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The Use of Nuclear and Isotopic Applications to Address Specific Coastal Zone Management Problems

Thomas TISUE
IAEA CONSULTING EXPERT
Environmental & Analytical Chemistry
International Technical Cooperation
60304 Oak Park, Illinois, USA

International Atomic Energy Agency

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

This thematic plan for the use of nuclear and isotopic techniques to address coastal zone management problems is a summation of discussions and recommendations put forth by a group of national and international experts on coastal zone management. This document provides strategic guidance and direction on how and where isotopic techniques can most effectively be utilized to address specific coastal zone problems.

The management focus for addressing marine issues is shifting to the coastal zone where impacts on sustainable development are greatest. Coastal ecosystems account for most goods and services and are a cornerstone for the ecological health of the marine environment. However the quality of this resource is unquestionably declining largely due to the processes of human cultural and economic development. For a long time, the situation was compounded by the fact that even though the problems are global, the priority issues vary from region to region. However, in the last few years there has been a marked effort to respond to these global problems on a regional basis and there are numerous national, regional and international legal and regulatory frameworks driving this concerted response to coastal zone management problems.

One of the most important problems facing coastal waters relates to the phenomena commonly known as "red tides" or "harmful algal blooms" or HABs, which have a wide array of economic impact on the fishing, seafood industry and tourism. The growing incidence of HABs related problems has created the need for a more rapid, sensitive and inexpensive assay rather than the mouse bioassay technique, which is not sensitive to low toxin concentrations or is faced with animal rights issues. The working group agreed that nuclear technologies and in particular the receptor binding assay or RBA certainly had a role to play in circumventing these problems. Although like the animal bioassay, the RBA provides an estimate of the integrated toxic potency of a sample, it has other advantages such as limited equipment costs, ability to work with crude extracts, greater sensitivity, large sample throughput and cost advantages per sample analyzed.

The working group on coastal management issues (other than HABS) identified phenomena to which nuclear techniques could make important contributions. These include studying contaminant biogeochemistry, ecosystem health, living marine resources, non-living marine resources and public safety issues. The experts concluded that although there are alternative techniques for studying organic and bioorganic contaminant uptake, the nuclear approach is rapid, mature, easily transferable to developing countries, and sustainable (although expensive). Nuclear techniques were felt to have a unique role for determining high-resolution chronologies of coastal sediments and could play a significant role in creating understanding about eutrophication and organic matter sources. They can also be used to determine habitat modification and loss resulting from submarine groundwater discharge or saltwater intrusion due to utilization of freshwater resources or mineral extraction activities adjacent to coastal zones.

The abundance of living marine resources can be affected by many factors some of which may be addressed using nuclear approaches. Some key areas identified include knowledge of fish population dynamics, stock segregation and migration and effects of mariculture. However, the working group concluded that although there is certainly a role for nuclear isotopic techniques, they do not have any distinct advantage over non-nuclear techniques. Further R&D is required in many cases.

The IAEA certainly has some comparative advantages in addressing some CZM issues. These include unique tools and techniques, facilities for research and technical capacities that are unique in the UN system, a relatively predictable funding base for implementing TC projects and a proven approach to the management of technology transfer. The IAEA brings not only unique tools and techniques but also a demonstrated capacity to the identification of problems, determination of causes, development of solutions and resolving of the barriers that may hinder the application of those solutions. As a generator of data and information, the IAEA has broad experience in the field of coastal and marine information management (acquisition, analysis, storage, retrieval, interpretation and application), which is invaluable to developing countries in the planning, and management of their coastal resources.

One of the weakest links in the process of integrated planning and management of coastal resources is the enforcement of regulatory mechanisms, in particular those that address the discharge of contaminants. IAEA can transfer techniques that make it possible to trace contaminants to their original source, as well as to predict the ultimate fate and impact of a particular discharge. This task, which is a requirement for legal proceedings, is comparatively simple in the case of known point sources. The IAEA may also be able to assist in the case of non-point sources, which are virtually impossible to characterize with other techniques.

A key limitation is that the IAEA is a technical organization and will therefore not normally seek to lead CZM initiatives. Rather, it will work to fill gaps in overall programmes by helping coastal zone managers in Member States meet specifically identified needs. The absence of IAEA representation at country level through which it can deliver its technical assistance can be a limitation. A possible disadvantage is that the "gateway" for IAEA technical co-operation in its Member States is normally the national nuclear authority or the Ministry of Science and Technology. These national focal points may not have knowledge of coastal zone issues, national programmes on that topic, or the level of priority they merit.

The experts recommended that the IAEA should consider broadening its scope of CZM to include "integrated" coastal zone planning and management so as to create other opportunities for the Agency to apply its capabilities beyond the sphere of its traditional comparative advantage. The IAEA can begin in the finite areas where it can clearly make a contribution now, and then seek to build upon this gradually in the future in support of the integrated approach.

The group also recommended that the IAEA should initiate consultations with Member States with severe HAB problems and conduct further assessments of HAB problems, socio-economic impacts and strategy for IAEA implementation in co-operation with UNESCO/IOC HABs programme where appropriate. The IAEA could also play a catalytic role to develop comprehensive plans for certification process, respective roles and responsibilities as well as to discuss other components for improving the enabling environment in collaboration with NOAA, USFDA, EU, FAO. The IAEA should explore potential for joint training activities with UNESCO/IOC HABs effort where appropriate via their regional HABs programmes. Workshop participants viewed it as imperative that the IAEA get the message out that nuclear approaches exist which have high applicability to solving ICZM problems.

In conclusion, the group agreed that nuclear techniques certainly have a key role in CZM problems, but crucial to the IAEA activities are partnerships particularly with those organizations that have already extensive experience in the sector.

1.0 DEVELOPMENT NEED

1.1 PROBLEM CHALLENGES

Many challenges face IAEA Member States in the 21st century, but managing ocean resources is particularly vexing. Ocean resources are vast but finite; a growing human population places ever-increasing demands on them. The problem is especially compelling because the quality of ocean resources is unquestionably declining. And the quality of this resource is a cornerstone of life on earth. The rate of the decline defies conventional solutions. Current institutions struggle even to comprehend the problems, much less to mitigate them. The status of the oceans is intertwined with human cultural evolution and economic development, especially the processes of industrialisation and globalization. Sound ocean resource management calls for application of the human values of good stewardship and responsible collective action.

The coastal zone---sometimes called the land-ocean margin---is a common resource shared by a majority of the sovereign states of the world. This zone is characterized by constant fluxes of matter, energy and life forms; it is in fact a globally interconnected set of ecological subsystems. Most member states have experienced depletion of this resource, but their strategies (and investments) to date have often tended to focus on defining problems rather than attacking their root causes. Many nations are now faced with an urgent need to take the next step.

1.2 RATIONALE FOR THEMATIC PLANNING

Member States increasingly recognize that developing the strategies and tools to preserve coastal zone resources poses both technical and institutional challenges. Collection and analysis of the data needed for making informed decisions is a key factor in sound resource management. Nuclear technologies have already demonstrated clear advantages in meeting some of coastal oceanography's information needs. The thematic planning meeting of 5-9 November 2001 culminated in proposals for expanding the IAEA's role in transferring these technologies to developing Member States. The meeting identified several techniques that can bring immediate benefits; in other cases, the impact will be felt over the longer term.

The following thematic plan outlines an approach the IAEA can take for addressing Member States' needs in coastal zone management. The plan lays out the problems, possible solutions, a programme development strategy and follow-up actions. Owing to the planning exercise, the Agency has far more specific information in hand---and to come---on Member States developmental and technical needs in this field. This knowledge will also prove valuable when the Agency begins to prepare its new programme of activities on Marine and Terrestrial Protection, scheduled to begin during the biennial Regular Programme for 2003-2004.

2.0 SETTING THE CONTEXT FOR CZM

2.1 ISSUES

The management focus for addressing marine issues is shifting to the coastal zone, where impacts on sustainable human development are greatest. Coastal ecosystems account for the most goods and services, and are a cornerstone for the ecological health of the marine environment. Recognition of these facts under girds concerns about the growing threats to coastal zones.

A recent World Bank publication, *Towards An Environment Strategy for the World Bank* (April 2000), suggests that

> "…the main constraints on the ability of coastal ecosystems to provide goods and services include habitat loss or conversion (such as coastal urbanization); over-exploitation (due to huge over-capacity fishing in commercial fishing fleets, and damaging extraction methods); pollution from land-based activities (toxic effluents, nutrient loading, and sediments); and on a longer time-scale, climate change."

While the problems are global, coastal zone priority issues vary from region to region. For example, in Latin America the Inter-American Development Bank (IDB) has suggested that the main CZM issues are:

- land use and resource allocation conflicts in the coastal zones;
- degradation of coastal ecosystems;

- depletion of commercial fisheries stocks;
- declining coastal water quality from land-based sources; and
- increasing coastal erosion, flooding, and shoreline instability.

The World Bank publication, *Africa: A Framework for Integrated Coastal Zone Management,* highlights the main issues in Africa. It underlines regional variability by stating, "While many of the problems overlap in the two regions (West Africa and East Africa), the magnitude of the problems may differ relative to one another." The major issues, listed in order of priority in each region, are:

<u>West Africa</u>

- deteriorating water quality and sanitation in urban areas and associated impacts on environment and public health;
- pollution of coastal waters;
- coastal erosion; and
- over-exploitation and degradation of marine resources.

<u>East Africa</u>

- destructive fishing methods and associated habitat degradation;
- eutrophication and siltation of coastal waters; and
- marine oil pollution from tanker traffic and ballast discharge.

In 2000, the World Resources Institute (WRI) completed the Coastal Ecosystems component of its Pilot Analysis of Global Ecosystems (PAGE) programme. The PAGE programme focused on the goods and services that the coastal zone can provide. The report notes that the "goods from marine and coastal habitats include food for humans and animals (including fish, shellfish, krill, and seaweed); salt; minerals and oil resources; construction materials (sand, rock, coral, lime and wood); and biodiversity including genetic stock that has potential for various biotechnology and medicinal applications".

Coastal ecosystems also perform valuable functions, which, though less readily quantified, are nonetheless invaluable to human society and to life on earth. These include shoreline protection (protecting the coastline from storms and erosion from wind and waves); storing and cycling nutrients; sustaining biodiversity; maintaining water quality (by filtering and degrading pollutants); and serving as areas for recreation and tourism. The PAGE analysis denotes five categories of goods and services derived from coastal ecosystems, including:

- shoreline stabilization;
- water quality;
- biodiversity;
- food production; and
- tourism and recreation.

The UNESCO/IOC Global Oceanographic Observation System's coastal component, Coastal GOOS, is closely related to the PAGE programme. The coastal GOOS is developing an observation system for the coastal zone that will provide essential information to coastal zone managers. It will also identify critical data requirements for decision-making, especially gaps that need to be filled.

One challenge to IAEA's thematic planning process has been identifying specific technology/problem linkages. As background to the thematic planning meeting, the IAEA commissioned two assessments. The first, *Use of Nuclear and Isotopic Techniques to Address Coastal Zone Management Problems*, provides an overall framework. The second focuses on *Use of Nuclear and Isotopic Techniques to Address Aspects of Harmful Algal Bloom Problems*. These documents are available on request.

These two papers suggested the following problem categories: fisheries, contaminants, eutrophication, groundwater, wetlands and harmful algal blooms. However, the participants at the Thematic Planning Meeting suggested using a slightly revised classification based on the Coastal GOOS categories:

- public health;
- ecosystem health;
- living resources;
- non-living resources; and
- hazards.

The challenges are 1) to determine the relative importance of these problems to Member States (particularly in socio-economic terms); 2) to define the strategic value of nuclear and isotopic tools in solving them; and 3) to develop a programmatic response.

2.2 GENERAL TRENDS

The following factors set the context for considering coastal zone issues:

- world population is rising, particularly in the coastal areas developing countries; in 1995 2.2 billion people, 39% of the world's population, lived within 100 km of a coast, up from 2 billion in 1990;
- sub-tropical and tropical nations are increasingly dependent on the coastal zone as a primary food source (both mariculture and agriculture), as well as on other coastal resources;
- concurrently, latest estimates show sobering decreases in natural fisheries, while mariculture is rapidly growing;
- rising levels of pollution, primarily from land based sources, are threatening or actually damaging coastal resources;
- the legal and regulatory framework for protecting coastal resources is not as developed as for terrestrial resources, although efforts at improvements are underway;
- there are tremendous gaps in the data needed to understand causes and effects; to develop mitigation strategies; and to initiate responses;
- the focus of both scientific inquiry and management is shifting to those areas with the most socio-economic importance, i.e., from the open ocean to coastal issues; and
- there is increasing realization that coastal issues often require transboundary co-operation, and that protection and mitigation require an ecosystem approach.

