

Rating Criteria for Transboundary Problems

Severity - The level of damage to the WIO coastal and marine ecosystem that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

- Very High: Likely to destroy or eliminate part of the ecosystem.
- High: Likely to seriously degrade part of the ecosystem.
- Medium: Likely to moderately degrade part of the ecosystem.
- Limited: Likely to only slightly impair part of the ecosystem.

Scope - Most commonly defined spatially as the geographic scope of impact on the ecosystem integrity that can reasonably be expected within 10 years under current circumstances (i.e., given the continuation of the existing situation).

- Very High: Likely to be widespread or pervasive in its scope and affect the ecosystem throughout the WIO region.
- High: Likely to be widespread in its scope and affect the ecosystem in many parts of the WIO region.
- Medium: Likely to be localised in its scope and affect the ecosystem in some parts of the WIO region.
- Limited: Likely to be very localised in its scope and affect the ecosystem in limited parts of the WIO region.

LEVEL 2: Prioritisation of direct causes

Simple Rating Form

For each transboundary problem, list and rank the immediate causes, using the criteria below.

Problem 1

	Contribution VH, H, M, or L	Irreversibility VH, H, M, or L	Overall rating VH, H, M, or L
Direct Cause 1:			
Direct Cause 2			
Direct Cause 3			

Rating Criteria for Direct Causes:
Contribution - The expected contribution of the cause, acting alone, to the full expression of a threat (as determined in the threat assessment) under current circumstances (i.e. given the continuation of the existing management situation).

- Very High: The cause is a very large contributor of the particular problem.
- High: The cause is a large contributor of the particular problem.
- Medium: The cause is a moderate contributor of the particular problem.
- Limited: The cause is a limited contributor of the particular problem.

Irreversibility - The degree to which the effects of a cause of problem can be restored.

- Very High: The cause produces a problem that is not reversible (e.g., destruction of coral reefs due to unsustainable fishing practices).
- High: The cause produces a problem that is reversible, but not practically affordable (e.g. changed river flow due to damming).
- Medium: The cause produces a problem that is reversible with a reasonable commitment of resources (e.g. conversion of mangrove wetland into fish pond).
- Limited: The cause produces a problem that is easily reversible at relatively low cost (e.g. degenerated water quality due to wastewater discharge).

LEVEL 3: Combining ratings

Combining problems (level 1) and causes (level 2) ratings results in a combined rating using the threat matrix below.

		Cause			
		Very High	High	Medium	Limited
Problem	Very High	Very High	Very High	High	Medium
	High	High	High	Medium	Limited
	Medium	Medium	Medium	Limited	Limited
	Limited	Limited	Limited	Limited	Limited

APPLICATION: DEGRADATION OF WATER AND SEDIMENT QUALITY

Level 1: Prioritisation of transboundary problems

Problems	Severity	Scope	Overall rating
Microbial contamination	H	H	H
High suspended solids	H	H	H
Chemical pollution	M	L	L
Marine litter and debris	L	L	L
Eutrophication	L	L	L

Level 2: Prioritisation of direct causes

Microbial contamination

Direct Cause	Contribution	Reversibility	Overall rating
Disposal of untreated or under-treated municipal wastewater	VH	H	VH
Industries discharging untreated or under-treated industrial effluents	L	H	L
Waste from coastal mining and minerals (oil, gas, etc) exploration activities	L	H	L
Contaminated surface and sub-surface runoff (from municipal, industrial and agricultural areas, as well as from accidental spills)	H	H	M
River discharges transporting high suspended sediment loads (as a result of basin soil erosion) and/or transporting municipal/ industrial wastes and agrochemicals from catchment areas	M	H	M
Runoff from livestock rearing areas	L	H	L
Inadequate collection, treatment and disposal of solid waste in urban areas	L	H	L

High suspended solids

Direct Cause	Contribution	Reversibility	Overall rating
Disposal of untreated or under-treated municipal wastewater	M	H	H
Industries discharging untreated or under-treated industrial effluents	H	H	H
Dredging activities in ports and harbours	L	H	L
Waste from coastal mining and exploration activities	M	H	M
Contaminated surface and sub-surface runoff (from municipal, industrial and agricultural areas, as well as from accidental spills)	VH	H	VH
Destruction of coastal forests contributing to high suspended solid loads	M	H	M
River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchment areas	VH	H	VH
Waste products from aquaculture farms - high in nutrients and suspended solid loads	L	H	L

Marine litter

Direct Cause	Contribution	Reversibility	Overall rating
Contaminated surface and sub-surface runoff from municipal, industrial and agricultural areas, as well as from accidental spills)	M	M	M
River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchments	M	H	M
Inadequate collection, treatment and disposal of solid waste	H	H	H
Public littering on beaches and in areas where marine litter can be transported into coastal areas	H	H	H

Chemical pollution

Direct Cause	Contribution	Reversibility	Overall rating
Industries discharging untreated or under-treated industrial effluents	VH	H	VH
Dredging activities in ports and harbours	L	L	L
Waste from coastal mining and mineral (oil, gas, etc) exploration activities	L	L	L
Contaminated surface and sub-surface runoff (from municipal, industrial and agricultural areas, as well as from accidental spills)	H	H	H
River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/industrial waste and agrochemicals from catchment areas	H	L	M
Leaking of agrochemical (fertiliser and pesticide residues) from inadequate storage facilities, dumping or return-flows	L	L	L
Inadequate collection, treatment and disposal of solid waste in urban areas	L	L	L

