CONTRIBUTIONS OF PAKISTAN IN THE IAEA/RCA/UNDP REGIONAL PROJECT ON MANAGEMENT OF MARINE COASTAL ENVIRONMENT AND ITS POLLUTION

(RAS/8/083)

*Riffat M. Qureshi**

ABSTRACT

The International Atomic Energy Agency (IAEA), Vienna, launched a five-years (duration: 1998 – 2002) Joint Project on "Better Management of the Environment and Industrial Growth Through Isotopes and Radiation Technology (RAS/97/030)" in co-operation with the RCA (Regional Co-operative Agreement) office, Vienna, and United Nations Development Programme (UNDP). The Marine Sub-project entitled "Management of Marine Coastal Environment and its Pollution (RAS/8/083)" is "Output 1.2" of this joint project.

Pakistan is very actively participating in activities of the IAEA/RCA/UNDP Marine Sub-Project that were planned in two Project-Formulation Meetings (PFMs) held at Manila, Philippines, during 1998. In Pakistan, various activities of the national marine-pollution project are being administered by the nuclear institute namely, Pakistan Institute of Nuclear Science and Technology (PINSTECH), in collaboration with national end-user institutions. To-date, Pakistan has significantly contributed in this project, both at national level and at RCA regional level. This paper highlights the progress and some accomplishments of Pakistan, up to the year 2001, for marine-pollution studies related to the IAEA/RCA regional marine sub-project.

OUTLINE OF MARINE COASTAL ENVIRONMENT OF PAKISTAN

The coast of Pakistan is about 960 km long and borders the Arabian Sea. It extends from the border of India near Rann of Katch in the South-East, to the border of Iran near Gwader in the North-west (Figure-1). The territorial coastal zone of Pakistan is 23,820 sq. km, while the 'Exclusive Economic Zone' (EEZ) of Pakistan's territorial marine waters is about 240,000 sq km. Administratively, the coast of Pakistan is divided into a 745 km long strip, called the Baluchistan/Makran coast, and a 215 km long strip, called the Sindh coast. The Balochistan coast has small towns with a population of about one million. Due to lack of industry and population, the Balochistan coast is relatively free of pollution. The coastal belt of Balochistan, specially the Makran coastal belt, is one of the eight ecological zones that are the most backward and non-productive areas of Pakistan. The Sindh coast consists of the Indus River Delta and Pakistan's largest population and industrial center namely, the Metropolitan Karachi. In contrast to the Balochistan coast, very serious problems of environmental pollution exist along the Sindh Coast (mainly along Karachi coast and Indus Delta zone). With the exception of Karachi metropolis, most of the coastal areas of Pakistan are sparsely inhabited. The coastal zone supports both living and non-living resources, which annually contribute to the national economy. Further, the mangrove ecosystem of the Indus deltaic region is also of significant economic as well as of scientific interest to Pakistan. The mangrove habitat supports the spawning and breeding grounds of commercially important shrimps as well as a variety of other fishes. In the absence of an alternative resource, mangroves also serve the underprivileged inhabitants of coastal communities as a valuable source of timber, charcoal and fodder for domestic animals.

There are a number of environmental issues in the coastal zone of Pakistan and, amongst these, the disposal of domestic wastes and industrial effluent, causing marine pollution problems along the urban centers, are the most significant. The pollution problems have arisen mainly from the indiscriminate discharge of effluent, from industrial and agricultural sources, and disposal of untreated liquid and solid wastes, generated from domestic sources, into the coastal environment. In addition, the coastal developmental activities involving man-made alterations of the coastal environment have also accelerated the impacts of pollution, leading to the deterioration of quality of coastal environmental, depletion of coastal resources, public health risks and loss of bio-diversity. The coastal city of Karachi has an estimated population of 13 million, and is the biggest

* Chief Scientific Officer, Radiation and Isotope Application Division (RIAD), PINSTECH, P.O. Nilore, Islamabad, Pakistan.

trade & economic center of Pakistan, with more than 6,000 small and large industrial units. The sewage waste generation in Karachi is some more than 300 m gal /day, out of which 40% is domestic waste and 60% is industrial waste. This waste is dumped into the Karachi sea, via Malir river (Ghizri-Korangi Creek area), Layari river (Manora Channel/Karachi Harbour area) and small waste-drains mainly along Clifton Coast and Korangi Coast (Figure-2). The other coastal areas having industrial-pollution problems are Hub Coast, through Hub Industrial Estate, and Gadani Coast, through industries based in Gadani area. The heavy metals, persistent organic pollutants, air pollution and oil pollution are the more significant factors. There is very little information available on the impacts of persistent organic pollutants in the coastal areas of Pakistan although, their presence is noticeable particularly in solid-wastes disposal. The heavy metals in the coastal waters of Karachi are being accumulated in the sediments and marine organisms, particularly those resident in the polluted areas. The accumulation of eight heavy metals (As, Cd, Co, Cr, Cu, Hg, Ni, Pb, and Zn) in the resident fauna from polluted coastal areas of Karachi has been reported. The heavy metals are being accumulated in considerably higher concentrations in marine organisms of the polluted localities. The accumulation of five heavy metals (Cu, Co, Mn, Zn, and Fe) in the resident fauna from Gharo, Bakran and Korangi Creeks in considerably higher concentrations has been reported in marine organisms comprising resident fauna of fishes including edible fishes, shrimps, some benthic organisms (bivalves and barnacles) from these areas. The concentrations of iron and zinc were found to be higher than the corresponding values for Mn, Cu and Co.