2.3 CURRENT RESPONSES (PROGRAMMES, INSTITUTIONAL FRAMEWORKS ETC.)

In the past, most coastal issues were addressed on a sectoral basis (fisheries, shipping, pollution, etc.) However, the UNIDO training manual on CZM points out that single-sectoral solutions often transfer or sideline problems. Instead, managing complex systems requires integrated approaches that can:

- bring together multiple and overlapping interests;

- harness coastal resources for maximum social and economic benefit for present and future generations; and
- consider sectoral activities holistically.

While there are signs of success in some countries, this transition to comprehensive management frameworks represents a significant challenge at the national, regional and international level. UNIDO's CZM training materials note that current institutional arrangements for responding to CZM problems include:

- a newly created, centralized government agency;
- use of the "Lead Agency" approach;
- permanent interministerial or intersectoral councils;
- non-executive advisory committees;
- regular interdepartmental consultations; and
- ad hoc panels.

While there is no generally accepted "best practice" for institutional arrangements, co-operation, a comprehensive approach and integration are included in most successful structures.

Because trans-boundary problems require trans-boundary responses, there are increasing efforts to respond to coastal problems on a regional basis. Moreover, unsolved problems can lead to increased conflict. Ecosystems cross-political boundaries; protecting them requires holistic, ecosystem approaches.

Both the UNEP Regional Seas Programme and the marine and coastal projects of the GEF International Waters programme reflect this approach, often in co-operation with bilateral donors and International Financial Institutions (IFIs).

The IFIs are increasingly moving beyond sectoral-based strategies to more integrated approaches. For example, the Inter-American Development Bank (IDB) has financed USD 60 million in coastal zone management initiatives since 1993 with approximately USD 90 million in pending operations. Adding coastal management features to the design of infrastructure loans is becoming more common.

The Global Environmental Facility addresses CZM issues primarily in the framework of its International Waters Focal Area (Water-body Based Operational Programme #8). The GEF Operational Strategy notes:

> "Water bodies with varied ecological systems and economic value will be the subjects of GEF projects. Freshwater systems range from transboundary river and lake basins to transboundary groundwater systems. Marine waters are primarily addressed through Large Marine Ecosystems (LMEs). These are the equivalent of sea-based ecosystems for areas of common circulation or enclosed/semi-enclosed seas."

The LME document addresses marine issues, coastal zone issues, and related freshwater basin concerns. Ninety-five percent of all marine fisheries in the world come from 49 large marine ecosystems on the continental shelf. These systems are essential for food security and for sustainable use of coastal resources. Linking coastal areas, marine waters, and their contributing freshwater basins provides the necessary comprehensive approach to addressing transboundary environmental concerns.

Management measures that combine freshwater basins with the coastal areas they influence are important for protecting large marine ecosystems. In hot spots of transboundary environmental damage, targeted technical assistance or investment projects are encouraged to address serious problems. If only several of a large number of riparian countries wish to proceed, formulation of a strategic action program would be a useful, incremental first step. In addition, co-operating countries may wish to jointly address environmental problems of an oceanic area not included in a large marine ecosystem. Use of new technological and institutional tools is encouraged. Technological advances are being introduced that use information technology and computer simulation to help make critical management decisions for marine resources and tools such as the Code of Conduct for Responsible Fishing consistent with the Law of the Sea Convention also exist. Some projects may address issues (e.g. destructive fishing techniques) that are common to many countries in which changes in sectoral policies or activities re needed to maintain the environmental sustainability of marine and coastal waters.

UNEP's Regional Seas Programmes are well established and have a wealth of experience in addressing cross-boundary coastal issues. In many cases they are co-operating with other bilateral and international organisations and are contributing directly to relevant GEF. The

NAML has considerable experience in partnering with UNEP; the programme managers involved are an important resource for developing future collaborations.

2.4 LEGAL & REGULATORY FRAMEWORK

2.4.1 General

National, regional and international legal and regulatory frameworks often drive responses to coastal zone management problems. Understanding these frameworks can help guide the IAEA in identifying appropriate responses and prioritizing activities.

Many member states have signed international agreements related to the coastal zone. Most member states have indicated their support of protection of the marine environment, for example via active participation at the Rio Conference of 1992 and by agreeing to Agenda 21 and/or the Convention on Biodiversity (CBD) which highlights the need to protect marine species from coastal zone problems. In 1995 the Global Plan of Action for the Protection of the Marine Environment from Land-Based Activities (GPA) was signed requiring that the impact of human activities on the marine environment be investigated, and effective protection measures be developed through effective international co-operation and collaboration. The MARPOL, London Convention and Basel Conventions are also of direct relevance. Also of importance is the UN Convention on the Law of the Seas (UNCLOS) and the FAO Code of Conduct for Responsible Fishing. In addition there are regional agreements on the protection of coastal zone and marine areas.

2.4.2 Harmful Algal Blooms (HABs)

Harmful algal blooms are natural phenomena that are no more subject to regulation than, say, clouds. They form when conditions are favorable and are not “treatable”, except on a small scale and by drastic means (use of herbicides, e.g.). On the other hand, anthropogenic activities such as nutrient-laden discharges, may induce or intensify HAB events. These activities are often subject to regulation for various reasons. But given the present state of knowledge, the evidence linking specific human activities to HAB events is generally too weak to form the basis for legislation and regulation. It is a major research challenge to bring our understanding of HABs and their causes to a level where predictive modeling is possible. Only then will there be sufficient scientific basis to regulate sensibly.

The situation is different, however, when HABs cause the entry of toxic substances into the human food chain, for example through ingestion of toxin-producing algae by edible shellfish. Because of the risk to health, many countries monitor and regulate the levels of such toxins in shellfish, just as they do with the bacterial and viral contamination to which shellfish are also subject. Regulation usually takes three forms: closure of commercial fisheries, warnings to subsistence harvesters, and prohibitions on commercial trade in shellfish products. Because of the obvious negative socio-economic impact, such measures need to be based on good science and sound risk assessment. Moreover, as far as possible, these measures should not be imposed abruptly, but only after "early warning" of a deteriorating situation.

Reliable, rapid, sensitive, and accurate assays for toxins are thus a cornerstone of any legal/regulatory framework. Standardization from country to country is the usual requirement for testing applied to goods traded in international commerce. This principle is equally important in setting the levels of toxins that trigger regulatory action.

There may be opportunities for the IAEA, because of its long experience in such matters, to contribute to the global dialogue in the legal/regulatory arena, particularly with regard to standardization of assay procedures and regulatory action levels.

2.4.3 Other Coastal Zone Problems

Because of the diversity of topics and issues addressed outside the HABs field, it is difficult to be specific about their legal/regulatory implications, unless one reviews them problem-by-problem. One can say, however, that three of the more rigorously regulated activities in the coastal zone globally are:

- fishing of all kinds, including mariculture;
- waste disposal;
- development or other alterations of the coastal terrestrial environment.

In all cases sensible regulation depends on good science and sound risk assessment.

In terms of seeking TC projects with high potential socio-economic impact, therefore, programme staff may wish to begin by looking at these regulated activities, using the experts' analyses to see how and where nuclear technology can contribute.

3.0 STRATEGIC ROLE OF NUCLEAR TECHNOLOGY

3.1 HABS-RELATED DEVELOPMENT PROBLEMS

One of the more serious and visible problems facing coastal waters relates to the phenomena commonly known as “red tides” but now called “harmful algal blooms” or HABs. These are caused by the growth and accumulation of microscopic algae in marine or brackish waters that can cause massive fish kills, contaminate seafood with potentially lethal toxins, and alter ecosystems or coastal aesthetics in many ways. Toxic and harmful blooms have a wide array of economic impacts, including:

- the costs of conducting routine monitoring programs for toxic shellfish and other affected resources;
- short-term and permanent closure of harvestable shellfish and fish stocks;
- reductions in seafood sales (i.e., the avoidance of even safe seafood’s as a result of over-reaction to health advisories);
- mortalities of wild and farmed fish, shellfish, submerged aquatic vegetation and coral reefs;
- impacts on tourism and tourism-related businesses;
- and medical treatment of exposed populations.

Losses from individual HAB events are significant, and in areas with extensive wild or cultured fish or shellfish industries, often exceed US$5-10 million per event. Compounding the problem is the fact that there has been a significant global expansion of red tide/HAB episodes and impacts over the last several decades. Virtually every coastal country worldwide is now affected, often by multiple toxic or harmful species, affecting multiple fisheries resources.

3.1.1 Paralytic Shellfish Poisoning

One of the most significant of the many manifestations of HABs is that certain algal species produce toxins that can accumulate in seafood products (predominantly shellfish and fish) that then pose a risk to human consumers. The effects on humans range from mild discomfort to debilitating, long-term illnesses and even death from the poisoning syndromes described as paralytic, neurotoxic, amnisic, azaspiracid, and diarrhetic shellfish poisoning (PSP, NSP, ASP, AZP, DSP), and ciguatera fish poisoning (CFP).

HAB neurotoxins pose a significant public health threat and an enormous economic challenge to the shellfish industry worldwide. The economic loss from toxic shellfish or fish can be catastrophic, but if harvesters, managers, and government officials work together to develop effective monitoring programs, viable and productive fisheries can be maintained in regions where HABs are recurrent phenomena. Of the different syndromes, PSP has the most significant impact on human health, affecting dozens of countries worldwide and resulting in human illness and death as well as significant economic losses from closed or quarantined shellfish resources. As a consequence, most seafood-exporting countries have established mandatory screening programs for PSP in toxins. The method most widely employed is the AOAC mouse bioassay, which measures the time to death after intraperitoneal injection of seafood extract.

The mouse bioassay has proven to be an effective and reliable management tool, but it has significant limitations. For example, the detection limit is such that the method cannot detect toxins at low concentrations, or in certain tissue types. Furthermore, major expansions of mariculture production and increasing regulatory scrutiny of shellfish product for domestic consumption or export have resulted in a large and growing number of samples to be tested, often on a flat or declining budget for sampling and analysis. Since the vast majority of monitoring samples that are typically tested are negative, considerable cost savings could be realised if a rapid, accurate, and inexpensive assay could be used to pre-screen samples. Animal rights issues have also arisen and some countries are no longer allowed to use live animals in testing. Clearly, a rapid, sensitive, and high-throughput assay that can complement or be an alternative to the live mouse bioassay is needed for sustained and effective shellfish toxicity monitoring worldwide.

3.1.2 A Role for Nuclear Technology in PSP Monitoring and Food Safety

A distinct advantage of the mouse bioassay is that it provides an integrated measure of total toxicity in a sample. This is an issue because each of the toxin poisoning syndromes results from the combined actions of distinct families of toxins. PSP, for example, results from a family of compounds called the saxitoxins, consisting of more than 20 related compounds or derivatives, each with a different intrinsic potency that vary by over three orders of magnitude. Analytical instruments such as HPLC can separate and quantify these individual compounds, but do not provide a simple and rapid measure of toxic potency, as does the bioassay. Likewise, antibody-based assays do not provide an accurate estimate of toxicity because the affinity of those antibodies for the multiple toxin derivatives in a sample varies with toxin structure in a way that may not reflect potency.

A key application of nuclear technologies that can circumvent the problems highlighted in the preceding paragraphs is the receptor binding assay or RBA. The detection of HAB toxins using an RBA is based on the function, or pharmacological activity of the toxins ñ i.e., the highly specific interaction of a toxin with its biological receptor. Like the animal bioassay, the receptor-binding assay provides an estimate of the integrated toxic potency of a sample. Other advantages of the receptor assay include limited equipment costs and ability to work with crude (unpurified) extracts. If funds are available, the procedure can be automated through the use of microtitre filter plates and microplate scintillation counters. With or without such automation, large sample throughput is nevertheless possible.

In addition to high throughput, the RBA offers cost advantages per sample analysed. Table 1 lists the total costs associated with both the mouse bioassay and the RBA. For small numbers of samples (<20), the costs are comparable, but for higher numbers, the RBA is considerably cheaper because the analysis time (labor cost) is shorter.

3.2 OTHER CZM ISSUES

The background assessments identified issues of concern to coastal zone managers and then assessed which nuclear and isotopic techniques may be used for which critical coastal zone issues. The working group on coastal zone management issues (other than HABs) worked to put these issues into context and took as a starting point, the priority areas and accompanying phenomena of interest identified by Coastal GOOS. Small modifications were made to the Coastal GOOS list including the addition of Non-Living Resources and consideration of the effects of mariculture. The group then identified phenomena of interest for which nuclear techniques could make important contributions. Finally, an assessment was made of the applicability of the nuclear technique to the phenomenon. Criteria developed for evaluation of the applicability included

- *Uniqueness:* is the nuclear technique the sole, or one of very few, applicable approaches
- *Cost-effectiveness*: is the nuclear technique cost-effective in comparison with non-nuclear approaches?
- *Rapidity*: can results be obtained rapidly compared with other methods?
- *Maturity*: Is the nuclear technique well established, including in applications to coastal ocean science, or is more R&D needed?
- *Transferability*: can the nuclear technique be readily transferred to developing countries?
- *Sustainability*: is the nuclear technique sustainable, at reasonable cost, once external inputs cease?
- *Complementarity:* is the nuclear complementary to other project components?
- *Social acceptability:* is the technique acceptable to the stakeholders?[1]

Consideration of the above criteria enabled a ranking of the applicability of the nuclear technique for addressing a specific CZM problem. Tables 1 and 2 list the issues, phenomena, nuclear approaches and their applicability; these are summarized in the sections that follow.