Eutrophication

Direct Cause	Contribution	Reversibility	Overall rating
Disposal of untreated or under-treated municipal wastewater	H	H	H
Industries discharging untreated or under-treated industrial effluents	L	H	L
Waste from coastal mining and exploration activities	L	H	L
Contaminated surface and sub-surface runoff (e.g. from municipal, industrial and agricultural areas, as well as from accidental spills)	M	H	M
River discharges transporting high suspended sediment loads (due to soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchment areas	M	H	M
Leaking of agrochemical (fertiliser and pesticide residues) from storage facilities, dumping or return-flows	L	H	L
Runoff from livestock rearing areas	L	H	L

Level 3: Overall ranking

TRANSBOUNDARY PROBLEM					DIRECT CAUSE
Microbial contamination	Eutrophi-cation	Marine litter	Suspended solids	Chemical Pollution	
H	L		H		Disposal of untreated or under-treated municipal wastewater
L	L		H	L	Industries discharging untreated or under-treated industrial wastewater
			L	L	Dredging activities in ports and harbours
L	L		M	L	Waste from coastal mining and mineral (oil, gas, etc) exploration activities
M	L	L	H	L	Contaminated surface and sub-surface runoff (e.g. from municipal, industrial and agricultural areas, as well as from accidental spills)
			M		Destruction of coastal forests contributing to high suspended solid loads
M	L	L	H	L	River discharges transporting high suspended sediment loads (as a result of soil erosion) and/or transporting municipal/ industrial waste and agrochemicals from catchment areas
	L			L	Leaking of agrochemicals (fertiliser and pesticide residues) from inadequate storage facilities, dumping or return-flows
L	L				Runoff from livestock rearing areas
L		L		L	Inadequate collection, treatment and disposal of solid waste
		L			Public littering on beaches and in areas where litter can be transported into coastal areas
			L		Waste products from aquaculture farms that are high in nutrients and suspended solid loads

Key: L: Limited M: Medium H: High VH: Very High

ANNEX 3: Comparison of data from national monitoring programmes in the WIO region

INTRODUCTION

In order to assess the status of marine pollution in the Western Indian Ocean (WIO) region, national monitoring programmes funded by the WIO-LaB project were implemented in most participating countries in 2007 and 2008.

This document synthesises the data generated and compares the results from the different countries. National reports providing more detailed and contextualised analyses of results from the monitoring programmes were compiled by each of the participating countries, and can be accessed at http://www.wiolab.org/. Information gained from the monitoring programmes was used in the validation of previously designated marine pollution hotspots in the WIO, and allowed their classification into categories during the 4th meeting of the Regional Working Group on Water, Sediment and Biota Quality Monitoring and Assessment in the WIO region (held in Dar es Salaam, Tanzania on 23-25 June 2009). The information also assisted in the identification of priority parameters to include in a long-term monitoring programme for the WIO region.

MATERIALS AND METHODS

Descriptions of the different hotspots monitored and the locations of study sites are given in relevant national reports, together with the field and analytical methods used (http://www.wiolab.org/). Sampling was conducted during 2007 and 2008 for all WIO-LaB funded programmes. Data from South Africa are courtesy of eThekwini Municipality Water and Sanitation Department and were from sampling conducted as part of outfalls monitoring programmes in 2006, 2007 and 2008. Most studies, in addition to sampling test stations at potential hotspot sites, included reference (or control) stations in their sampling strategies to allow some comparison with data from nearby uncontaminated areas. This has been accounted for in this regional-level comparison.

A generic approach to developing WIO-LaB national monitoring programmes was discussed and accepted at earlier meetings of the Regional Working Group on Water, Sediment and Biota Quality Monitoring and Assessment. The aim was to adopt a uniform approach to ensure consistency in parameters monitored and results generated so that the data would be comparable. Complete uniformity was, however, not achievable due to financial and logistical constraints and differences in equipment available and analytical methods used. Final datasets were therefore inconsistent in terms of sets of parameters monitored at different sites and in different countries. For the purposes of this document, comparison of results was limited to parameters where sufficient data had been generated for two or more countries.

Differences in analytical methods will account for some of the variability in the results from different countries. Acids used in the digestion of samples for metal analysis, for example, differ in their efficiency of extraction. Natural differences in results could also be expected because of the range of different water bodies and habitats sampled. For example, dissolved oxygen, pH, nutrients and a range of other parameters in semi-enclosed (and freshwater-influenced) creeks and bays will differ naturally from open marine waters.

Potential seasonal influences were recognised in the early stages of developing a generic monitoring strategy. Financial and logistical constraints however, prevented the collection of seasonal data in all of the monitoring programmes. This precluded any analysis of seasonal trends in this regional assessment. However, in most cases samples were collected on more than one occasion, so data are representative of some degree of temporal variability at different sampling sites.

Data are presented in graphical and tabular format in this report. Selected parameters are shown as bar charts with standard errors to indicate a measure of variability in the data (test station, or hotspot data only). Tables giving average values for different parameters in participating WIO countries are also given (both test-station and control-station data) .