Oil pollution appears to be of some concern along the Pakistan coast. Sources of oil-pollution include effluent discharges from two oil refineries, mechanized fishing boats and the cleaning of bilges and tank-washing by the large number of merchant vessels, as well as oil-tankers that pass through the EEZ of Pakistan yearly (2500 oil tankers carry 33 million tons of crude oil, ICZM report, 1994). As a consequence, tar balls (residues of weathered oil at sea) are commonly found on beaches. The recent case of oil-spill (4 June, 1998) from the ship R.V. Yashica, abandoned about 304 km south-west of Karachi (approximately 112 km south of Pasni), which was carrying 1500 tons of furnace oil.

The problem of Harmful Algal Blooms (HABs) in Pakistan is very recent. It is not that it was not occurring in the past, but we were not in fact taking notice of it, due to lack of information of its occurrence and absence of HAB alarm network. However, in the last few years several incidences of mass-mortality of fishes have been recorded in the marine coastal environment of Pakistan. Type and origin of bloom observed at specific sites along the coast varies: it may be generated locally or may have originated at some distant location and then moved by coastal currents. Factors that trigger Harmful Algal Blooms are also yet unknown. Likewise, spatial origins of blooms are presently unknown in this area. Increasing frequency and intensity of harmful algal blooms in the region and their concomitant adverse socioeconomic impacts pose a major problem in affected countries. Developing countries, like Pakistan, are especially vulnerable to the effects of toxic bloom and red tide outbreaks, because of lack of information on how to cope with red tides, and insufficient scientific and managerial expertise in this field. The toxic algal bloom appears usually once or twice in every year in this region, and cause mass mortality among fishes. *Prorocentrum minimum* bloom was observed in Gwadar Bay, which was the main factor for the poisoning of fish (Rabbani, 1990). The bloom occurred in 1987 in east Gwadar bay, a semi-enclosed shallow coastal body of highly productive water, on west coast of Pakistan. This bloom lasted for about a week that is why it was possible for the scientists to take samples and analyze them.

Over the past twenty years or so, toxic algal blooms have increased around the world in their frequency, magnitude and geographic extent, as well as in their resulting effects. It is also observed that unusual mortality of fish in the Arabian Sea has increased in last few years, which ultimately adversely affects fish-marketing and fisheries industry and is of increasing public concern. Though potential "*Red Tide'* forming organisms like *Gonialax* (Saifullah, 1973, 1978), *Noctiluca scintillans* (Saifullah, 1990), *Phaeocystis* (Chaghtai, 1997) & *Peridinium* (Hassan, 1973) have been reported by several workers, in recent incidences (Year: 1999 - 2000) of red tide in Pakistan's coastal waters where wild fish population were hit by this phenomenon including Rough tooth & Bottle nose Dolphins, Speckled Siderial Moray, File fish and Parrot fishes, baleen whale was also found dead. During this period, water-samples showed the bloom forming concentrations of *Gymnodinium*

and *Noctiluca species*. In order to minimize the damage to public health, aquaculture and marine ecosystem, a comprehensive monitoring system is essential.

IAEA/RCA/UNDP MARINE SUB-PROJECT *(RAS/8/083)*

Regional Scenario

The IAEA (International Atomic Energy Agency), Vienna, in co-operation with the RCA (Regional Co-operative Agreement) office, Vienna, and the UNDP (United Nations Development Programme) has launched a Joint UNDP/IAEA/RCA Project (RAS/97/030) on "*Better Management of the Environment and Industrial Growth Through Isotopes and Radiation Technology (1998 – 2002)"*. The Joint Project 'RAS/97/030' has five outputs; the Marine Sub-project entitled *Management of the Marine Coastal Environment and its Pollution (RAS/8/083)* is designated as output 1.2 of this Project The UNDP has funded the Marine Sub-project under the project RAS/8/080, while the RCA Member States fund the Marine Sub-project in its initial phase under the project RAS/8/083. The IAEA funds the Marine Sub-project under the combined projects: RAS 8/076, RAS 8/082 & RAS 8/084. The Australian Nuclear Science and Technology Organization (ANSTO) and the Philippines Nuclear Research Institute (PNRI) are potentially funding the project-activities. Australia is also acting as the Lead Country for this project, assisted by India. The RCA Member States have to perform field and laboratory activities for the respective national marine sub-project, through in-kind contributions and national collaborative arrangements among end-user institutions.