3.2.1 Public Health: Radio-isotope Methods for Studying Contaminant Biogeochemistry

To varying degrees, edible marine organisms concentrate inorganic and organic contaminants from either water, their food or sediments. Understanding the transfer of contaminants through the food web is critical to predicting the exposure of humans to contaminants (either through subsistence or commercial consumption of seafood) and the possible health consequences of such exposure. In addition, such information is crucial to making accurate risk assessments for seafood safety purposes, a topic which is attracting much attention. Risk assessments based on sound science are the key to cost-effective management strategies.

The use of radiotracers to obtain such information involves exposing organisms to radiolabelled forms of the contaminant of interest, often trace metals. The amount of tracer incorporated into the organism is followed over time using gamma spectrometry. Bio-

[1] This point pertains particularly to activities involving the controlled release of radio-active tracers into the environment.

accumulation potential is rapidly screened, and assimilation or uptake efficiencies can be calculated. Likewise the depuration rates and half-times of the radio-labeled contaminant in the live organism can be followed after exposure. Exposing organisms to radiolabelled food such as phytoplankton, detritus or larger food matter and following the distribution and fate of the radiotracer as it moves through a food web can elucidate trophic transfer pathways. In some cases, use of selected stable isotopes of the heavy metal in question, measured for example by ICP-MS, can also give important insights into contaminant behavior and fate; however, the chemical analysis involved requires destruction of the samples.

Using a similar experimental design, radio-labeled organic contaminants (e.g. pesticides), most often tagged with ^{14}C, can be monitored over time by liquid scintillation counting techniques although this radio-analytical methodology also is necessarily destructive and therefore time-consuming.

The use of radiotracers to determine uptake of heavy metal contaminants by organisms under controlled laboratory conditions is a rapid and sensitive, non-destructive approach. Moreover it offers the opportunity to determine uptake patterns and rates in living organisms using environmentally realistic concentrations of the contaminant of interest. Although the radiotracer approach is not unique, it is preferred in many applications. The property of radioactivity offers the ability to detect low concentrations of the contaminant in water, sediment or organism tissue.

Some disadvantages include the relatively high cost of the radiotracers and the fact that the radioactivities are significant, requiring their regulation and the establishment of safety protocols for laboratory handling. The technique also requires the maintenance of organisms in a controlled laboratory setting

The major alternative---determining uptake rates with the stable form of a metal---requires using elevated mass concentrations to improve detection, clean laboratory conditions to avoid contamination, acid digestions, and exhaustive wet chemical analyses..

Although as noted above, alternatives exist to using nuclear techniques to determine rates of contaminant uptake and retention, the nuclear approach is rapid and mature. It is transferable to developing countries and sustainable (although expensive) once transferred. The approach complements other methods of assessing contaminant uptake and lends itself especially well to providing information on parameters needed to model uptake and trophic transfers of contaminants. The MEL has a dedicated in-house capability in this approach and thus can provide significant advice and guidance in transferring it to a developing country. The approach can thus be considered as having high applicability but requires considerable Government investment on an ongoing basis.

3.2.2 Ecosystem Health

Nuclear technology can contribute in various ways to assessment of the health of an ecosystem. But in the context of technology transfer, the technology's applicability varies widely depending on the particular application. The following sections discuss the degree of applicability in several fields.

Habitat Modification

Nuclear techniques are particularly well suited for studying several important aspects of habitat modification and loss.

For example, the input and accumulation of sediments and associated contaminants to a coastal area can have impacts on habitat. Natural and anthropogenic radionuclides that associate with particles may be used to establish sediment chronologies for reconstructing the history of contaminant inputs. It is also possible to resolve atmospheric and non-atmospheric sources of contaminants through a comparison of contaminant and radionuclide (^{210}Pb) inventories in sub-total and wetland sediments.

The nuclear techniques are mature and well established for such applications. Indeed, their "uniqueness" is high because there are few alternatives to nuclear techniques for determining high-resolution chronologies of coastal sediments. Once the capability is established in a developing country, there are numerous applications of these approaches that make them complementary to other applications. Training is necessary to avoid pitfalls in determining chronologies (for example due to the mixing effects of in fauna), but such training courses already exist. Thus this approach has high applicability.

Nuclear techniques also lend themselves to assessing the extent to which wetlands are responding to changes in sea level. Global increases in the rate of sea level rise have caused concomitant increases in the accretion rate of coastal wetlands such as salt marshes. The application of radionuclides to determining accretion rates of wetland deposits is analogous to the approach used for sub-tidal sediments. The technique applied to wetlands has a comparable strategic value and thus has high applicability.

Finally, changes in circulation and current patterns can affect the distribution of passive marine biota such as phytoplankton and certain larval forms. Numerous isotopic techniques exist to trace circulation. These range from the use of naturally occurring radionuclides such as the Ra isotopes to anthropogenic ^{137}Cs to stable isotopes (e.g. of O), as well as radiotracers added purposefully. Many alternatives exist to the use of these nuclear techniques and perhaps their greatest utility is in validating models of circulation and dispersal. As a consequence, the techniques do not have a high priority for technology transfer.

Eutrophication/Hypoxia and HABs

Eutrophication is an important coastal zone problem, as it often leads to degraded water quality, including hypoxia and harmful algal blooms, with consequent impacts on living resource. Assessment of the sources of nutrients and organic matter in a coastal ecosystem is critical to understanding the causes of eutrophication. Two aspects of eutrophication are especially suitable for the application of nuclear techniques; these are the determination of the sources of nutrients and of organic matter.

Determination of nutrient sources

The relative abundances of the stable isotopes of N, P and C constitute isotopic "fingerprints" that can be used to evaluate the relative contributions of various sources of these elements to coastal waters. Indeed for N at least, these approaches provide the best way of obtaining such information. As a consequence isotopic techniques have high applicability in this case.

A related aspect of nutrient source characterisation is the discharge of groundwater directly to coastal waters. Groundwater is often contaminated with nitrate, for example, and discharges may lead to enhanced biological production in coastal waters. Nuclear and isotopic approaches are well suited to characterising the regional rates of input of groundwater to a coastal area and thus have high applicability. Further details on this approach are provided in Section 3.2.4.1.

Determination of organic matter sources

The relative abundances of the C isotopes in organic matter found in coastal waters and sediments can be used to assess the contributions of terrestrial, sewage-derived and marine organic matter to the total organic carbon inventory. The approach is mature, and analyses can be made rapidly. Because there are high costs associated with acquiring and running the necessary mass spectrometric facility, the approach is usually cost-effective only when developed as a regional capability. Isotopic techniques are not the sole approach to this problem, however---biomarkers also can be used effectively---but they do provide complementary information to the other approaches. Therefore the IAEA should not assign high priority to capacity building in this area, but rather focus on strengthening capabilities where they already exist.

3.2.3 Living Resources

Changes in the abundance of exploitable living marine resources

The abundance of living marine resources is affected by many factors, some of which may be addressed using nuclear approaches. In particular, changes in the frequency and intensity of coastal upwelling can directly affect fishery production and yield. Such changes can be assessed through a combination of radiometric sediment core chronologies and stable C isotopes or biomarkers that gauge marine organic matter production. The use of sediments to conduct retrospective studies of up-welling history and associated primary productivity changes might yield valuable insight into the functioning of individual systems and their fisheries. Comparisons of similar databases between different up-welling systems should permit the verification of connections brought on by such events as El Niño. Such comparisons would aid our understanding of the effects climate change has on the functioning of the oceans and their living resources. Nuclear approaches have a high applicability in this area because they are uniquely well suited to determining sediment chronologies.

Changes in the structure of marine food webs also can affect the abundance of living marine resources. Information on trophic relationships is very important for coastal planners and managers. Indeed, this is essential when considering comparative productivity of discrete localities; biological diversity and intrinsic ecological values; inter-dependencies of particularly important species (whether for commercial, subsistence or ecological value); and potential for bioaccumulation of contaminants.

Among the tools most commonly used for such studies are various sampling techniques and fish-gut analyses. The use of stable isotopes (C and N) can sometimes reveal subtleties such as “short circuits” in the food chain that may not be discernible with the more common methodologies. Nuclear/isotopic techniques are also capable of faster results. Nonetheless, nuclear/isotopic techniques are not notably cost-effective when applied to the study of trophic relationships, and the results tend to be site specific.

In general nuclear/isotopic techniques do not have an advantage over non-nuclear/isotopic approaches for the study of trophic relationship and thus have low priority for application.

Changes in landings

Knowledge of fish population dynamics is key to understanding changes in landings. Indeed, management of commercial fisheries is highly dependent upon life history investigations, particularly studies of populations’ age structure. “Reading” the number of annuli on scales, otoliths or other hard body parts is a typical method for determining age. However, such traditional techniques can sometimes prove totally ineffective, and therefore need verification. This is especially true in the tropics, where water temperature is less variable, thus providing conditions less conducive to the formation of annuli. Even some cold water or deep-water species may exhibit similar problems.

Naturally occurring radioisotopic tracers are an effective means of determining the ages of fish, but the technique is not widely used. Isotope technology for conducting such studies is both cost effective and technically mature, and effectively complements traditional methodologies. It is thus judged as highly applicable and appropriate for technology transfer.

Stock segregation and migration

Although there are isotopic techniques that address the issues of stock segregation and migration, the methods need more R&D. Furthermore, there are other methodologies for studying these concerns that are in some cases easier and more cost-effective. Thus isotopic approaches are considered to be a low priority for application in this case.

Effects of mariculture

Mariculture brings new challenges to the coastal zone. One of the major impacts of fish farms, and of mariculture in general, is the localized introduction to the ecosystem of highly labile organic matter in the form of uneaten fish food, ammonia (animal excretion products), feces (fishes, bivalves) and pseudo-feces (bivalves). This continuous organic input can eventually lead to eutrophication of the production site. The continuous input of organic matter gradually changes the biogeochemical conditions of the seafloor. These changes are initially undetected in the water column characteristics. However, the final state is anoxia accompanied by liberation of poisonous gases such as H_2S and the death of native and cultured species.

Such biogeochemical changes can be studied by using naturally occurring radionuclides to determine the rates of bio-irrigation and biological mixing in bottom sediments. These two rates determinations can then be combined with measurements of sediment oxygen profiles. All three measurements together provide a better biogeochemical characterisation of the sea floor in response to incoming organic matter than any one of them alone.

Another important aspect that can affect the future of a mariculture activity is a well-characterised production site. Traditionally, oceanographic tools (currents, nutrients, bathymetry, etc.) have been extensively applied to answer this need. However, radiological techniques are a highly desirable complement to traditional methods. Radiochronology and sediment accumulation rates are powerful tools for characterizing past input fluxes from both natural and anthropogenic sources.

Nuclear techniques provide tools that may help emerging and established seafood farmers to comply with national and international regulations governing the use and production of farmed fish and shellfish. Nuclear approaches are highly applicable to address such concerns, but have not yet been widely applied for this specific purpose.

3.2.4 Non-living resources

This category involves two aspects: a) extraction of mineral resources from the coastal zone, and b) utilization of freshwater resources adjacent to coastal zones. With respect to freshwater resources, at least two issues are significant: inputs of freshwater to the coastal ocean via submarine groundwater discharge (SGD) and saltwater intrusion into coastal aquifers.

Submarine groundwater discharge

The SGD phenomenon can be an important component of water balance in coastal zones. A significant percentage of the total freshwater discharge into the oceans comes in the form of SGD (for the Mediterranean Sea the proportion is about 70%). As a result, SGD is increasingly being recognized as an important factor in sustainable management of coastal fresh water aquifers in many highly populated areas of the world. Depending on the location, SGD may be of greater ecological significance than surface runoff, and a significant pathway for nutrient and contamination transport from land-based activities to coastal zones. Inputs of the nutrients nitrogen and phosphorous are important to the overall nutrient economy, and their presence in SGD may contribute to the development of phytoplankton blooms and algal mats.

In some areas of the world both contaminant and nutrient inputs play a crucial role in the management of coastal zones, e.g., in the South Mediterranean region (Egypt, Israel, Lebanon, Syria); in Asia (China, India, Bangladesh); and in Central America (Mexico and Cuba). Elsewhere, the contamination factor is the most important, e.g., in. the Philippines, Vietnam, Brazil. The contribution of SGD to nutrient and contaminant inputs can be especially important in regions where there are little or no riverine inputs.