Environmental Quality Guidelines (EQGs) for a range of parameters have been suggested for the WIO region[1]. Where appropriate, data returned from the monitoring programmes and presented here were compared with the relevant WIO EQG.

RESULTS AND DISCUSSION

A total of 4734 measurements (from test and control sites) are included in this assessment as indicated in Table 1. Physico-chemical parameters included properties such as water temperature, pH, dissolved oxygen, total suspended solids, biological oxygen demand and chlorophyll-a. A variety of microbiological parameters was measured in different countries. Nutrient measurements included nitrite, nitrate, and phosphate. Ammonia can be regarded as a toxic substance, and is included here separately from nutrients. Metals and organic compounds (also toxic substance) were monitored in sediments and included an array of different forms.

Table 1 **Numbers of measurements made of different parameters sampled in participating WIO countries**

	Sampling media	Kenya	Madagascar	Mauritius	Seychelles	South Africa	Tanzania
Physico-chemical	Water	255	196	248	48	132	151
Microbiology	Water	53	31	216	20		85
Nutrients	Water	68	92	98	18	18	60
Ammonia	Water	31	10	2	6	22	26
Metals	Sediment	105	296		43	1760	34
Organics	Sediment				28	570	12

Water quality: physico-chemistry

Average values for physico-chemical parameters measured in waters of the participating WIO countries are given in Table 2 at the end of this Annex and selected parameters are plotted in Figure 1. Establishing Environmental Quality Guidelines (EQGs) for physico-chemical parameters in the WIO region will require the collation of data from appropriate reference systems, so no specific values could be used to assess the results presented here.

Biological oxygen demand and chlorophyll-a were not widely measured, with only Kenya and Tanzania including them in their monitoring programmes. Dissolved oxygen concentrations were low in Madagascar and Seychelles compared to other countries (especially Kenya and Mauritius, Figure 1a). This was true at test stations as well as control stations (Table 2). pH varied insignificantly amongst countries (Figure 1b). Total suspended solids we very high in Madagascan waters (at both control and test stations) compared to elsewhere (Figure 1c). Surprisingly, the highest mean turbidity was measured in the Seychelles (Figure 1d) although this was heavily influence by readings from a single station at a hotspot, and does not reflect the typical situation.

[1] UNITED NATIONS ENVIRONMENT PROGRAMME/NAIROBI CONVENTION SECRETARIAT and CSIR (2009). Guidelines for the Establishment of Environmental Quality Objectives and Targets in the Coastal Zone of the Western Indian Ocean (WIO) Region. WIO-LaB Technical Report Series No. 01/2009, United Nations Environment Programme, Kenya, Nairobi. 146 pp.

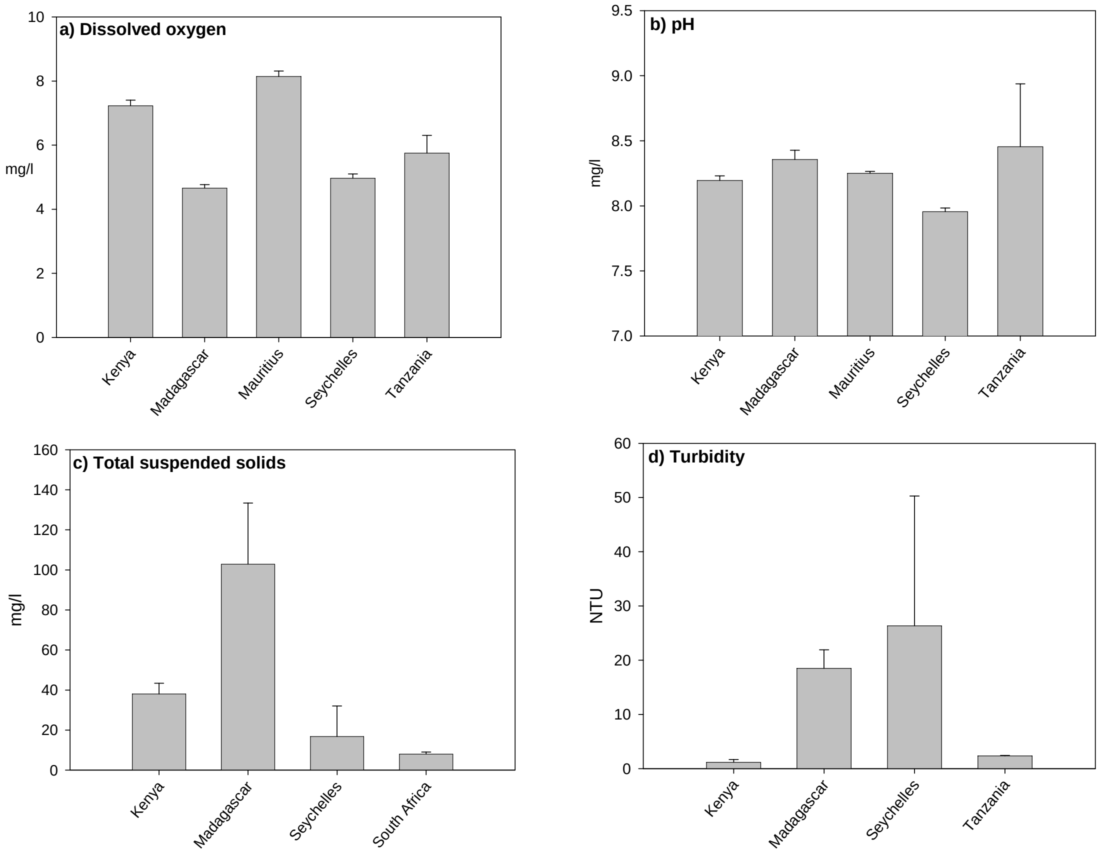

Figure 1 **Selected physico-chemical parameters (mean + SE) measured in waters at test stations from participating WIO countries**