Various activities of the IAEA/RCA/UNDP Marine Sub-project were decided in two Project-Formulation Meetings (PFMs) held at Philippines Nuclear Research Institute (PNRI)-Manila, Philippines (23-27 Feb., 1998 and 30 Nov. - 04 Dec. 1998). National Coordinators from various RCA Member States attended the PFM and discussed availability of in-kind financial resources, national collaborative arrangements, training requirements, as well as needs for RCA regional collaboration and inputs required from IAEA to properly execute project-activities along the RCA national coastal marine environments. The Marine Sub-project was thus designed to:

a. Accomplish the following four tasks along the RCA national marine coastal environment:

   i Establishment of a National Database on Marine Radioactivity;
   ii Establishment of Levels, Behaviour and Fate of Radioactive and Non-radioactive Pollutants in the Marine Water and Food web, through Nuclear and Conventional Techniques
   iii Application of Nuclear and Modelling Techniques to Sustainable Development in the Coastal Zone
   iv Evaluation of Harmful Algal Bloom (Red Tide) Concerns, along the Coast, through Application of Nuclear Techniques

b. Hold training events and mid-term review meetings, in Marine Sub-project Lead Countries (Australia, India, Philippines) and Regional Resource Units/Participating RCA Member States, for project specific activities (Pakistan, China, Thailand, Philippines, Malaysia, Australia & India) to assist the participating RCA Member States in South Asia to adequately perform project-activities

c. Organize execution of national marine pollution project related specific activities, through collaborative in-kind arrangements at national level involving the National Atomic Energy Authorities and the national/regional End-user institutions.

The project document for the marine sub-project was finally compiled, updated by the Lead Country Coordinator: Dr. Peter Airy (ANSTO/Australia), and distributed to the designated RCA national coordinators of the marine sub-project.

National Scenario

Following the two PFMs held at PNRI-Manila (1998), Pakistan is very actively participating in the IAEA/RCA Marine Sub-Project. Various activities of the national marine pollution project are being administered by the Pakistan Atomic Energy Commission (PAEC), in collaboration with the national end-user institutions of this project and according to the programme set-forth by the Lead Country Coordinator (Dr. Peter Airy, *ANSTO/Australia)*.

Under the charter of the IAEA/RCA/UNDP Marine Sub-project RAS/8/083, the national nuclear institute viz. PINSTECH, Islamabad,

initiated essential field and laboratory activities in collaboration with other key end-user institutions. PAEC has designated the following officials to co-ordinate Pakistan's National Marine Sub-project activities among National End-User institutions:

RCA National Coordinator

Director, International Affairs and Training
Pakistan Atomic Energy Commission (PAEC)
P.O. Box 1114, Islamabad, Pakistan
Phone: 92-51-9201862
Fax: 92-51-4908

RCA National Project Counterpart

Director General
Pakistan Institute of Nuclear Science & Technology (PINSTECH)
P.O. Nilore, Islamabad, Pakistan
Telephone: 92- 51- 2207201
Fax No.: 92- 51- 9290275

RCA National Sub-Project Coordinator

Dr. Riffat Mahmood Qureshi
Head, Environment Research Group,
Radiation and Isotope Applications Division (RIAD),
Pakistan Institute of Nuclear Science & Technology (PINSTECH)
P.O. Nilore, Islamabad, Pakistan
Telephone: 92- 51- 2207228 and 9290231- 7 (Extension: 3433)
Fax: 92- 51- 9290275
Email: riffat@pinstech.org.pk

At the national level, essential infrastructure and scientific facilities exist at the nuclear institute and potential end-user institutions. The Pakistan Institute of Nuclear Science and Technology (PINSTECH) has well-established capabilities for application of both stable isotope (^{13}C, ^{15}N, ^{34}S, ^{2}H, ^{18}O) & radioactive isotope (^{3}H, ^{14}C, ^{137}Cs, ^{90}Sr) techniques, as well as nuclear related analytical techniques (NAA, ICP, XRF, AA etc.) for study of the four components/tasks of the marine pollution project. Development of facilities for measurement of natural levels of radionuclides, such as ^{210}Po, ^{210}Pb, $^{239+240}Pu$, are underway. Based on this, the IAEA has recognized PINSTECH as a Regional Resource Unit (RRU) for the Component-II (Fate & Behaviour of Pollutants/ Contaminant Transport) of the IAEA/RCA Marine Sub-project, to help participating RCA member states in the development and application of stable isotope methods and the Direct $^{14}CO_2$ Absorption Technique for ^{14}C dating for the identification of pollution source terms and for isotope analysis of marine environment samples. Field sampling equipment, as well as analytical facilities for organic pollutant analysis (HPLC, G.C.) and biological analysis, are also available at the potential national end-user institutions of the marine project, such as the NIO-Karachi, PN, CEMB-Karachi University, HEJ-Karachi University, MFD (GoP)-Karachi, MSA and KFHA, KPT etc. It is worth mentioning that Pakistan Navy (PN), National Institute of Oceanography (NIO)-Karachi, and the Center of Excellence in Marine Biology (CEMB), Karachi University, Karachi are very strongly supporting execution of various national activities of this project through in-kind contributions.