The estimation of groundwater fluxes into the marine environment is complicated by the fact that direct measurement is not possible by conventional means. Measurement of tracers--- including stable isotopes (^{2}H, ^{3}He, ^{4}He, ^{18}O, ^{13}C, B, Li and Sr), and both short-lived (^{3}H, ^{85}Kr, ^{222}Rn, ^{223}Ra, ^{224}Ra, ^{228}Ra) as well as long-lived (^{14}C, ^{226}Ra, ^{234}U) radioactive isotopes--- at the aquifer-marine interface can provide estimates of integrated discharge fluxes not possible by non-nuclear methods. Although the details of the application of these tracers to SGD are still being refined (through an IAEA CRP and a SCOR Inter-comparison Study, for example), the fact that other approaches are not presently available makes the nuclear and isotopic techniques highly applicable.

Saltwater Intrusion

The increasing population in coastal urban areas, along with growing industrial water usage, creates increasing demands for fresh water. In many places, per capita water consumption is rising as well. Scanty water resources and contamination problems restrict the availability of clean water; in many coastal plains, the limits have already been reached. In these cases, groundwater is typically used to supplement drinking water supplies, sometimes without proper resource management. The result is often abstraction rates that are too high, leading to significant decreases in hydraulic head, and seriously affecting the natural groundwater flow regimes.

In coastal urban areas that lie near the underground freshwater/saltwater interface, over utilization of groundwater often has caused saltwater intrusion. As the freshwater/saltwater interface shifts inland, drinking water wells tapping the affected aquifers become saline. In serious cases, extraction wells have to be closed. Unfortunately, remediation of salt-affected aquifers by natural flushing takes much longer than the time span of overexploitation itself. Decreased recharge rates due to over exploitation only serve to exacerbate the problem.

Salinity itself is the primary tracer for mapping existing saltwater intrusions. Stable isotopes can further differentiate intruded seawater from other sources of salinity, such as leaching of salt domes or admixture with deeper, saline aquifers. A conceptual model of groundwater flow in such environments, based on all available data on hydraulic heads, is the basis of all further assessments; numerical models can provide greater detail.

Groundwater age-dating tools for the range of the last several decades include ^{3}H, ^{3}He, the anthropogenic chlorfluorocarbons, and SF_6. Determinations of ^{14}C provide ages in the range of thousands to tens of thousands of years. The age determinations often also shed light on water mass-flow fluxes, and can be used for the calibration or for the verification of numerical models.

All these assessments require close co-operation among several partners, each with a different role to play:

- geological and hydrogeological institutions, which
    - monitor water levels

        - provide information on aquifer parameters such as thickness, hydraulic conductivity, and geology
        - perform water flow modeling,
- water management organizations, which
    - regulate the water supply
    - provide information on extraction rates
    - conduct routine water sampling
- chemical laboratories, which
    - characterize water chemistry, and
- isotope hydrology laboratories, which
    - analyze for both stable isotopes and radioactive tracers

The stable and radio-isotope techniques for studying saltwater intrusion are mature, and their usefulness has been well demonstrated in many field studies. However, use of the techniques presupposes that suitable, specially cased wells are available or can be drilled. TC projects in several countries have supported establishment of analytical capabilities for stable isotopes, tritium and ^{14}C.

The main impediments to successful TC activities based on tritium and ^{14}C determinations are managerial rather than technical. They are a) the need for close co-ordination and co-operation of different institutions to provide the necessary background information and b) the importance of proper study design, especially the sampling regime. While the second constraint can be covered by the TC project components (training, expert services), co-ordination among institutions within the country has to be assured before the project can be successfully implemented. Before starting a project using isotope methodologies, it is essential that all the necessary background information on wells, geology etc. be collected and disseminated, otherwise the problem cannot be assessed properly.

Extractive industries

A final set of coastal zone problems associated with non-living resources arises from the activities of extractive industries. In general the nuclear approaches associated with the problems created by such industries relate to questions of material transport and deposition, coastline changes and the effects on marine biota. While individual applications may have high relevance in certain instances, they must be evaluated on a case-by-case basis (see information on feasibility studies below).

3.2.5 Hazards

Natural and anthropogenic radionuclides provide many potential approaches for dealing with issues of hazards and public safety in the coastal zone. Such issues include extreme events such as storms and typhoons, consequences of sea level rise forced by global climate change, the effects of coastal engineering works and of extractive industries in the coastal zone. It is important to optimize dredging strategies, including the choice of dredging technologies, the alignment of dredging channels and the location of dredge-spoil dumps. Nuclear techniques may be used to:

- measure the rates of erosion and redistribution of sand and sediments;
- compare the impacts of extreme events such as storms with processes occurring under normal conditions; and
- establish a basis for predicting the impact of natural phenomena and coastal engineering works on erosion and accretion.

Radiolabeled sand can help assess the large-scale transport of sediment, as can naturally occurring radionuclides. Both approaches support the development and validation of mathematical models of sand and sediment movement.

Radiotracers are useful for sand and sediment transport studies, as they permit underway in situ measurement of the tracer distribution with equipment deployed from monitoring vessels. However, other tracer techniques (e.g., activatable and fluorescent tracers) are available. Radiotracers are extremely cost effective as the data are collected (and could also be processed at a basic level) during the survey. However, environmental radiotracing is highly regulated and this adds significant cost at the design and approval stage.

The radiotracer technology is mature and is generally viewed as socially acceptable provided that the community, through its representatives, is convinced of the value of the work, and regulators are convinced that critical groups within the community are not subject to any radiological hazard. Thus these nuclear techniques are judged to have high applicability.

Natural and anthropogenic radionuclides and purposeful radiotracers also are useful tools for providing a basis to predict the transport and dispersion of pollutants and nutrients released to the coastal environment through engineered structures (e.g. sewage outfalls) or river systems. Radiotracer techniques provide a powerful method for validating models although other tracer techniques (e.g. fluorescent tracers) can be used. However radiotracers have a major advantage in working in highly polluted areas (high fluorescent background) and at very high dilution. The tracer technology is mature and generally socially acceptable (see above). This approach is considered to have a high level of applicability.

4.0 ROLE OF IAEA

4.1 THE IAEA COMPARATIVE ADVANTAGES

The IAEA clearly has some comparative advantages within the UN family for addressing certain CZM issues. These include: unique tools and techniques; facilities for research and technical capacities that are unique in the UN system; a relatively predictable funding base for implementing technical co-operation projects; and a proven approach to the management of technology transfer.

The IAEA brings not only unique tools and techniques but also a demonstrated capacity to the identification of problems, determination of causes, development of solutions and resolving of the barriers that may hinder the application of those solutions. As a generator of data and information, the IAEA has broad experience in the field of coastal and marine information management (acquisition, analysis, storage, retrieval, interpretation and application), which is invaluable to developing countries in the planning, and management of their coastal resources.

One of the weakest links in the process of integrated planning and management of coastal resources is the enforcement of regulatory mechanisms, in particular those that address the discharge of contaminants. IAEA can transfer techniques that make it possible to trace contaminants to their original source, as well as to predict the ultimate fate and impact of a particular discharge. This task, which is a requirement for legal proceedings, is comparatively simple in the case of known point sources. But the IAEA may also be able to assist in the case of non-point sources, which are virtually impossible to characterize with other techniques.

Another of its strengths is the IAEA's relatively predictable budget for technical co-operation. The IAEA Technical Co-operation Fund (TCF) is based on voluntary contributions from its Member States and consistently has about 65 million USD per year for TC projects. Projects are demand-driven, i.e. based on requests from Member States.

The IAEA is increasingly looking to work with partners and appreciates co-funding opportunities. Partnerships increase impact; assure complementarity instead of duplication; and are an indication of the priority and importance of an activity. Co-funding is often a requirement of other organisations. The IAEA TC funds can match contributions of partner organisations to satisfy their requirements. For example, a TC project could be included in the national baseline studies that, under GEF projects, are the Member State Government's responsibility.

4.2 LIMITATIONS, CONSTRAINTS AND RISKS FOR THE IAEA

The IAEA is a technical organisation and will therefore not normally seek to lead CZM initiatives. Rather, it will work to fill gaps in overall programmes by helping coastal zone managers in Member States meet specifically identified needs. Nevertheless, in the consultants' opinion, while the IAEA has selected the frame of Coastal Zone Management as an entry point, it should consider broadening its scope to include "integrated" coastal zone planning and management. Doing so could create other opportunities for the Agency to apply its capabilities beyond the sphere of its traditional comparative advantage. The IAEA can begin in the finite areas where it can clearly make a contribution now, and then seek to build upon this gradually in the future in support of the integrated approach.

The IAEA does not have a network of country offices through which it delivers its technical assistance, which can be a limitation. However, the centralised structure of the Agency can be turned to advantage in terms of response speed, fewer bureaucratic hoops and a more streamlined operational structure.

A possible disadvantage is that the "gateway" for IAEA technical co-operation in its Member States is normally the national nuclear authority or the Ministry of Science and Technology.

These national focal points may not have knowledge of coastal zone issues, national programmes on that topic, or the level of priority they merit.

Nuclear technology is not always perceived in a positive light by all segments of society; in some cases there is a bias against all that is “nuclear”. Thus there may be a large need for public information to explain the advantages of the peaceful uses of nuclear technology.

4.3 PARTNERSHIPS

4.3.1 UN agencies and ICZM

The integrated approach to coastal zone planning and management (ICZM) gained momentum some 10 years ago when it was accepted by the UNCED as the most rational way in which to approach the complex problems evident in the coastal environment world-wide. Among the UN family, UNEP, through its Regional Seas Programme, has been applying such an integrated approach for some time, even if this has not been recognised specifically. FAO applies an integrated approach to the management of coastal zone fisheries and fish resources. IOC, with its foundations in the mandate of UNESCO, approaches the topic from a scientific and educational perspective. It has, for example, created specialised sub-groups working on HABs and ICZM respectively.

As implementers of the GEF portfolio of projects for the protection of international waters, the World Bank, UNDP and UNEP usually plan their efforts as components of broader projects/programmes on an individual country basis or, more often, on a regional basis. In the past, these activities were often executed by UNOPS. More recently, IMO and UNIDO have assumed the role of executing agencies for some GEF projects with major ICZM components. Other key actors are regional development banks, such as the Asian Development Bank and the Inter-American Development Bank.

IAEA should work with these organizations as partners in pursuing the problems of the coastal environment. At the international level, the majority of projects addressing ICZM seem to originate in the GEF through one of the agencies involved, particularly the World Bank and UNDP. In addition, projects at the regional development banks also address ICZM, with or without GEF funds. The IAEA could work directly with the GEF Secretariat to enhance co-operation and set the basis for longer term planning.

4.3.2 Bilateral and Regional Partners

In some cases, specific expertise may exist in IAEA Member States that can be transferred to others. For example the National Oceanographic and Atmospheric Agency (NOAA) has been instrumental in developing the RBA technique. A partnership could be developed to both improve the technology package, achieve its certification, and assure appropriate transfer of the technology. Both the US Food and Drug Administration (US FDA) and the European Union could be partners in assuring that nuclear and isotopic tools, like the RBA, form the basis for appropriate responses to their respective regulations for seafood safety, while complementing partnerships with FAO in relation to the Codex Alimentarius. Existing or established capacities (like the HABs work in the Philippines) offer opportunities for facilitating TCDC through technology transfer to other countries. Regions that share similar ecological characteristics, such as the Humboldt Current and the Benguela Current ecosystems, could benefit from co-operation catalyzed through IAEA activities.

Regional partners would include the respective Regional Seas Programmes of UNEP as well as the programmes funded by the GEF, including the PEMSEA, Benguela Current, and Caspian Sea Programmes.

4.3.3 National Level

At the national level, the services and capabilities of IAEA must be brought to the attention of sectors with specific interests in CZM. In particular, these could include Ministries of Environment; Water Resources; Coastal Planning and Fisheries; Transport; and Foreign Affairs. The application of nuclear technology for socio-economic benefits and sustainable development should be “marketed” to the broadest possible clientele.

4.3.4 NGOs

Co-operation with NGOs should also be considered where appropriate and mutually beneficial. These could include environmental groups such as the IUCN Marine Programme or WWF, both of which would have good knowledge of ecological conditions as well as broad involvement of stakeholders or interest groups related to fisheries (e. g., BENEFIT from Southern Africa, SADC, etc.).

5.0 PROGRAMME STRATEGY

5.1 PRIORITIES AND OBJECTIVES

This programme strategy provides a framework for developing activities in support of coastal zone management to guide future technical co-operation programmes (including the upcoming IAEA 2003-2004 TC Programme.) The strategy should also assist in planning future IAEA regular budget-supported research activities related to coastal zone management (as reflected in the new Programme H on "Protection of the Marine and Terrestrial Environment"). Priorities should follow from the socio-economic importance of the problem; the strategic value of the nuclear technology; and the commitment by IAEA Member States, especially as reflected in their own programme investments.