Water quality: microbiology

Average values for microbiological indicators measured in waters of the participating WIO countries are listed in Table 3 at the end of this Annex and selected indicators are plotted in Figure 2. Environmental Quality Guidelines (EQGs) for microbiological indicators in the WIO region are expressed in terms of 95th percentile compliance with levels of Enterococci. This requires much larger datasets than those available from the monitoring programmes conducted, so no comparison with WIO EQGs is presented here.

Escherichia coli levels were measured in four countries; Kenya, Madagascar, Seychelles and Tanzania. Surprisingly, in Tanzania, control stations returned higher average *E. coli* counts than did the test stations at the hotspot sites (Table 3). This was attributed to the proximity of a hotel or the influence of river runoff. *E. coli* levels in Tanzania were much lower than those reported from other counties' hotspot stations (Figure 2a). This trend was not carried through in faecal coliform counts, which were high in Tanzania compared to Mauritius and Kenya (Figure 2b). Total coliforms were the most widely measured microbiological indicator and were highest in Madagascar and the Seychelles.

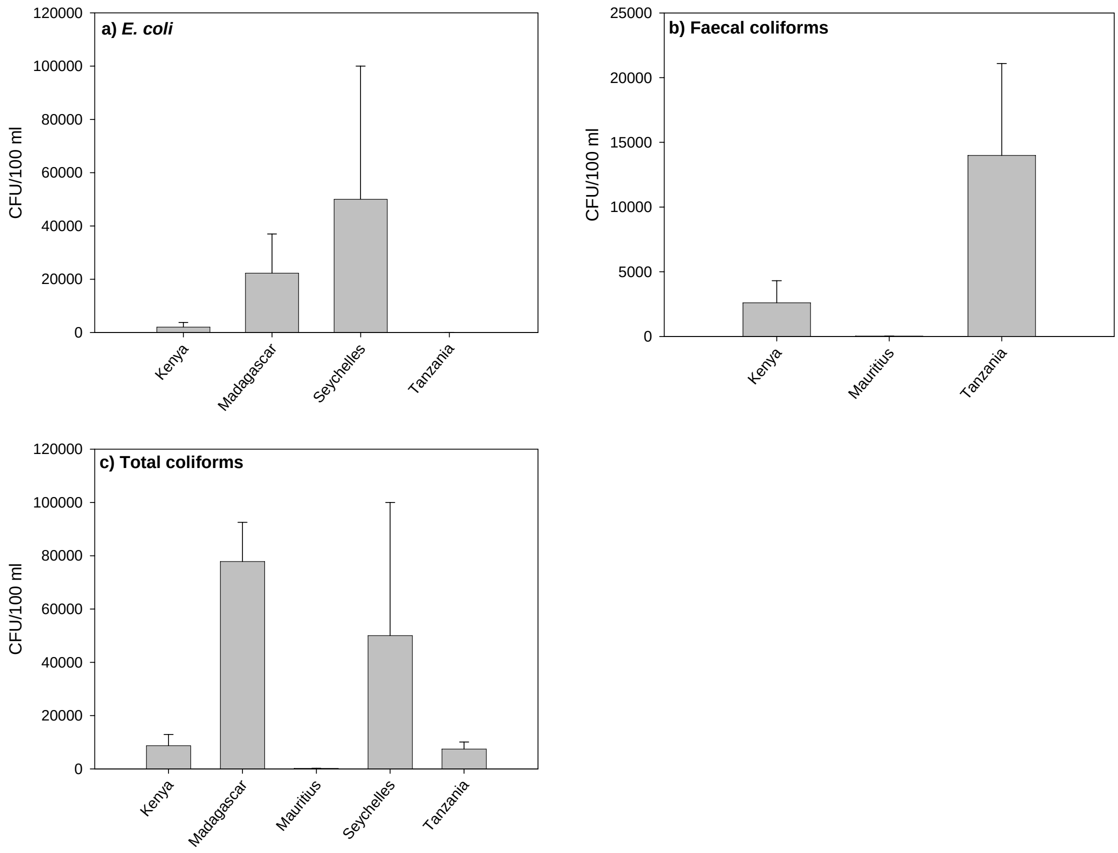

Figure 2 Selected microbiological indicators (mean + SE) measured in waters at test stations from participating WIO countries

Water quality: nutrients

Average values for nutrient parameters measured in waters of the participating WIO countries are given in Table 4 at the end of this Annex and selected parameters are plotted in Figure 3a-c. Establishing Environmental Quality Guidelines for nutrients in the WIO region will require the collation of data from appropriate reference systems, so no specific values could be used to assess results presented here.