NATIONAL PLAN OF ACTIVITIES

Development of Collaboration Among End-User Institutions

The National Coordinator of the IAEA/RCA marine sub-project made successful efforts to strengthen collaboration between National Nuclear Institute [PINSTECH/ Pakistan Atomic Energy Commission (PAEC)] and the end-users of the national marine-sub-project to mobilize local resources for accomplishment of research-plans in view of the activities of the Marine Sub-project. The following End-User Institutions indicated their willingness to participate in the field and laboratory activities of the national marine pollution project:

KFHA:	Karachi Fisheries Harbour Authority, Karachi
FCS:	Fishermen Co-operative Society Ltd. (Karachi)
KPT:	Karachi Port Trust -Karachi
KU	University of Karachi, Karachi
CEMB:	Center of Excellence in Marine Biology
DoG:	Department of Genetics (Karachi University)
HEJ:	Hussain Ebrahim Jamal Institute of Chemistry
MEL:	Mangrove Ecosystem Laboratory (Department of Botany)
MFD:	Marine Fisheries Department, Government of Pakistan -Karachi
MSA:	Maritime Security Agency Karachi
NGO:	Non Governmental Organizations
WWF:	World Wildlife Fund for Nature (Pakistan Office-Karachi)
IUCN:	International Union for Conservation of Nature & Natural Environment (Karachi Office)
NIO:	National Institute of Oceanography (Karachi)

PAEC: Pakistan Atomic Energy Commission (Islamabad):
PINSTECH: Pakistan Institute of Nuclear Science & Technology, (Islamabad)
RIAD: Radiation & Isotope Application Division (PINSTECH)
HPD: Health Physics Division (PINSTECH)
KNPC: Karachi Nuclear Power Complex (Karachi)
HPD: Health Physics Division (KNPC)
PAK-EPA: Pakistan Environmental Protection Agency (Islamabad)
EPA-Sindh Province
EPA-Balochistan Province
PN: Pakistan Navy, Naval Headquarters, Islamabad
PN Dockyard Lab: Pakistan Naval Dockyard Laboratory, Karachi
MA & EC: Directorate of Maritime Affairs & Environmental Control (Naval Headquarters, Islamabad)
MPCD: Marine Pollution Control Department (Karachi)
ZSD: Zoological Survey Department of Pakistan (Karachi Office)

Planning Meeting of National End-User Institutions

PINSTECH organized a meeting of the representatives of above mentioned key end-user institutions for the Marine Sub-project at the National Institute of Oceanography, from 2-3 June, 2000, to formulate national plan of activities for marine pollution studies along the coast of Pakistan, in relation to the Marine Sub-project. The meeting was attended by 35 representatives belonging to 21 different government and non-government organizations involved in the management of coastal areas.

The following objectives were accomplished at the planning meeting:

- Review of progress made to-date on execution of various field & laboratory activities and studies, participation in IAEA/RCA sponsored training fellowship programmes, hosting of RCA Review Meetings and RCA Regional Training Courses in Pakistan, in line with the Pakistan's National Marine Pollution Project.

- Dissemination of up-to-date information received from the IAEA/RCA Office-Vienna to end-user institutions on various components of the IAEA/RCA/UNDP Marine Sub-project (RAS/8/083).

- Evaluation of available in-kind resources & future requirements by collaborating end-user institutions for proper execution of field and laboratory activities, in view of tasks as defined in the Pakistan's National Marine Pollution Project Proposal, and handle any shortcomings through in-kind arrangements, IAEA/RCA expert missions and/or training fellowships & available funds for supplies.

- Organization of suitable work plan, time schedule / protocols and field teams for execution of field-sampling trips (tentatively during Fall 2000 and Summer 2001/2002) along selective locations of Pakistan Coast (mainly in the vicinity of developing harbours and fish concentration centers, such as: *Indus Delta, Karachi Coast, Damb Sonmiani, Miani Hor, Ormara, Kalmat Khor, Pasni, Gwader, Gwater and Jiwani (Ref. Figure-1)* for collection of shallow seawater samples (mainly within 30 meter depth line, and a few samples from deeper depths within the Exclusive Economic Zone (EEZ) limits of Arabian Sea along Pakistan Coast, sea-bottom sediment samples, sea-bottom sediment core samples, marine biota samples (fish, crabs, mussels, seaweeds, mangroves etc.), as well as, transportation of marine samples to concerned end-user institution laboratories for chemical, biological, radioactive and non-radioactive isotopic analysis.