The overall objective of TC activities in coastal zone management should be to transfer nuclear and isotopic techniques that address priority coastal zone problems of socio-economic importance to Member States. This programme strategy outlines a medium term plan of programme development: 2002-2006 (including the 2003-2004 and 2005-2006 TC Programmes) including pilot activities, feasibility work, assessments etc.

The thematic planning meeting participants decided to make two background assessments. One working group focused on HABs, the second group on other coastal zone management problems that can be addressed by nuclear and isotopic techniques. The programme strategy is thus divided into a HABs component and a broader CZM component.

5.2 TIME FRAME FOR THE 2003-04 TC PROGRAMME

The IAEA TC programming cycle requires submission of national project proposals for the 2003-2004 cycle by Dec. 31, 2001, and regional proposals by June 2002. There is an open timeframe for inter-regional project activities. Activities that require immediate attention may qualify for IAEA Reserve Fund allocations of up to 50,000 USD if requirements are met following a Member State's official request. Feasibility activities and/or assessments may also be supported by funds earmarked for pre-project planning.

5.3 PROGRAMME DEVELOPMENT FRAMEWORK: PILOT ACTIVITIES, FEASIBILITY, ENABLING ENVIRONMENT, AND ASSESSMENTS

A crucial decision faces IAEA management during the early stages of programme development in coastal zone management: whether to allocate resources to acquire core technical competency and support full-scale socio-economic development projects (model project approach), or to defer activities due to a lack of clear benefits (tangible or intangible), and/or uncertain technical justification.

The TC Department proposes a two-stage approach to programme development based on its standard appraisal criteria: a pilot activity will be considered only when information exists to prepare a project definition statement, a requirements analysis, and a general design.

Where such data does not exist, TC will support the preparation of feasibility studies designed to provide sufficient functional, operational and technical information. These studies should define:

a) the problem being addressed
b) the specific objectives leading to its resolution or mitigation; and
c) the tasks that will lead to achieving those objectives with a high degree of confidence

In particular, it is important to present evidence of a defined social or economic objective common to several Member States. The feasibility study should provide adequate information about the expected costs, benefits, risks and demand for a proposed project. The project justification should go well beyond the scope and specificity of thematic planning. It should make possible a "go/no go" decision before committing significant funds to the pilot or model project phases.

The thematic planning process revealed that the receptor binding assay technique has significant value for managing HABs phenomena. It addresses a recognised problem with specific characteristics whose consequences are clearly stated in national mitigation strategies. Thus, the RBA is ready for demonstration in pilot scale activities.

Discussions also identified a suite (or "toolbox") of other techniques have significant application in the coastal zone. However, these techniques may require further validation within a defined problem context and are thus more suited to feasibility studies. Such feasibility studies should be structured to provide the information Agency management and national institutions need to develop plans for technical co-operation activities involving counterpart organizations, the MEL, and the TC Department.

5.4 PROGRAMME STRATEGY FOR HABS

The thematic planning process has shown that the IAEA can make an immediate, significant contribution to addressing HAB problems that have significant socio-economic in IAEA Member States. The receptor binding assay (RBA) is:

- quick;
- simple
- sensitive; and relatively inexpensive.

It works with all toxins that act by blocking nerve cells' Na-channel. And it correctly integrates a sample's total toxicity over the whole range of toxin congeners, families of related substances that may be present in varying proportions.

5.4.1 An outstanding opportunity for transfer of nuclear technology

Hundreds of laboratories around the world currently detect neurotoxins in seafood by means of a bioassay that uses live mice and whose endpoint is lethality. The mouse bioassay (MBA) is certified for this purpose by the Association of Official Analytical Chemists and is thus the "gold-standard" against which other methods are judged. While it is simple, rugged, and reliable, the method is neither inexpensive, rapid, nor particularly sensitive. Large sample loads require that mouse colonies numbering in the thousands be maintained, with the attendant space requirements and maintenance costs, even when no testing is being conducted. Moreover, the use of live animals for product testing is prohibited in many countries and on its way out in others.

Clearly, the time is ripe for a switch to an alternative such as the RBA, at least for routine screening. The scope of the paralytic shellfish poisoning (PSP) problem, and HABs in general, ensures that the impact of a program to encourage this change will be significant and will eventually involve a large number of countries.

The IAEA should seize the opportunity for taking a leadership role in delivering the benefits of the new radio-assay technology to Member States, assigning this effort the highest priority under the coastal zone management theme. It could do so in a constructive manner, by establishing a collaborative arrangement between MEL and NAAL. The latter unit has the trained manpower and experience in radio-assay methodology, including quality assurance, and a mandate to help Member States extend their capabilities to detect harmful residues in foods.

This approach also would build upon the recommendations of the recently completed PPAS on Marine and Terrestrial Environment Programmes, which recommended closer co-operation between Seibersdorf and the MEL. The MEL is well known and respected in the oceanographic community. Its ties to the developers of the RBA at National Oceanic & Atmospheric Administration (NOAA) Marine Biotoxins Programme have been strengthened through collaboration in HAB related projects such as PHI7006 and RAS8082, as well as through the Thematic Planning exercise just concluded.

5.4.2 HAB Programme Components: Implementation Strategy

It was the consensus of the workshop that initial efforts in the 2003-2004 TC programme should be directed to RBA technology for algal neurotoxins. The IAEA can transfer the assay technology to interested Member States, thereby enhancing the enabling environment while preparing the way for other promising nuclear and isotopic applications in the HABs area. The implementation strategy might consist of the following inter-related components.

The receptor binding assay is a mature and highly practical nuclear technology, ready for immediate transfer to countries that do not possess this capability. The first step is to develop pilot activities for the 2003-2004 TC programme that will demonstrate the significance of the nuclear technologies for addressing high-priority socio-economic problems. In 2002 the focus should be on preparing pilot activities with those countries most in need of the technology, i.e., where socio-economic impact is greatest. National, regional and inter-regional pilot activities would all be appropriate.

5.4.3 Rationale

The RBA method is mature and highly practical and has been transferred to five SE Asian member states through the Philippine national TC project (PHI-7-006) and the regional UNDP/RCA/IAEA Project (RAS-8-080) on HABs. Once AOAC certification of the RBA is achieved (see Component #2 below), the method will be even more in demand for transfer to additional member states that do not possess this capability. The framework established in the previous projects was successful and therefore could be applied more widely. The IAEAs should also link its efforts with other HAB training activities such as those sponsored by the IOC HAB Programme.

5.4.4 Project Framework and Design

Activity 1: Pre-project mission

The first activity would be a pre-project assessment mission and/or project formulation meeting involving RBA and seafood safety experts as well as TC and NAML staff, targeting partnering institutions to assess the capabilities and facilities for biotoxin detection technology and shellfish monitoring. This assessment should increase awareness of the utility of the RBA method amongst the experts from the national IAEA focal point, university research laboratories, health regulatory authorities, and government agencies responsible for HAB monitoring.

Activity 2: Project Website

The second activity would be to establish a project website to exchange information among partnering institutions, and to provide educational/technical resources specifically related to HABs and their toxins. This could be done either through a modest subcontract to a partnering institution, though existing staff and resources within IAEA, or through collaboration with the IOC HAB Programme, which maintains several related websites.

Activity 3: In-country implementation

<u>Step 1. Receptor Assay Training</u>. Following the pre-project mission and planning activities, the next activity will be training and technology transfer. Two sequential approaches are

recommended: (1) to hold a demonstration training workshop to which participants travel for a week or more of intense group training, and (2) to fund training fellowships which would bring personnel to expert laboratories where they would learn the methods over a few weeks to a month. Both of these approaches have been shown to be useful in the regional HAB project in Southeast Asia, and both should be supported in other countries or regions.

Step 2. In-country implementation. Following training, the next phase of implementation will involve efforts by the trainees to initiate the use of the RBA for toxin detection and shellfish monitoring at their home institutions. Funding should be provided to support the purchase of necessary supplies and equipment, including scintillation counters in specific cases.

Step 3. Inter-calibration exercises. An inter-laboratory calibration study is needed involving a comparative analysis of contaminated shellfish samples between partner laboratories. This should be organised and implemented by an RBA expert, with all analyses conducted in-country using the facilities and personnel available. Data should be exchanged, evaluated, and integrated and returned to all participants in the form of a report. Experience gained during Component # 1 will be valuable here, since the inter-calibration envisioned will be similar to the inter-laboratory trials conducted for AOAC certification.

Activity 4: Synthesis workshop

A follow-up workshop is needed to address problems encountered with the assay, as well as other troubleshooting issues encountered by participants. By sharing experiences in this manner, participants will benefit from the efforts others have made to introduce the technology to their countries.

5.4.5 Necessary Infrastructure and Capabilities

Facilities

At a minimally, partner laboratories must be equipped with standard instrumentation to carry out biochemical measurements. Supplies specific to carrying out receptor assays for algal toxins using a standard scintillation counter are also required. These items might be supplied through IAEA funding if they are not already available in the partner laboratory.

Capabilities

The expertise required to carry out quantitative biochemical assays includes making up molar stock solutions; making serial dilutions in small volumes using micropipettors; familiarity with radioisotope safety; application of curve-fitting software and interpretation of results; and the use of QA/QC measures.

Member State Commitment

In order to successfully implement the use of receptor assays for algal toxins by monitoring or regulatory agencies in participating member states, the appropriate end-users must be identified and included in IAEA funded programs. In most cases, this will be a fisheries or health department, or a university laboratory contracted to perform these functions. In member states where multiple regulatory laboratories ultimately need to be trained, a one-week national workshop will be needed. Further, it is necessary that a member state is committed to provide support for manpower and supplies to continue beyond the duration of the project. There should also be an ongoing national monitoring program for HABs. Without a sound monitoring program design, and without a steady supply of samples to analyse, the assay training will be of little practical use.

5.4.6 Potential pilot activities

There are many countries with PSP problems, and it is generally known where HAB outbreaks are occurring worldwide. The frequency and severity of outbreaks, as well as the importance of shellfish and fisheries to exports (i.e. the most important socio-economic concern), indicate sites for potential pilot activities. Only some of these countries may be able to support local or regional RBA training activities. Likely candidates for pilot activities include Chile, (and the southern part of South America), authorities for the Benguela area of Africa (South Africa, Namibia, and Angola); Vietnam; Kuwait, and China. Other Member States may be added if the appropriate national bodies express interest.

5.4.7 Enabling Environment for Transferring the RBA Technology

One significant limitation to the recognition of the value of the RBA methodology is that the regulatory authorities that certify shellfish for human consumption do not yet officially accept the RBA for determining PSP toxins. This technique can therefore not be used to certify shellfish for export to the European Union, the U.S., Japan, or many other countries or economies with significant demand for seafood.

A series of activities is proposed that will ultimately lead to the certification of the RBA method and enhance its transfer to Member States as a tool to protect public health through routine monitoring of shellfish for PSP toxins. These activities include:

- organising an inter-laboratory trial to obtain AOAC certification of the method;
- facilitating a reliable and sustained supply of saxitoxin standard and radio-labeled saxitoxin (or saxitoxin analogues);
- and developing robust kits for applications of the RBA in remote locations.

5.4.8 Inter-laboratory validation trial to obtain AOAC certification of the RBA method for PSP toxins.

Rationale. The objective of Component # 2 is to obtain official acceptance of the RBA method for regulatory use in certifying shellfish for human consumption. The Association of Official Analytical Chemists (AOAC) is an international professional organisation dedicated to the development, validation and performance testing of analytical methods. A method may be sanctioned as an "official AOAC method" only if it meets AOAC standards for accuracy, precision and ruggedness in an inter-laboratory validation trial. Recognition as an official AOAC method is often sufficient to achieve acceptance of a method by regulatory authorities who establish quality and safety criteria for food imports to the U.S., E.U., and many individual countries. The US FDA has already expressed strong interest in the RBA as a complementary method to the mouse bioassay.

Project framework and design. An official AOAC inter-laboratory validation trial requires a minimum of eight laboratories. An inter-laboratory trail of the RBA for PSP will include laboratories in both developed and developing nations. Laboratories experienced in the RBA for PSP toxins that might participate in such a trial include: Univ. of Chile (Chile); PNRI (Philippines); Univ. of Malaysia (Malaysia); Burapha Univ. (Thailand); NOAA Charleston

Lab (USA); FDA (USA); California Dept. of Health Services (USA); and Army Medical Research Institute (USA). The National Reference Laboratory for Marine Biotoxins (Scotland) or another E.U. regulatory laboratory, and IAEA Seibersdorf Laboratory should be considered for participation in the trial.

The NOAA Charleston Laboratory will co-ordinate the trial. Toxic shellfish will be obtained from Chile or Canada. NOAA Charleston will prepare shellfish samples spiked with pure toxin. U. S. FDA will provide saxitoxin (STX) standard. Labeled STX will be provided by IAEA through contract with Amersham. NOAA Charleston will make membrane preparations available. All materials will be assembled at NOAA Charleston and shipped to each participant for use during an agreed upon Trial week. Data from the analysis will then be sent to AOAC for statistical analysis. The anticipated duration for this activity is two years.