Nitrogenous nutrient levels were highest in Madagascar, where results from both test and control stations were orders of magnitude higher than measured elsewhere (Table 4, Figure 3a and 3b). Phosphates were, on average, highest in Mauritius, although very high levels were reported from Madagascar (Figure 3c).

Water quality: toxic substances - ammonia

Average values for ammonia measured in waters of the participating WIO countries are given in Table 4 and selected parameters are plotted in Figure 3d. The suggested EQG for ammonia in the WIO region is 910 µg/l.

Ammonia levels were highest in Madagascar (along with other nitrogen-based parameters, see above, Figure 3d). Low levels were reported from Kenya, Seychelles, South Africa and Tanzania. All the concentrations measured were below the suggested EQG of 910 µg/l.

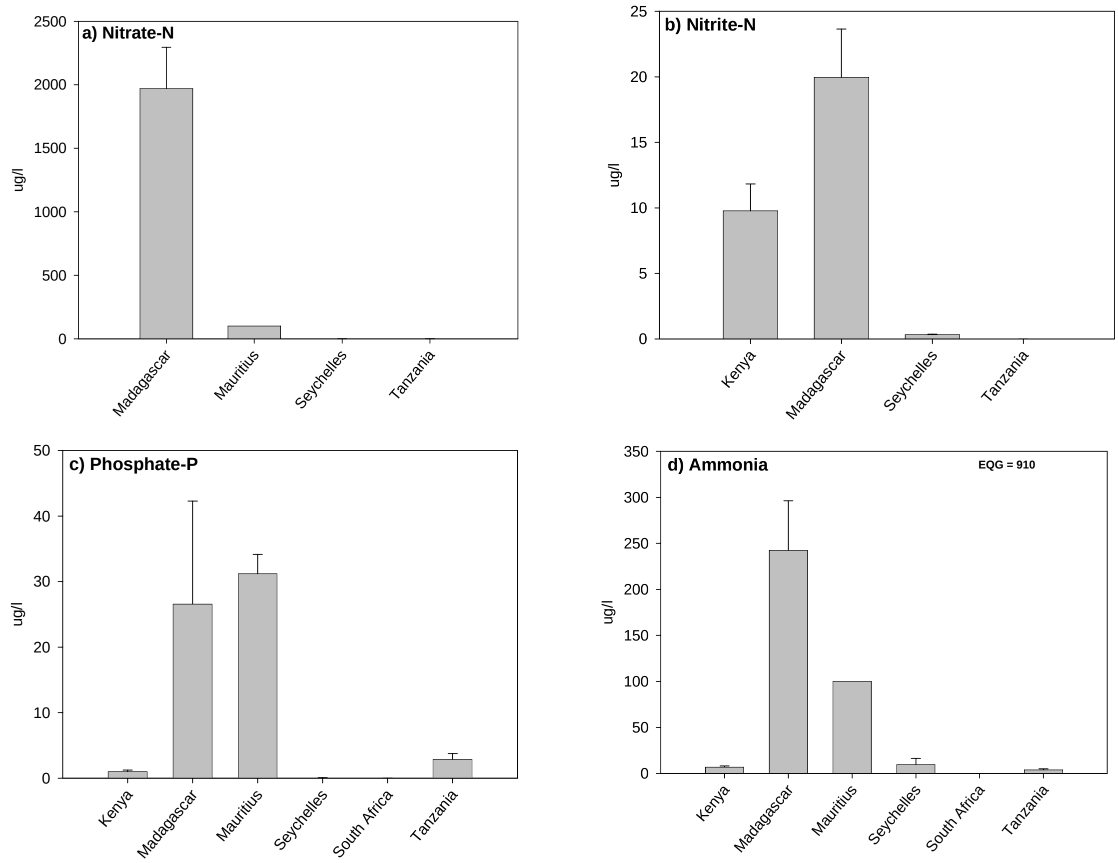

Figure 3 **Selected nutrient parameters and toxic substances in water (ammonia) (mean + SE) measured at test stations from participating WIO countries**

Sediment quality: toxic substances - trace metals

Average values for trace metals measured in sediments of the participating WIO countries are given in Table 5 at the end of this report section and selected parameters are plotted in Figure 4a to 4i. WIO EQGs have been suggested for most of these trace metals and are indicated on the plots where appropriate.

Comparison of levels of trace metals in sediments from different participating WIO countries is not possible without sediment granulometric data, or a normalising element (such as aluminium or iron) that can be consistently applied. That said, concentrations of trace metals recorded in sediments were consistently high in Madagascar and Tanzania, compared to other WIO countries (Figure 4, Table 5). Madagascar and Tanzania were the only countries with average metal concentrations higher that the suggested WIO EQGs, in many cases markedly so (Figure 4).

Sediment quality: toxic substances – organic parameters

Average values for organic parameters measured in sediments of the participating WIO countries are given in Table 5 at the end of this Annex and selected parameters are plotted in Figure 4j to 4l. Where WIO EQGs for organic parameters have been suggested, these are indicated on the plots. Levels of dieldrin, lindane and total DDT were similar in Seychelles and South Africa, while in Tanzania much lower levels were reported. In all cases the levels were below the relevant EQG.