Representatives of participating institutions presented a 15-20 minutes duration seminar on their interest / level of participation in specific components of the National Marine Pollution Project, work plan, existing experience, field & laboratory facilities available at institute/department, requirement of collaboration from participating end-user institutions for sampling/analysis, baseline data available at participating department for a specific component of project. At the National Planning Meeting, the participating end-user institutions agreed to collaborate for accomplishment of marine pollution studies along the coast of Pakistan, under a National Marine Project Title: *'Application of Nuclear Techniques For Management of Marine Coastal Environment And Its Pollution In Pakistan*. It was further agreed to accomplish various tasks of the national marine project under the following four components, in line with the IAEA/RCA/UNDP Marine Sub-project RAS/8/083:

Component-I:	*Establishment of marine radioactivity database for the coast of Pakistan, with special reference to Karachi coast and Indus delta*
Component-II:	*Establishment of levels, behaviour and fate of radioactive and non-radioactive pollutants in the marine water and food web, through nuclear and conventional techniques*
Component-II A:	*Baseline studies of chemical pollution inventory in the mangrove ecosystem off the Pakistan coast*
Component-II B:	*Isotopic and chemical investigations of pollution inventory in marine water and sediments, with special reference to the mangrove ecosystem off Pakistan coast*
Component-II C:	*Environmental isotope content of marine food web in selective estuarine and near-shore shelf ecosystems off the Pakistan coast*
Component-III:	*Application of nuclear and modeling techniques to sustainable development along Karachi Coast and Gwadar Coast*
Component-IV:	*Baseline studies on harmful algal bloom concerns, in coastal marine environment of Pakistan*

Various activities and tasks involved in the four components of National Marine Pollution Project were discussed in the planning meeting. Discussion were also made on designation of field-sampling and laboratory-analysis teams and related task-distribution among participating end-user institutions. The participant from Pakistan Navy (Dockyard Laboratory-Karachi) indicated its serious concerns on heavy corrosion problems to naval vessels and structures in the Karachi Harbour, mainly due to marine pollution and activities of sulfate-reducing bacteria (SRB). The laboratory has requested to probe the problem through national collaborative arrangements. Likewise, the participants from CEMB-Karachi University indicated the need to study the Harmful Algal Bloom Concerns along the Coast of Pakistan, with special reference to the Karachi Coast.

Projections of Work Plan

In order to accomplish tasks related to the four components of the National Marine Pollution Project, and those identified by the representatives of the participating end-user institutions, specifically, the Pakistan Navy and the Center of Excellence in Marine Biology-Karachi University, it was decided to carry out specific field-sampling activities at selective locations along the coast of Pakistan at least twice: once during Fall 2000 (*Calm sea period*), and then again in Summer 2001/2002 (*rough sea period*). The main study-sites of interest include the following:

Sindh Coast:	*Indus River Delta, Karachi Coast, Damb Sonmiani*
Balochistan Coast::	*Miani Hor (Coastal Lake), Ormara, Kalmat Khor (Coastal Lake), Pasni, Gwader, Gwater and Jiwani*

Table-1 (annexed at the end of the paper) highlights tentative marine sampling activities along the coast of Pakistan, in terms of proposed participation of end-user and institutions for in-kind provision of facilities for sample collection, manpower & transport and logistics for the sampling team, etc., as well as the type and amount of samples to be collected at each location. The key elements of tentative work-plan off Pakistan coast during the period 2000 - 2002 are summarized in the following section.

1. **Year 2000**

   a. Representative collection of water, sediment and biota samples for chemical, stable isotope, radioactivity and biological analysis along the coast of Pakistan during (winter monsoon period, calm sea conditions).
   b. Sampling of HAB Cyst/sediment Core samples at specific locations along the coast of Pakistan, for biological analysis and sediment core dating.
   c. Participation in the IAEA/RCA Training Workshops/Meetings/Activities related to marine sub-project
   d. Preparation of Interim reports for presentation at the IAEA/RCA Meetings and publication.

2. **Year 2001 & 2002**

   a. Representative collection of water, sediment and biota samples for chemical, isotopic and biological analysis along the coast of Pakistan during Fall 2001/2002 (Summer monsoon period, rough sea conditions).
   b. Sampling of HAB Cyst/sediment Core samples at specific locations along the coast of Pakistan for biological analysis and dating.
   c. Strengthening the establishment of Harmful Algal Bloom Network along the Coast of Pakistan and Training of Fishermen for Alert Network Activities
   d. Study of Coastal Sediment Erosion at selective marine sites, using nuclear techniques (using ^{137} Cs Isotopes etc.)
   e. Modeling of pollution transport in Karachi Harbour and associated sea-environment, using chemical analysis and tracer data.
   f. Establishment of HAB Analysis Laboratory at NIO-Karachi and Organization of National/Regional Training Workshop for the HAB Component, in Collaboration with IAEA/RCA.
   g. Organization of National/Regional Training Workshop for Computer Modeling of contaminated estuarine environments/quality evaluations, Interpretation of data & computer modeling.
   h. Participation in the IAEA/RCA Training Workshops/Meetings related to the marine sub-project
   i. Preparation of Interim and final reports.
   j. Publication of research findings for each component of the National Plan of Activities.