Necessary infrastructure and capabilities. The minimum requirement for laboratory participation in the collaborative trial will be demonstrated experience and competence in RBA assay performance. Training in the method at the NOAA Charleston Laboratory must be provided to the laboratories that have no previous experience in the RBA, prior to the trial.

The costs to IAEA for this activity will include purchase of tritiated STX, shipping of materials, and two one-week training visits (Scotland and IAEA Seibersdorf).

5.4.9 Reliable and sustained supply of saxitoxin standard and radio-labeled saxitoxin (or its analogues)

Rationale. IAEA member states wishing to implement RBA technology will be constrained by the lack of readily available and affordable purified toxin standards and radiolabeled toxin. It is therefore critical that a reliable and sustained supply of these materials be available.

Project framework and design. A calibration standard for saxitoxin (STX) is presently available at no charge from the US FDA, Washington D.C., as long as the material is used for monitoring purposes. STX is also marketed (at cost recovery) by the NRC Certified Reference Materials Program [Institute of Marine Biosciences (IMB), National Research Council (NRC), Halifax, Canada], as part of its Marine Analytical Chemistry Standards Programme (MACSP). The USFDA has traditionally supplied STX standard to all countries for monitoring purposes, and thus it is reasonable to expect that it will do so for RBA analyses under this program.

An additional potential source would derive from an existing IAEA project with the Philippines that is attempting to produce pure STX standards. A contract could be issued to the University of the Philippines or other possible suppliers to purify STX and supply it at a reasonable cost to partner countries.

For the moment, the only activity required for this sub-component is for the IAEA or its Technical Officer to obtain assurances from the USFDA that it will supply pure STX to all countries and agencies participating in this RBA program. An estimate would be 1 mg per country per year, with perhaps 10 or more countries participating.

Radiolabeled STX is another critical need. It is used in the receptor assay, which relies on the displacement of the radiolabeled toxin to measure the amount of unknown toxin in a sample. The sensitivity of the method is due to the use of tritiated STX, (3H-STX) which can be detected in low concentrations using scintillation counting techniques. There is no non-nuclear alternative for this procedure that will provide suitable accuracy and sensitivity.

A reliable supply can initially be ensured if the IAEA arranges a contract with Amersham that guarantees availability of high quality product at a reasonable cost. If this arrangement proves inadequate for any reason, the project will need to produce its own supplies. Again, this may be accomplished through the University of the Philippines or others who can be issued contracts to produce sufficient material. The University of Philippines and the Philippine Nuclear Research Institute have already demonstrated the capability to purify STX and to label it under the framework of a national TC project with the IAEA.

An important activity for the IAEA (through its MEL or Seibersdorf Laboratory) would be to organise and oversee the external quality assurance procedures for both purified STX and radio-labeled STX. This will include activities such as establishment of data quality objectives, distribution of spiked samples, reference materials, organisation of inter-laboratory comparisons, documentation of standard procedures and protocols, etc. These IAEA laboratories can also be of great help in trouble shooting and diagnosing problems. This might entail a few months of effort spread out over two years.

Necessary infrastructure and facilities. If supplies of STX and ^{3}H-STX are to be obtained from the USFDA and Amersham respectively, there is no need to address issues of infrastructure and facilities. However, if other sources are to be used to obtain this material, it is critical that those laboratories demonstrate the appropriate chemical and production skills to provide high quality materials. They will require access to shellfish containing STX and/or a capability to grow large volumes of toxic algal cultures. Other needs include the chemical facilities and expertise for extracting this material and purifying the toxins from the different matrices. The participating laboratory should be licensed to work with the quantities of isotope needed for the synthesis of radio-labelled STX. The laboratory must also be able to purify the product and measure its specific activity using the appropriate instrumentation.

The IAEA's MEL and Seibersdorf Laboratory both have the necessary skills and facilities for the quality assurance activities of this sub-component.

5.4.10 Robust RBA assay kits for use in remote locations

Rationale. The RBA technology is currently used in relatively well-equipped and controlled laboratory environments, with reliable power supply, refrigeration and air conditioning, and access to regular delivery of mail and supplies. In practice, however, some or all of these conditions may be difficult to ensure in remote locations in many member states. The IAEA has considerable experience in adapting analytical procedures to render them less susceptible to non-ideal laboratory conditions. For example, a progesterone radioimmunoassay has been modified so that it now can be used in agricultural field stations with limited resources.

For the RBA, it is desirable to explore modifications to the existing assay format for application under non-ideal conditions. This could include efforts to: 1) increase the stability of the labelled STX or STX analogue; 2) modify the isotopic label to enable gamma counting; 3) modify radiometric detection and data acquisition hardware; and 4) make the receptor complex less susceptible to degradation (e.g., in the absence of refrigeration).

Project framework and design

Activity # 1: Increase the stability of the labeled STX of STX analogue.

One of the problems with the STX RBA as it is currently configured is that the 3H-STX label is "soft", meaning that it readily releases tritium through keto-enol equilibration. A promising development in this regard is the discovery of a procedure that yields a tritium-labelled STX analog called acetyldecarbamoyl saxitoxin (ACdcSTX) by Y. Oshima at Tohuku University in Sendai, Japan. Dr. Oshima has achieved a good yield of this analog in a relatively simple procedure that uses decarbamoysaxitoxin (dcSTX) as the starting material.

The following steps are needed to make 3H- ACdcSTX or 3H-STX available to IAEA member states. Note that either of these labeled toxins or toxin analogs would be of great use to IAEA member states.

<u>Step 1: Identify Expert Laboratory.</u> Dr Oshima has kindly offered to provide the chemical protocol needed to produce ACdc-STX to any laboratory that would be willing to undertake the project. IAEA will need to contract directly with a chemical laboratory to do the labeling, but concerns about the storage or handling of large amounts of highly tritiated materials need to be addressed. Another alternative is to contract directly with Amersham or some other chemical company to do the chemistry and the labeling. Yet another option would be to use the facilities of the IAEA/MEL in Monaco. They have the facilities and experience for producing and distributing standard reference materials. Again, a concern may be whether the amount of highly tritiated material needed for the synthesis falls within the site license for the facility.

<u>Step 2: Obtain purified STX or dcSTX.</u> The laboratory contracted to do the tritium labelling will need to be supplied with the chemical procedure as well as with either dcSTX or STX. The quantity of 3H- ACdcSTX needed can be estimated as follows: Amersham's tritium 3H-STX (20 Ci/mmol) contains 5 μg/vial. For tritiated ACdcSTX at the same level of specific radioactivity, 100 vials can be produced from 1 mg of dcSTX, assuming 50% yield from the reaction and subsequent work up. It is impossible to estimate the global demand for this material, but if one initially produces 50 vials, this will require 5 mg of dcSTX. Dr. Oshima has kindly offered to give the project 5 mg of dcSTX.

If it becomes necessary to produce more dcSTX in the future, separate arrangements will be needed, either with Dr Oshima or teams at the University of the Philippines or elsewhere who are capable of extracting and purifying STX from shellfish or cultures. Funding, and possibly some expert assistance, will need to be provided for this supplemental toxin purification effort.

Step 3. Produce radiolabeled STX or ACDC-STX. Once an expert laboratory has been identified and purified ACdcSTX or dcSTX supplied, the labeling can proceed, and vials produced that are then certified for use. Bids should be solicited from several laboratories experienced with radio-ligands.

Step 4. Certify, distribute and evaluate the radioligand standard. Once 3H-ACdc-STX is available, it needs to be tested and certified. This is best accomplished by experts in the receptor assay technique. After certification, the standard should be distributed to those laboratories that have been trained in the RBA in several of the IAEA projects (i.e., those that are presently ongoing, as well as any that are initiated as new TC projects). This material should be used by these laboratories, and results compared. If it performs adequately, then efforts should be made to produce sufficient quantities for future needs within IAEA member states. A cost recovery program would also have to be instituted, though it is hoped that the costs would be below those presently charged for commercial standards.

Activity # 2: Modify the isotopic label to enable gamma counting

Given the existence of inexpensive, rugged, battery-operated gamma counters, it would be desirable to explore the utilisation of a gamma-emitting radiolabel such as ^{125}I. Likewise a sulfur label could be explored.

Step # 1. Identify expert laboratory and initiate testing. A laboratory needs to be identified that is capable of selecting appropriate candidate isotopes and conducting the chemical reactions to couple gamma-emitting labels to STX or its analogues. The labeled analogue would must be stable, have a high specific activity, and must exhibit a sufficiently high binding affinity with the receptor.

Step 2. Produce radiolabeled STX or ACDC-STX. Once an expert laboratory has been identified and purified ACdcSTX or STX are supplied, the labeling can proceed and vials produced that are then certified for use. Bids should be solicited from several laboratories experienced with radio-ligands.

Step 3. Certify, distribute and evaluate the radioligand standard. Here again, the labeled STX or STX analog needs to be tested and certified. This is best accomplished by experts in the receptor assay technique. After certification, the standard should be distributed to those laboratories that have been trained in the RBA in several of the IAEA projects (i.e., those that are presently ongoing, as well as any that are initiated as new TC projects). This material should be used by these laboratories, and results compared. If it performs adequately, then efforts should be made to produce sufficient quantities for future needs within IAEA member states. A cost recovery program would also have to be instituted, though it is hoped that the costs would be below those presently charged for commercial standards.

Activity # 3: Modify radiometric detection and data acquisition hardware

The equipment presently used for RBA analysis is expensive and are is designed to be used in regular laboratory environments. Therefore there is a need for alternative, less-expensive instruments and data acquisition hardware that can be used in more demanding environments, such as those at a field station at a remote site. For this activity, IAEA experience with simplified gamma counters for the progesterone radioimmunoassay will be useful and can guide RBA developments. Specific steps to be followed would be for IAEA staff at the Siebersdorf Laboratory to work with RBA experts to select and test appropriate equipment. This might entail a month or two of time for an IAEA staff member.

Activity # 4: Make the receptor complex less susceptible to degradation (e.g., in the absence of refrigeration)

There will be situations in which RBA analyses are needed at locations far from centralised, environmentally controlled laboratories. The limited stability of the receptors used in the assay will be a concern. When stored frozen at –70°C, the receptor preparation is stable for greater than a year. It is not known how long it will last at –15°C (the normal refrigerator freezer temperature). Studies are therefore needed on the stability of receptor preparations at other temperatures, and on methods to improve stability. This is clearly a research area that could be conducted by an expert laboratory, perhaps in collaboration with the IAEA laboratory at Seibersdorf.

5.4.11 Future program development considerations

This programme strategy for harmful algal blooms focuses on a set of techniques and activities that together comprise a coherent and logical program to provide a nuclear solution to the global problem of HAB toxin detection and monitoring. There are a number of other applications of nuclear technologies that target different aspects of the HAB problem. These could be candidates for future TC projects. IAEA Member States will need to determine which issues pertain to their situation or needs. For example, states with significant eutrophication problems and an associated prevalence of high biomass HABs might find it useful to initiate a program that would identify and quantify the sources of different types of nutrients to a water body, so as to determine which of those nutrient sources is most closely linked to the bloom phenomena. Similarly, radiometric dating methods for sediment cores can help to identify patterns of HAB cyst abundance that reflect changes in eutrophication, land use, or even the accidental introduction of species. All of these issues are of great importance to managers, as has been demonstrated in the national TC project on red tides in the Philippines.

5.4.12 Further assessments

While much is known about the harmful algal bloom problem, more comprehensive information concerning Member States' problems, their scale, ecological and socio-economic impact etc. would allow TC to more precisely respond to Member States' needs and further design the programme in this field. Therefore:

- a more precise assessment of the HABs problems, scale, scope, frequency and socio-economic impact for developing precise responses could be done in conjunction with the UNESCO-IOC HABs programme which has already begun related work; and

- a questionnaire could be developed and distributed in order to assess the interest of Member States as was done for example with the dam management theme.

5.4.13 Partnerships

As the developer of the RBA technique, the NOAA Marine Biotoxins Laboratory in Charleston, SC is an ideally suited, ready and willing partner for all programme development components related to HABs. NOAA Staff has already been chosen as the “steward” for the certification process of the RBA, and there is already a commitment to provide resources for the certification. The US Food and Drug Administration (US FDA) is also interested in co-operation and providing guidance on how to link the RBA for the certification of exports in relation to the legal and regulatory framework for exports. There are opportunities for complementary co-operation with the appropriate EU authority, as well as with FAO units responsible for the Codex Alimentarius. The UNESCO- IOC HABs programme would be a strong partner for global information, with an already established network of partner institutions organised on a regional basis. A logical step would be to work together to co-ordinate capacity building/training activities where appropriate.