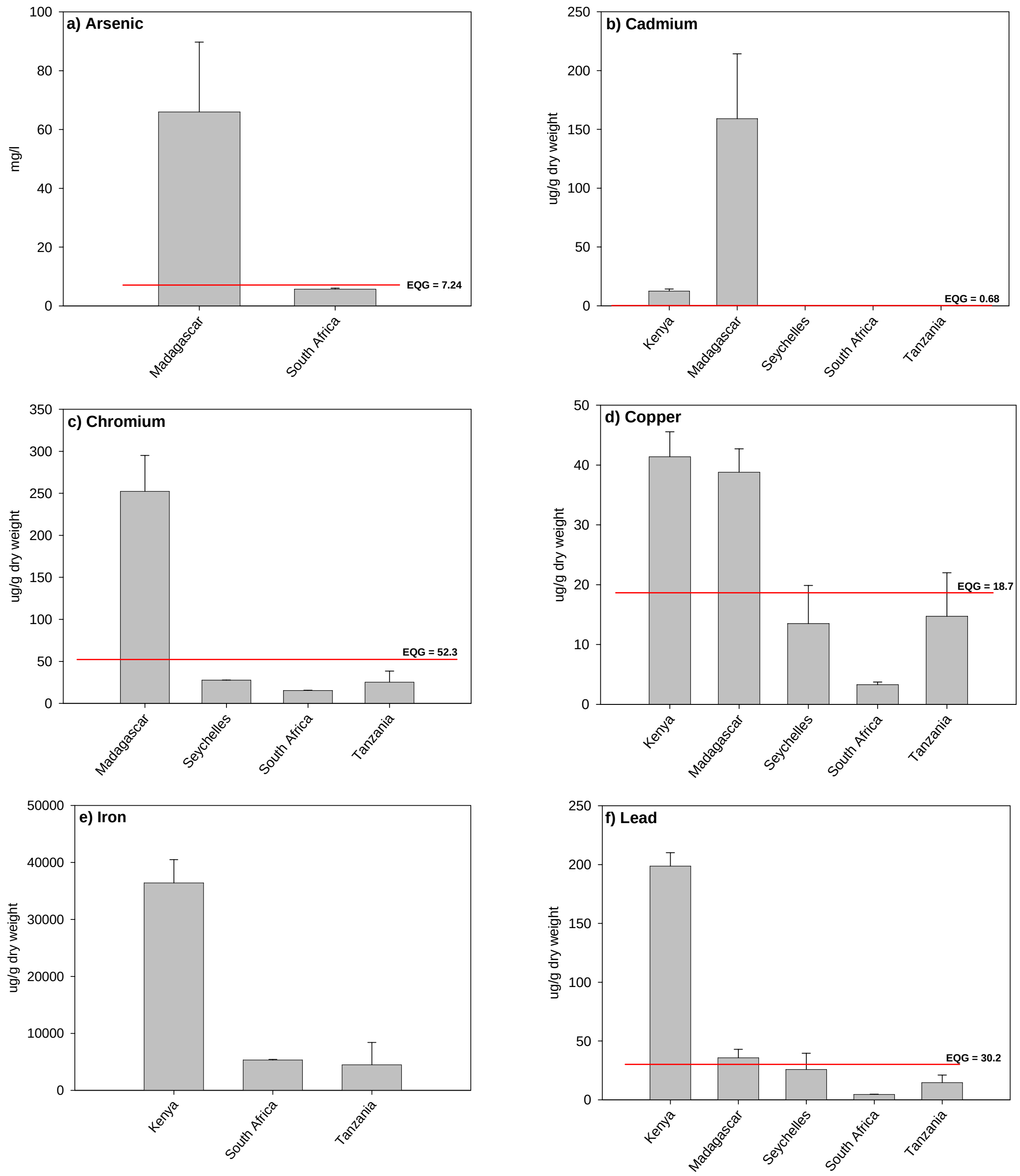

Figure 4 **Selected toxic substances in sediments (trace metals and organics) (mean + SE) measured at test stations from participating WIO countries (*continued on next page*)**