In addition, upon request from an RCA Member State, Pakistan will provide service analysis (being an RRU for the marine sub-project RAS/8/083) for stable isotope (O-18, H-2, C-13, S-34, N-15) analysis (by mass spectrometry) and C-14 analysis (by LSC and CO_2 Absorption Technique) and H-3 analysis (by LSC and Electrolysis Enrichment Technique) at the nuclear institute (PINSTECH).

UPDATES ON ACCOMPLISH-MENTS OF NATIONAL MARINE PROJECT RELATED FIELD AND LABORATORY ACTIVITIES

Component-I: Establishment of a Regional Database on Marine Radioactivity

Organization of the 1st IAEA/RCA Review Meeting (ASPAMARD):

PINSTECH/PAEC organized the 1st IAEA/RCA Review Meeting to Analyze Regional Database on Marine Radioactivity (RCA) in Islamabad from 12 to 14 April, 1999, to assess the current status of marine radioactivity database, to identify gaps in the database and to plan how the gaps might be filled. Thirteen (13) participants from twelve (12) RCA member states (Australia, Bangladesh, China, Republic of Korea, India, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, Vietnam) and three (3) observers from national end-user institutions attended the meeting. The deliberations of the meeting consisted of four (4) Technical Sessions. A full report of the Meeting has been issued [IAEA, 1999].

Pakistan's Marine Radioactivity Database:

Water and sediment samples collected by PINSTECH designated field-team from polluted Layari & Malir River downstream (pre-outfall), Ghizri Creek, Layari River outfall in Karachi harbour, Karachi Harbour/Manora Channel Mains, as well as from open sea (South-East Coast and North-West Coast) within the 10m depth contour. The samples were analyzed at HPD/PINSTECH for a range of natural radionuclides (^{40}K, ^{60}Co, ^{137}Cs, ^{226}Ra, ^{228}Ra), using a Hyperpure Germanium (HPGe) Gamma Spectrometer. In addition, radioactivity data of selective fish-flesh samples and sediment samples was obtained from Health Physics Division, Karachi Nuclear Power Plant (KANUUP). Results are summarized in Table-2, vis-à-vis comparison with IAEA radioactivity Reference Materials for similar matices. No artificial radionuclides (e.g. ^{60}Co, ^{137}Cs and ^{134}Cs) were detected in both water and sediment samples at any of these locations. The activity of ^{226}Ra in coastal river sediments is found to be below its limit of detection (<18.35 Bqkg^{-1}).

Component-II: Determination of the Levels, Behaviour and Fate of Radioactive and Non-Radioactive Pollutants in the Environment Through Isotope and Nuclear Techniques:

Stable Carbon Isotope Analysis of Marine Environment Samples:

Stable carbon isotope analysis ($\delta^{13}C$) of total dissolved inorganic carbon (TDIC), seaweeds, mangroves, animal shells and sea-bottom sediments was made to quantify the flow /transport of carbon from Layari River Outfall Zone and Malir River outfall Zone (Ghizri-Korangi Creek) in to the Karachi sea environment, with special reference to the impact of mangrove ecosystem on marine pollution. $\delta^{13}C$ (TDIC) values enabled identification of areas of high pollution inventory, in shallow off-shore waters of Karachi coast (within 20 m sea depth line). This study indicated that stable carbon isotopes can be used as a dynamic tracer for the study of pollution-transport in marine environment.

Application of Environmental $\delta^{18}O$ (water) and $\delta^{34}S$ (Aqueous Sulfate) as Tracers of Pollution Transport:

In the year 1999-2000, preliminary investigations were made to explore the potential and suitability of stable isotopes of oxygen ($\delta^{18}O$) in water molecule, and sulfur isotopes ($\delta^{34}S$) in aqueous sulfate, for use as pollution tracers. Selective water-samples collected during low-tide conditions from various locations, in Manora Channel/ Karachi Harbour, Layari River, Ghizri Korangi Creek and the Karachi Sea, were analyzed for $\delta^{18}O$ (water) and $\delta^{34}S$ (aqueous sulfate). Using the chemical as well as isotope balance equation for mixing of two water bodies (two-component mixing system), the polluted mixture of sea water and Layari river water/Layari River Outfall Zone water, across a mixing profile opposite KPT Shipyard in Karachi Harbour area, was analyzed to identify the % contribution of: inorganic pollution, inorganic carbon coming from Layari River and Layari River Outfall Zone, as well as the amount of Layari River water in the mixture (Table-3). Results indicate that, within the measuring precision limits for oxygen isotopes, $\delta^{18}O$ (water) can be used to as a reliable tool to identify the amount of water coming from either of the water-sources (sea or polluted river or outfall zone) for modelling purposes (application for Component-III of the Marine Sub-project). Results on $\delta^{34}S$ (aqueous sulfate) also gave a good clue to the input percentages of sulfur from the polluted Layari river. However, the applicability of both these isotopes is restricted to narrow navigational channels and backwater zones.