Finally, given that HABs are part of the problem context of most GEF funded regional coastal zone/ marine programmes (Benguela, PEMSEA, Yellow Sea, etc.), it would behoove the IAEA to work to develop a mechanism to link IAEA projects within the framework of these larger initiatives. This could be best be done by following pipeline development and interact with GEF implementing (World Bank, UNEP and UNDP) as well as executing agencies (FAO, UNIDO, ADB, IDB, EBRD, AfDBAFDB, IMO etc.)

5.4.14 Staffing and Resource Requirements

A key requirement would be to identify a staff member (probably at NAAL) who could be trained in the RBA by its developers at the NOAA laboratory in Charleston, South Carolina. This staff member would then be in a position to conduct workshops, provide backstopping to TC, and assist in further refining the technology. This might be done in conjunction and/or under the guidance of a NAML focal point for future HABs activities.

5.5 OTHER COASTAL ZONE MANAGEMENT PROBLEMS

Nuclear and isotopic techniques can play a strategic role in managing coastal zone problems other than harmful algal blooms. The analysis of the CZM working group (Section 3, Strategic Role for Nuclear Technology for CZM Problems), is an important step in understanding how to identify and prioritize opportunities for technical co-operation. The following Table is a reasonably comprehensive yet succinct guide to topics of concern in coastal environments to which nuclear technology (that is, isotopes- and radiation-based techniques) can contribute. The Table helps to define the scope of nuclear technologies applicability and points to processes amenable to study by these means (first column below).

The selection of topics is closely reasoned and mostly non-contentious. Other topics may be of high priority at a given place and time, do not usually rise to the significance of those in the first rank.

Process	Example of Related Problem
Uptake and retention of contaminants in seafood	Paralytic shellfish poisoning
Erosion, transport and deposition of sand and sediment in the terrestrial, inter-tidal, littoral, sub-littoral, and benthic regimes[2]	Beach erosion; loss of wetlands
Transport of solids and solutes across the sediment-water interface	PCB reflux from contaminated sediments
Sub-surface groundwater discharges	Groundwater contaminants in coastal ecosystems
Episodic events such as up-wellings, HABs, and major storms that leave sedimentary signatures	Unpredictable red tides
Changes in fish community structure or population dynamics	Reproduction failure and loss of fish stock
Saltwater intrusion into freshwater aquifers	Inadequate drinking water supply/quality
Water circulation and sediment transport	Harbour/channel siltation
Dispersion of riverine plumes and sewage outfalls	Beach closings
Interactions of mariculture inputs and wastes with water and sediment biogeochemistry	Induced sediment anoxia

This analysis helps define opportunities for technical co-operation, although it focuses more on processes than on actual problems. In fact, most of the processes in the first column go on all the time without necessarily causing problems to people or economies. Thus the analysis has answered the "what" questions but not those of the "who, where and how" variety.

The challenge in the next step is to identify places where these processes are causing significant problems; to determine if Governments or donor organisations will fund or already are funding study and remediation efforts; and to seek out the appropriate partners so as to ensure that the IAEA's technical co-operation is carried out within an appropriate context.

One efficient mechanism for answering these "who, where and how" questions is to link IAEA TC efforts with established coastal marine programs. The meeting participants identified several promising prospects in Africa, Asia & Pacific, and Africa, where regional-scale projects are underway with assured medium-term funding.

[2] Many often inter-related processes including coastal flooding; shoreline changes due to engineered structures; beach replenishments; stability of dredge spoils; etc.

Co-operation in the frame of regional projects offers several advantages for further development of IAEA activities in CZM. Regional programmes that are already approved, funded and established provide:

- clear analyses of problems in a defined area;
- an analysis of data gaps, capacity needs, etc.
- assured government commitment often including co-funding;
- defined institutional frameworks; and
- ready-made co-operation between different international, regional and bilateral organisations based on relative strengths.

5.6 PROGRAMME COMPONENT: FEASIBILITY/ PILOT ACTIVITIES WITH REGIONAL CZM PROGRAMMES

The background assessment, as well as the results of the thematic planning meeting showed, that there is a suite of techniques that appear to be of strategic value for specific CZM problems. However there is a need for more region specific information on problems and responses, and a better understanding of the technology/problem linkages. The meeting had too broad a focus, and lacked participants with the expertise to address all issues. Therefore, the group proposed to take the identified "toolbox" of techniques to the field, and carry out the assessment in this framework (GEF funded regional programme or UNEP Regional Seas programme.)

The proposed approach would allow a better understanding of the use of nuclear techniques in the frame of existing projects. It would clarify the relative priority of the nuclear techniques and outline the project context for transferring technology.

It is suggested to undertake these feasibility assessments in the frame of different regions of the world that have different problem mixes in order to develop the "toolbox" approach for different problem sets.

5.7 SELECTION CRITERIA FOR FEASIBILITY/PILOT STUDIES

Workshop participants developed the following criteria for selecting feasibility pilot studies. To be eligible, the proposed study must:

- address an existing, well-characterised problem;
- employ existing infrastructure and a regional commitment;
- apply nuclear techniques that are mature and provide added value;
- be replicable in other areas;
- be sustainable after the pilot study is completed; and
- be assessable.

5.8 PROPOSED FEASIBILITY STUDIES

The workshop recommended three feasibility/pilot studies for IAEA/TC consideration. Of course, these suggestions are predicated on the interest of IAEA Member States in conducting such assessments.

5.8.1 Sustainability of Living Marine Resources: Benguela Current Large Marine Ecosystem

The Earth has four major coastal up-welling systems that lie at the eastern boundary of oceans adjacent to continental margins. These are the Humboldt Current along the west coast of South America; the California Current off the west coast of northern Mexico and California, USA; the Benguela Current off southwestern Africa; and the Canary Current near Northwest Africa. Each of these systems is characterised by nutrient-laden, cold water upwelled from the ocean's depths. These upwelled waters are the most productive areas of the world's oceans, supporting abundant and valuable fishery resources. However, the phenomenon of up-welling is highly variable on annual and decadal scales. Declines in fisheries along the Chilean and Peruvian coasts are associated with decreased up-welling caused by ENSO[3] events in the Pacific, and there is evidence that such a phenomenon is lagged by a similar event in the Southeast Atlantic. The net effect is reduced socio-economic benefits within the affected regions, and a threat to food security globally.

The Benguela Current region in southwestern Africa has forwarded a request to the IAEA through the Benguela Environment Fisheries Interaction & Training (BENEFIT) Program for

[3] El Ninõ Southern Oscillation

transfer of nuclear and isotopic technology to assist in the assessment and management of living resource and ecosystem health issues. BENEFIT is a partnership between Angola, Namibia and South Africa devoted to the long-term sustainability of the Benguela ecosystem.

BENEFIT also is a formal project of the Southern Africa Development Community (SADC), a 14-country body promoting economic development, with eight members being coastal states. The role of BENEFIT in SADC is to facilitate training and technology transfer. Thus, it is expected that experiences gained by BENEFIT through a TC project could have far broader impact than within the 3-country area.

The feasibility work would assess the suite of activities identified by BENEFIT for which nuclear techniques may be appropriate for assisting with high priority problems including:

- harmful algae blooms (HABs),
- population dynamic issues for assessing fishery stocks, especially ageing techniques,
- up-welling variability, as determined through sediment chronology,
- ecosystem health, especially contaminant uptake and monitoring, and
- human health issues related to seafood safety, e.g., mariculture activities and processed fishery products.

While these represent specific areas of interest, other applications of nuclear isotopic technology might apply, including applications to shoreline changes, groundwater hydrology, freshwater/saltwater interface, and wetlands. These applications could be explored in a feasibility study/mission visit to the region, and phased in as appropriate.

GEF-supported Benguela Current Large Marine Ecosystem (BCLME) Project is in the process of being implemented. It complements BENEFIT's mandate of addressing the living marine resources and natural environmental variability of the Benguela Current region. BENEFIT will be the science and technology arm for the BCLME in those areas where there is overlap. All areas of interest for technical co-operation identified above are implicit or explicit in the BCLME Project Document. The proposed term for the BCLME Project is 5 years, extendable. Thus the IAEA activity could be crafted so as to be complementary to the UNDP/GEF Benguela project.

A further potential benefit is that the Benguela Current shares many of the same characteristics as the Humboldt Current (Chile and Peru). Thus efforts here could eventually lead to TCDC opportunities between the two regions.

The workshop participants recommended that the feasibility study be undertaken beginning with a mission or workshop to pave the way for an eventual Benguela Pilot activity.

5.8.2 Managing and Sustaining Mariculture Activities: The East Asia Seas Programme

Mariculture is increasing in socio-economic importance in Southeast Asia, the Pacific, and Latin America. It is imperative to manage organic carbon input at the production sites in order to avoid degradation of water and sediment quality and collapse of the industry. This feasibility study will lead to a pilot activity to provide for nuclear techniques to be used to characterise the biogeochemical impacts of the organic inputs and assess seafood contamination.

If successful, the results will:

- increase the market value of the product;
- provide for sustainability of the industry;
- provide job security at the regional level;
- support market expansion at the national and international levels;
- help producers comply with national and international standards;
- add ecological value to the products.

The workshop recommended that this feasibility study/ pilot activity be undertaken in association with the IMO/UNDP/GEF PEMSEA program, with the Philippines as a likely focal area.

5.8.3 Eutrophication and Contamination in the Coastal Regions of Central America

The coastal marine environment of Central America (the Gulf of Mexico and the Caribbean Sea) is an important natural resource. Both the Gulf of Mexico and the Caribbean Sea are semi-enclosed marine systems with specific water circulation patterns. They form one of the most sensitive ecosystems in the world. It has been recognised that the convergence of numerous economic activities (fishing, navigation, the oil industry, tourism, mariculture, etc.)

which utilise the coastal marine environment for different purposes, as well as land-based activities which contaminate coastal zones, create conflicting interests that can compromise the health of this valuable ecosystem.

The economic activities can lead to enhanced inputs of nutrients and organic matter to coastal areas, which enhance the growth of marine organisms (blooms) and impact water quality. Further, these activities increase the input of contaminants (both radioactive and non-radioactive) to coastal waters, biota and sediment with possible impact on human health through their uptake through the marine food web to consumption by humans. Nuclear and isotopic approaches are highly applicable to addressing these problems.

The objectives of a feasibility study/pilot activity in this area might include:

- increasing the capabilities of Central American countries to use nuclear and isotopic techniques for studying eutrophication and contamination in coastal zones;
- assessing the inputs of nutrients and organic matter to coastal areas leading to eutrophication and growth of blooms that are often harmful to marine biota and humans;
- assessing the impact of submarine groundwater discharge (SGD) on the delivery of nutrients and contaminants in coastal zones and to contribute to better understanding of water balance (groundwater-seawater interaction) in coastal zones;
- developing a database on the levels and distribution of natural radionuclides (^{226}Ra, ^{210}Pb, ^{210}Po) in marine biota in areas of phosphate mining and industry and coal power plants;
- developing sediment chronologies of previous inputs of contaminants (both radioactive and non-radioactive) in coastal zones and to assess whether bloom organisms are an introduced species or have been consistently present in an area.

Numerous Caribbean/Latin American countries are appropriate to include in a feasibility/pilot study in this area, including Mexico (in bilateral collaboration with the USA), Cuba, Venezuela, Jamaica and other Caribbean nations. The regional activity could be structured in the frame of ARCAL and possibly together with UN and inter-governmental organisations and in particular with the UNEP Regional Seas Caribbean Environmental Program (CEP).

5.4.18 Further Research

The workshop participants highlighted the radiometric dating of fish otoliths as an important area requiring collaboration among fisheries and nuclear scientists. The workshop recommended a joint IAEA/FAO activity such as a workshop that would bring these groups together. This was noted as being a special concern of the Benguela LCME program. It was suggested that IAEA/FAO attendance at a BENEFIT workshop to discuss otoliths age dating (to be held in late 2002) is appropriate.

5.4.19 Resource Needs

In light of the above recommendations for pilot studies, the workshop participants recommended that resources be allocated to hold feasibility workshops to evaluate each of three pilot studies. The hope is that at least one feasibility/pilot project could be launched in the next funding cycle.

The workshop participants also took note of the central role that the IAEA MEL facility in Monaco would play in future TC projects focusing on CZM. It was viewed as highly desirable to enhance the administrative support at the MEL for such activities.

5.4.20 Partnerships: Making the link between TC and ICZM efforts

Workshop participants viewed it as imperative that the IAEA get the message out that nuclear approaches exist which have high applicability to solving ICZM problems. Thus an active "engagement" strategy is proposed, including:

- proactive communication with Member States about IAEA capacities;
- participating in international and regional fora (i.e. Regional Seas meetings, GEF Biennial International Waters Conference etc.); and
- development of appropriate public information material.

It is also important to explore new ways for the receipt of TC proposals, for example from regional programs and partnerships between marine institutions and national nuclear agencies.

6.0 RECOMMENDATIONS

The time frame foreseen for implementation of this thematic plan is 5 years (2002-2006), which would include Programme Cycles. Recommendations for implementation are listed below.