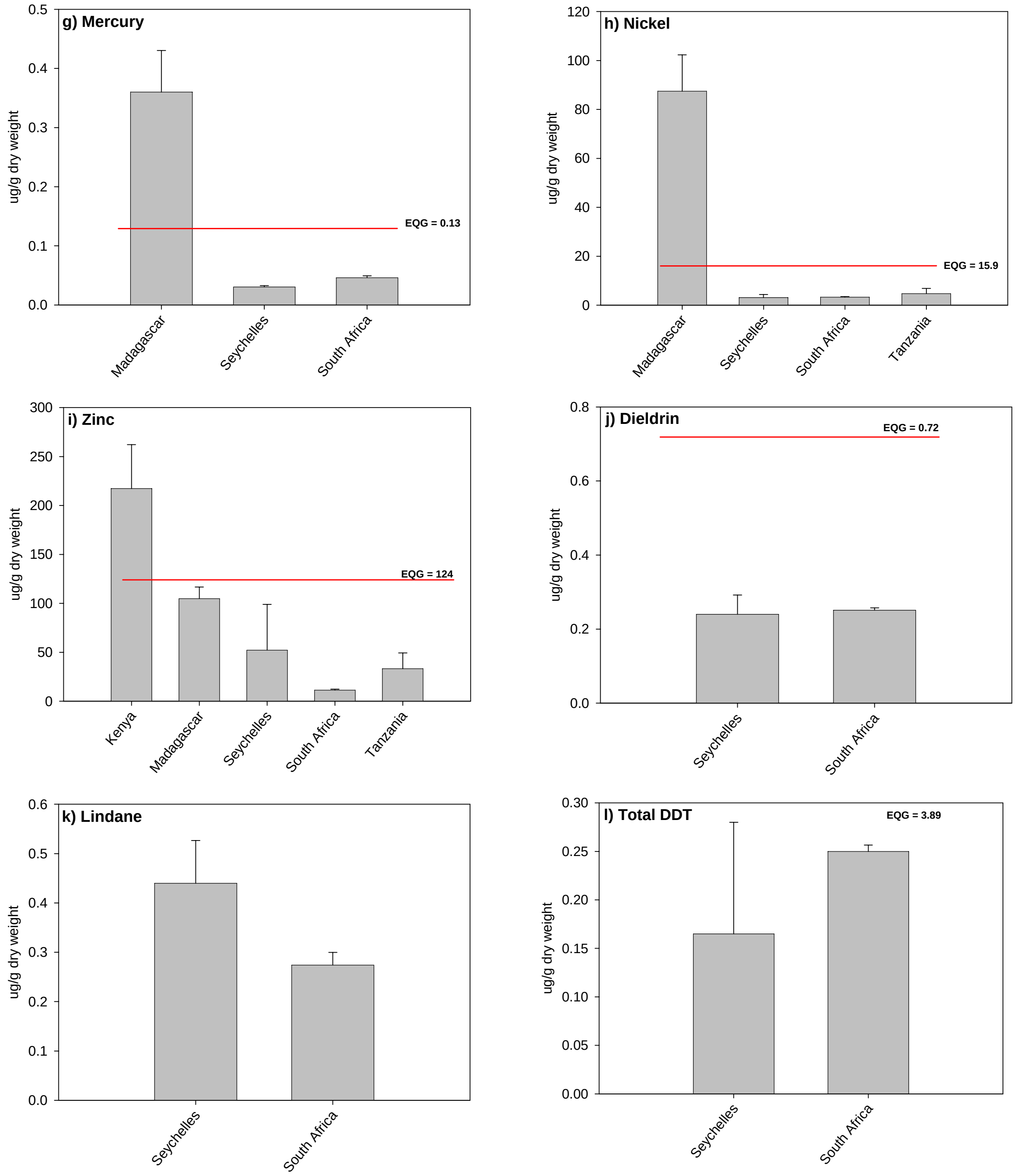

Figure 4 **Selected toxic substances in sediments (trace metals and organics) (mean + SE) measured at test stations from participating WIO countries (*continued from previous page*)**

Table 2 Average values for physico-chemical parameters measured in waters in WIO-LaB monitoring programmes

Parameter	Country	Mean (control stations)	Mean (test stations)
BOD (mg/l)	Kenya		1.50
	Tanzania	2.20	3.39
Chlorophyll-a (mg/l)	Kenya	11.45	40.92
	Tanzania	0.25	-
COD (mg/l)	Madagascar	36.35	76.19
	Mauritius	-	0.80
	South Africa	0.8	0.82
Dissolved Oxygen (mg/l)	Kenya	-	7.23
	Madagascar	4.92	4.66
	Mauritius		8.14
	Seychelles	4.60	4.97
	Tanzania	6.86	5.75
pH	Kenya	7.31	8.20
	Madagascar	8.30	8.36
	Mauritius	-	8.25
	Seychelles	7.82	7.96
	Tanzania	7.65	8.07
Salinity	Kenya	29.10	26.99
	Madagascar	28.00	30.35
	Mauritius	-	33.43
	Seychelles	33.10	33.38
Temperature (°C)	Kenya	28.11	28.90
	Madagascar	29.53	29.31
	Mauritius	-	27.00
	Seychelles	28.05	28.23
Total suspended solids (mg/l)	Kenya	86.03	38.05
	Madagascar	181.00	102.80
	Seychelles	1.00	16.83
	South Africa	6.00	8.00
Turbidity (NTU)	Kenya	-	1.18
	Madagascar	13.24	18.49
	Seychelles	1.00	26.33

Table 3 Average values for microbiological parameters measured in waters in WIO-LaB monitoring programmes

Parameter	Country	Mean (control stations)	Mean (test stations)
E. coli	Kenya	23.5	2011.1
	Madagascar	5.0	22227.4
	Seychelles	2.5	50003.0
	Tanzania	38.5	8.1
Enterococci	Madagascar	15.0	22248.0
	Seychelles	12.5	50000.5
Faecal coliforms	Kenya	33.3	2605.8
	Mauritius	-	38.0
	Tanzania	12.5	13995.0
Salmonella	Seychelles	0	0
	Tanzania	97.6	350.0
Staphylococcus aureas	Seychelles	<1 - TNTC	<1 - TNTC
	Tanzania	-	34.3
Total coliforms	Kenya	43.5	8650.2
	Madagascar	50004.5	77783.0
	Mauritius	-	167.3
	Seychelles	9	50012.5
	Tanzania	21.7	7406.6

Table 4 Average values for nutrient parameters and ammonia measured in waters in WIO-LaB monitoring programmes