Use of Mangrove Tree Rings as Indicators of Pollution Inventories:

Studies were also made to identify the potential of Mangrove Tree Rings as qualitative tracers of pollution-inventory in polluted zones off Karachi Coast. Mangrove tree rings, pertaining to a profile of trees (growth age band: Years: 1918 – 1996) collected from Manora Channel Backwaters (Layari River Outfall Zone) and a profile of trees collected from Korangi Creek/South-east coast of Karachi/industrial area (growth age band: Years: 1948 – 1996), were analyzed for $\delta^{13}C$. Tree ring were separated with a fine chisel, freeze dried, grounded in a Whiley™ Grinding Mill, combusted in a modified Parr™ Oxygen Combustion bomb for conversion into CO_2 gas, and analysed for stable carbon isotope ratios ($\delta^{13}C$ per mil. PDB), using a gas-source mass spectrometer. Results indicate that $\delta^{13}C$ values of mangrove tree-rings grown in Korangi Creek area are depleted by about 1 to 1.5 per mill in ^{13}C, as compared to mangroves grown in the polluted outfall zone of Layari river outfall zone in Manora channel. This signifies the impact of industrial pollution (in addition to domestic waste) drained by the Malir River in to Ghizri/ Korangi Creek, in contrast to mainly domestic wastes drained by the Layari river. Work is in progress.

Component-III: Application of Nuclear and Modelling Techniques to Sustainable Development in the Coastal Zone

Two manuals containing details on subroutines and use of two-dimensional and three-dimensional "Finite Element Models" for Environmental Modelling Using the "RMA Suit" (evaluation of flow/quality in estuaries and streams), along with related programmes on computer CD & Floppies as obtained through participation in the Regional Training Course (RCA) held at the Water Research Laboratory, University of New South Wales, Australia (16-20 Nov., 1998), were provided to an End-user institution (NIO-Karachi) for installation / testing of software and routine analysis of field data to be obtained through activities under national programme for marine pollution studies.

Component-IV: Application of Nuclear Techniques to Address Red Tide (Harmful Algal Bloom) Concerns

Field Sampling:

During November - December, 2000, PINSTECH field-team performed coastal marine sampling trip along the entire 960 km long coastal strip of Pakistan and collected 28 shallow off-shore sediment cores (25 -35 cm depth), as well as 11 net samples of marine phytoplankton for identification of HAB Cyst and dominant diatoms, dinoflagellates & Siliflagellates by CEMB-Karachi University and NIO-Karachi and radiometric dating at PINSTECH; also 111 seawater samples for stable isotope analysis of H, O in seawater, C (total dissolved inorganic carbon) at PINSTECH.

Cyst Identification:

To-date, out of 28 sediment cores, only 7 cores (25 % of the total sediment core samples) have been analyzed by a researcher from CEMB-Karachi University for cyst identification, etc., initially at CEMB-Karachi University, Pakistan, and then at the University Marine Biological Station, Millport, Isle of Cumbrae, Scotland, United Kingdom, and Marine Science Institute, University of Philippines, Quezon City, Philippines. In six sea sediment-cores, only diatom shells, dinoflagellate organism and pollens, and some cysts of different non-toxic dinoflagellates were detected. Only one sediment-core (No. GW1) collected off Gawadar Coast (along coastal strip of Balochistan Province) has clearly indicated presence of Toxic/Harmful Algal Species namely: *Pyrodenium Bahamense* and *Protoperidinium sp*. at a depth of 2 cm (Chaghtai and Qureshi, 2001). The Scanning Electron Micrographs of these cores were obtained for record. This finding is quite important, as mass mortality of fish has been reported previously along Gawadar coast. Researchers from NIO-Karachi independently performed field-studies for measurement of seasonal variations in some key physical parameters in marine sediment-cores collected during July-October, 2000 and February-April, 2001 off Sindh coast and Balochistan coast. IAEA/RCA has awarded training fellowships to two researchers from key end-user institutions in Pakistan.