6.1. HARMFUL ALGAL BLOOMS

6.2. IMMEDIATE FOLLOW-UP AND MEDIUM TERM STEPS (2002-2004)

6.2.1. Pilot Activities/Feasibility/ Assessments

Further consultations with Member States with severe HAB problems and where appropriate look to hold project assessment missions and/or formulation meetings in the first and second quarter 2002 to allow time to submit regional and inter-regional requests for the 2003-2004 TC programme (by June 2002) where appropriate. Where TC model project and General Criteria are met, prepare pilot activities for 2003-2004 TC Programme in the frame of regional and/or an inter-regional pilot activity.

Conduct further assessments of HAB problems, socio-economic impacts and strategy for IAEA implementation in co-operation with UNESCO/IOC HABs programme where appropriate. Also consider preparing a questionnaire for Member States to better understand their needs and requirements;

6.2.2. Enhancing the Enabling Environment

Immediately undertake the 3 identified components to clarify and improve the enabling environment in 2002 and 2003: 1) AOAC certification; 2) secure supply of saxotoxin and 3) ruggedization of the RBA technique. (See programme strategy for details.) Hold a HABs planning meeting (1st quarter 2002) with representatives from NOAA, USFDA, EU, FAO etc. to develop comprehensive plans for certification process, respective roles and responsibilities etc. as well as to discuss other components for improving the enabling environment. This is urgent given NOAA's plans to begin the certification process in 2002. This will also serve a first step in developing partnerships with NOAA, US FDA, EU, and FAO.

6.2.3. Partnerships and Outreach

Interact with relevant World Bank projects, GEF projects and UNEP Regional Seas programmes to link IAEA TC project activities where appropriate including the following: follow GEF pipeline development to identify co-operation possibilities early in the process; establish direct contact with appropriate programme managers as well as participate in GEF International Waters Biennial Meeting (Oct. 2002).

Disseminate results of the meeting and discuss specific project cooperation opportunities (for example: UNDP: Benguela, PEMSEA, Yellow Sea etc., UNIDO: Humboldt Current, Gulf of Mexico, World Bank: METAP programme, Bohai Bay etc.)
Explore potential for joint training activities with UNESCO/IOC HABs programme where appropriate via their regional HABs programmes.

2005-2006

Integrate initial lessons learned from first pilot activities as well as enhancements in enabling environment and build into related project activities for the 2005-2006 TC programme.

ANNEX 1: LIST OF PARTICIPANTS

Charles Hocutt
Executive Officer, BENEFIT Programme
P.O. Box 912
Swakopmund, NAMIBIA
Tel: 264-64 410-1164; Fax: 264-64 405913
E-mail: chocutt@mfmr.gov.na

Benjamin A. Suárez-Isla
Director – Laboratorio de Toxinas Marinas
Programa de Fisiología y Biofisíca
Instituto de Ciencias Biomédicas
Facultad de Medicina, Universidad de Chile
Av. Independencia 1027
Casilla 70005
Santiago 6530499, CHILE
Phone: (562) 777-6886; Fax: (562) 777-6916
E-mail: bsuarez@machi.med.uchile.cl

Gil Suico Jacinto
Professor & Director
Marine Science Institute
University of the Philippines Diliman
1101 Diliman, Quezon City, PHILIPPINES Tel: +632 922 3962 (direct); 920 5301 (Ext. 7416)
Fax No.: (632)-924-7678
E-mail: gilj@upmsi.ph

Philip Tortell
UNDP/GEF Consultant
Environmental Management Limited
P.O. Box 27-433 Wellington
NEW ZEALAND
Tel.: +64 4 384 4133; Fax.: +64 4 384 4022
E-mail: tortell@attglobal.net

Peter L. Airey
Senior Principal Research Scientist
Environment Division, ANSTO
New Illawarra Road, Lucas Heights,
NSW 2234, AUSTRALIA
Tel: + (02) 9717 3272; Fax: (02) 9717 9293
E-mail: pla@ansto.gov.au

Fran Van Dolah
Marine Biotoxins Programme
NOAA National Ocean Service
Center for Coastal Environmental Health and Biommolecular Research
Charleston, SC 29412, USA
Phone: +1 843 762-8529
Fax: +1 843 762 8700
E-mail: Fran.Vandolah@noaa.gov

Tom Malone
Co-Chairman, UNESCO/IOC COOP Programme
Horn Point Laboratory
University of Maryland Center for Environmental Science
PO Box 775, 2020 Horn Point Road
Cambridge, MD, 21613-0775, USA
E-mail: malone@hpl.hpl.umces.edu

Nguyen Ngoc Lam
Institute of Oceanography
Nhatrang, VIET NAM
Phone number: +84 58 590 476
Fax: +84 58 590 034
E-mail: lam@bot.ku.dk

Hugh Livingston
Director, Marine Environmental Laboratory
International Atomic Energy Agency
4, Quai Antoine 1er, B.P. 800
MC 98012 MONACO Cedex
Tel.: ++ 377 9797 7279
Fax.: ++ 377 9797 7273
E-mail: H.Livingston@iaea.org

Scott Fowler
Radioecology, Section
Head Marine Environmental Laboratory
International Atomic Energy Agency
4, Quai Antoine 1er, B.P. 800
MC 98012 MONACO Cedex
Tel.: ++ 377 9797 7251
Fax.: ++ 377 9797 7273
E-mail: S.Fowler@iaea.org

Pavel Povinec
Radiometrics, Section Head
Marine Environmental Laboratory
International Atomic Energy Agency
4, Quai Antoine 1er, B.P. 800
MC 98012 MONACO Cedex
Tel: ++ 377 9797 7216
Fax: ++ 377 9797 7273
E-mail: P.Povinec@iaea.org

Stephen de Mora
Environmental Studies, Section Head
Marine Environmental Laboratory
International Atomic Energy Agency
4, Quai Antoine 1er, B.P. 800
MC 98012 MONACO Cedex

Tel.: ++ 377 9797 7236
Fax.: ++ 377 9797 7276
E-mail: S.de_Mora@iaea.org
Sandor Mulsow
Radiometrics Section
Marine Environmental Laboratory
International Atomic Energy Agency
4, Quai Antoine 1er, B.P. 800
MC 98012 MONACO Cedex
Tel.: 00 377 9797 7230
Fax.: 00 377 9797 7273

Florence Boisson
Radioecology Section
Marine Environmental Laboratory
International Atomic Energy Agency
4, Quai Antoine 1er, B.P. 800
MC 98012 MONACO Cedex
Tel.: 00 377 9797 7264
Fax.: 00 377 9797 7273
E-mail: F.Boisson@iaea.org

Manfred Groening
Isotope Hydrology Section
International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 200
A-1400 Vienna, AUSTRIA
Tel: 43 1 2600 21740
Fax: 43 1 26007
Email: M.Groening@iaea.org

Jihui Qian
Deputy Director General
Head, Department of Technical Co-operation
International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 200
A-1400 Vienna, AUSTRIA
Tel: 43 1 2600 22300
Fax: 43 1 2600 26007
E-mail: J.Qian@iaea.org

Thomas Tisue
Technical Co-operation Specialist
Concepts and Planning Section
Division of Planning and Coordination
Department of Technical Cooperation
International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 200
A-1400 Vienna, AUSTRIA
Tel: 43 1 2600 26042 (office)
Tel: 43 1 328 4607 (home)
Tel: 43 (0)664 473 2403 (mobile)
E-mail: T.Tisue@iaea.org

Carlito R. Aleta
RCA Coordinator
East Asia and the Pacific Section
Division for Africa, East Asia and the Pacific
Department of Technical Co-operation
International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 200
A-1400 Vienna, AUSTRIA
Tel: ++ 43 1 2600 22313
Fax: ++ 43 1 2600 26007
E-mail: C.Aleta@iaea.org

Andy Garner
Programme Planning Specialist
Concepts and Planning Section
Division of Planning and Coordination
Department of Technical C-operation
International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 200
A-1400 Vienna, AUSTRIA
Tel: ++ 43 1 2600 22446
Fax: ++ 43 1 2600 26007
E-mail: w.a.garner@iaea.org

C. Nelima Okhoya
Programme Planning Officer
Concepts and Planning Section
Division of Planning and Coordination
Department of Technical Cooperation
International Atomic Energy Agency
Wagramer Strasse 5, P.O. Box 200
A-1400 Vienna, AUSTRIA
Tel: ++ 43 1 2600 26005
Fax: ++ 43 1 2600 29500
E-mail: N.Okhoya@iaea.org

Yves Henocque
UNESCO/IOC CZM Prog.
UNESCO
7, place de Fontenoy
75352 Paris 07 SP, FRANCE
Tel: ++ 33 (0)1 4568 1000
Fax: ++ 33 (0)1 4567 1690
E-mail: Yves.henocque@unido.org

Roberta de Palma
Associate Expert
United Nations Industrial Organisation
Wagramerstrasse 5, P.O. Box 300
Vienna, AUSTRIA
Tel.: ++ 43 1 26060/5397
E-mail: rdepalma@unido.org

Donald M. Anderson
Senior Scientist,
Biology Dept., MS #32
Woods Hole Oceanographic Institute
Woods Hole, MA 02543, USA
Tel: +1 508 289 2351
Fax: + 1 508 457 2027
E-mail: danderson@whoi.edu

J. Kirk Cochran
Professor
Marine Sciences Research Centre
State University of New York
Stony Brook,
New York 11794-5000, USA
Tel: +1 631 632 8733
Fax: 1 631 632 3066
E-mail: kcochran@notes.cc.sunysb.edu

ANNEX 2: Components of a Typical Feasibility Study

The feasibility study builds on analyses, information and questions already collected by the Agency during the thematic planning process. As noted earlier, MEL or outside technical experts should prepare a basic project outline: project definition statement, a requirements analysis, and a general design. The feasibility study summarises the findings and places them in the appropriate functional, operational and technical context in a way that supports sound decision making. In particular, the feasibility study elaborates and expands the project definition statement as an operating thesis adding in an iterative and investigative manner a number of new sections and data. The intention is that where a project definition statement, a requirements analysis, and a general design have been prepared, it will be confirmed, updated and expanded where necessary. Much of the supporting detail will be included by reference to other documents and studies.

In order to focus on the most critical information, the feasibility study should be initiated as a one to three page outline containing the following components. The individual items in each component are intended to provide guidance as to the type of information required. (The study need not address items that are not applicable to the proposed project.)

1. Project definition

A brief statement of the technical objective(s) and developmental context, technical approach, comparative advantages, expected costs, benefits, and risks of the proposed project.

2. Background and requirements assessment

Discuss the reasons for the study, such as:

- technical environment
- social/economic need(s)
- commercial opportunities
- functional/operational environment
- statutory/regulatory requirements
- risks to developing a full-scale application
- other

3. Objectives

Discuss the primary objectives of the proposal, such as:

- problems to be solved/opportunities to be gained
- service/product (ion) enhancements
- response to statutory/regulatory requirements
- other

4. Impacts and beneficiaries

Identify the entities which will be impacted by the proposed project, such as:

- inter-IAEA
- intra-IAEA

- regular program(s) and subprogram(s)
- stakeholders of agency activities (e.g., member state organisations, NGOs, governing and technical bodies, etc.)
- other

Identify the beneficiaries which will be impacted by the proposed project, such as:
- affected population groups
- commercial interests
- scientific and academic communities

5. Organisational effects (as applicable)

Discuss how implementation of the investment may affect the agency's organisation, such as:
- impact on work processes
- training needs
- staffing profile and competencies
- other

6. Proposed technical approach/solution

Show how the proposed approach will meet the objectives outlined above. Present the solution in terms of:
- specific work processes and outcomes
- technical tools used to support the solution
- major functions to be provided
- new organisational structures and processes necessary to support implementation.

7. Major alternatives considered
- present the major alternatives considered and compare these with the proposed solution
- reflect that the current state can be considered one alternative
- describe why the alternatives not chosen were rejected

8. Conformity with Agency mission and objectives
- discuss how the proposed project supports/advances the Agency Programmes.
- strategic focus (technical and operational goals)
- effect on infrastructure and technical technology
- other

9. Project management and organisation (including external resources)
- describe the desired project management approach and implementation strategy.
- roles and responsibilities
- decision-making process
- management qualifications
- technical requirements/competencies
- project management organisation
- quality assurance requirements

10. Estimated Timeframe and Work Plan

Provide an estimated timeframe, by project phase, for the formulation through implementation. Identify major tasks and resources required for each project phase, including external and internal staff resources. Identify key milestones and decision points.

11.Cost Benefit Analysis (CBA)

The Agency does not use a standard approach to the cost and benefit analysis. However, standard methodologies exist to provide a structured, calculated method for delivering data in a usable and comparable format. Thus it is not critical but could be important to later steps and partners be able to state the cost and benefit of a proposed application and to do so in a matter that is empirical and evidentiary.