Parameter	Country	Mean (control stations)	Mean (test stations)
Ammonia (µg/l)	Kenya	5.95	6.82
	Madagascar	109.97	242.46
	Mauritius		<100.00
	Seychelles	1.21	9.51
	South Africa	0.03	0.02
	Tanzania	0.25	3.86
Nitrate-N (µg/l)	Madagascar	1106.36	1970.33
	Mauritius		<100.00
	Seychelles	0.65	0.41
	Tanzania	0.01	0.11
Nitrite-N (µg/l)	Kenya	4.48	9.77
	Madagascar	11.23	19.96
	Seychelles	0.11	0.33
	Tanzania	0.10	0.10
Phosphate-P (µg/l)	Kenya	0.29	1.00
	Madagascar	21.41	26.55
	Mauritius	-	31.20
	Seychelles	0.08	0.06
	South Africa	<0.01	0.01
	Tanzania	0.19	2.87
Ammonia (µg/l)	Kenya	5.95	6.82
	Madagascar	109.97	242.46
	Mauritius		<100.00
	Seychelles	1.21	9.51
	South Africa	0.03	0.02
	Tanzania	0.25	3.86

Table 5 Average values for selected trace metal and organic parameters in sediments measured in WIO-LaB monitoring programmes

Parameter	Country	Mean (control stations)	Mean (test stations)
Arsenic (µg/g dw)	Madagascar	49.03	65.96
	South Africa	7.67	5.73
Cadmium (µg/g dw)	Kenya	-	12.56
	Madagascar	252.68	159.05
	Seychelles	0.11	0.11
	South Africa	0.08	0.13
	Tanzania	0.10	0.06
Chromium (µg/g dw)	Madagascar	137.80	252.29
	Seychelles	26.30	27.77
	South Africa	17.14	15.35
	Tanzania	10.86	25.21
Copper (µg/g dw)	Kenya	-	41.39
	Madagascar	2372.10	38.79
	Seychelles	2.92	13.50
	South Africa	2.50	3.29
	Tanzania	22.95	14.72
Iron (µg/g dw)	Kenya	-	36406.48
	South Africa	5935.17	5339.86
	Tanzania	165.33	4497.11
Lead (µg/g dw)	Kenya	-	198.78
	Madagascar	10.49	35.76
	Seychelles	2.43	25.85
	South Africa	5.54	4.56
	Tanzania	5.31	14.72
Manganese (µg/g dw)	Kenya	-	589.40
	Madagascar	411.13	565.37
Mercury (µg/g dw)	Madagascar	0.19	0.36
	Seychelles	<0.01	0.03
	South Africa	0.03	0.05
Nickel (µg/g dw)	Madagascar	58.75	87.46
	Seychelles	0.32	3.13
	South Africa	4.44	3.29
	Tanzania	6.09	4.74
Zinc (µg/g dw)	Kenya	-	217.29
	Madagascar	53.79	104.74
	Seychelles	2.79	52.27
	South Africa	9.81	11.35
	Tanzania	14.09	33.16
Dieldrin (µg/g dw)	Seychelles	0.05	0.24
	South Africa	0.25	0.25
	Tanzania	<0.01	<0.01
Lindane (µg/g dw)	Seychelles	0.89	0.44
	South Africa	0.25	0.27
Total DDT (µg/g dw)	Seychelles	0.07	0.17
	South Africa	0.25	0.25
	Tanzania	<0.01	<0.01

SYNTHESIS - COMPLIANCE WITH EQGS SUGGESTED FOR THE WIO

Percentage compliance of all results (test and control stations) generated with appropriate EQGs suggested for the WIO is presented in Table 6. All ammonia concentrations measured in WIO waters were within the suggested guideline level. However, analysis of sediments returned concentrations of numerous trace metals that did not comply with relevant guidelines. The most frequent non-compliance of sediment trace metals was reported from Madagascar and Kenya, and included a wide array of elements. Over 30% of arsenic measurements were found to be above the WIO suggested EQG. However, closer analysis of the data from Madagascar and South Africa indicated that similar percentage compliance was reported from test and control stations. South African data have been analysed using aluminium normalised baseline models and found not to be representative of enrichment. This suggests that levels reported here might not be indicative of pollution at these sites. As noted above, without compensating for mineralogic and granulometric factors meaningful interpretation of sediment metal concentrations is not possible. This should be addressed once larger dataset have been developed, but it is important that suitable normalisers (or reference elements) are measured in monitoring programmes.

Table 6 Percentage compliance of selected parameters with Environmental Quality Guidelines suggested for the West Indian Ocean (- = no data). Compliance < 75% highlighted

Country	Ammonia	Arsenic	Cadmium	Chromium	Copper	Lead	Manganese	Mercury	Nickel	Zinc	Dieldrin	Total DDT
Kenya	100	-	0	-	10	0	100	100	-	30	-	-
Madagascar	100	60	0	20	17	71	100	26	16	65	-	-
Mauritius	-	-	-	-	-	-	-	-	-	-	-	-
Seychelles	100	-	100	100	67	67	-	100	100	80	100	100
South Africa	100	68	97	99	99	100	-	98	99	100	100	100
Tanzania	100	-	100	80	40	100	-	-	100	100	100	100
All WIO data	100	67	83	88	79	87	100	87	88	89	92	100

ACKNOWLEDGMENTS

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