Training Fellowship:

IAEA/RCA Office Vienna awarded Training Fellowships to two researchers from end-user institutions in Pakistan for laboratory-oriented training in the field of Harmful Algal Bloom Concerns.

i. Ms. Furqana Khalid Chaghtai (IAEA Fellowship Code: Pak/01012RV), Research Officer, Center of Excellence in Marine Biology-Karachi University, Karachi, completed 2-weeks training in Cyst identification at the Marine Science Institute, University of Philippines, Quezon City, Philippines, during June, 2001, under supervision of Dr. Rhodora Azanza. This researcher is responsible for identification of HAB Cyst in all marine sediment samples off the Pakistan coast for the IAEA/RCA Marine Sub-project.
ii. Ms. Hina Saeed Baig (IAEA Fellowship Code: Pak/01013R), Research Officer, National Institute of Oceanography (NIO), Karachi, completed 6 weeks training in the field of Radionuclides and Radiation in Aquatic Biology, with special reference to Receptor Binding Assay (RBA) Technique at the Philippines Nuclear Research Institute (PNRI), Quezon City, Philippines, starting on 2 November, 2001. Ms. Hina Saeed Baig is now preparing for establishment of the RBA Laboratory at the National Institute of Oceanography-Karachi. IAEA/RCA has provided some minor supplies & accessories to NIO for this purpose.

RRU ACTIVITIES

PINSTECH/Pakistan is an IAEA/RCA designated Regional Resource Unit (RRU) for the Component-II of RCA/IAEA Marine Sub-project (RAS/8/083) for provision of training, and environmental isotope-analysis of marine water, sediment and biota samples. The Environment Research Group of the Radiation and Isotope Applications Division (RIAD) at Pakistan Institute of Nuclear Science & Technology (PINSTECH) organized the IAEA/RCA Regional Training Course on Application of Stable Isotope and Direct $^{14}CO_2$ Absorption Techniques in the Analysis of Marine Pollutants, held at Islamabad & Karachi from 04 to 13 October, 1999. The main objective of Training Course was to train RCA participants for determination of the levels, behaviour and fate of radioactive and non-radioactive pollutants in the marine environment, mainly

through isotope or nuclear techniques. The deliberations of the Training Course consisted of rigorous lecture-sessions as well as laboratory & field practical demonstrations. A total of fifteen (15) participants from Eight (8) RCA Member States (China, Indonesia, Malaysia, Pakistan, Philippines, Sri Lanka, Thailand, Viet Nam) and four (4) observers from end-user institutions in Pakistan [NIO-Karachi, Pakistan Navy, CEMB-Karachi University, KNPC-Karachi] participated in the training course. Lectures were delivered by three (3) IAEA/RCA Experts from Australia (Mr. Ronald Szymczak, ANSTO, Sydney, Prof. Allan Chivas , School of Geosciences, Wollongong University and Dr. Stewart Walker, Chemistry Centre, East Perth) and a number of local experts (from national end-user institutions, Islamabad/Karachi). At RIAD/PINSTECH, Islamabad, the participants were trained in laboratory sample-preparation techniques for stable isotope analysis of H, O, C, S and N by Gas Source Mass Spectrometry, as well as C-14 determinations in marine water, sediment and biota samples, using the novel Direct $^{14}CO_2$ Absorption Technique (developed by Dr. Riffat Qureshi, PINSTECH) and Liquid Scintillation Spectrometry. At the National Institute of Oceanography (NIO), Karachi, the participants were trained for marine organic pollutant analysis, using the conventional HPLC and G.C. techniques. The field-demonstrations for in-situ physiochemical measurements and collection of sea-water, sediments and biota samples were performed at Karachi-sea, using Survey Boats and Oceanographic Research Vessel named: SV Behr Paima provided by the Pakistan Navy. Copies of course-material (lectures & laboratory sample preparation & measuring procedures) were distributed among the participants.

CONCLUSION

Initial field and laboratory studies along the coast of Pakistan for the IAEA/RCA Marine Sub-project RAS/8/083 are very encouraging. Stable isotopes of carbon, oxygen and hydrogen have been potentially used to trace transport of pollution in shallow marine waters off the Pakistan coast, specially, the Karachi coast. Environmental radioactive isotope contents of Uranium series radionuclides: ^{40}K, ^{137}Cs, ^{90}Sr are determined in selective marine samples (water, sediment and biota). Toxic cysts of *Pyrodinium bahamens* and *Protoperidinium sp.* have been identified in a sediment core from Gwadar.

Pakistan has also contributed, at the regional level, by hosting the RCA Review Meeting in Islamabad for Component-I and a Regional Training Course for Component-II in Islamabad/Karachi, in collaboration with Pakistan Navy and NIO-Karachi.

The key end-user institutions of the marine sub-project, namely: Pakistan Navy, Karachi Port Trust and the National Institute of Oceanography, Karachi, have significantly contributed in the accomplishment of field-sampling activities. However, there is a dire need for further collaboration at national level and provision of in-kind contribution from end-user institutions for timely completion of various activities of the national marine pollution project.

REFERENCES

- Chaghtai, F. and S.M. Saifullah (1997). Occurrence of Phaeocistis in Mangrove creeks near Karachi. Pak. J. Mar. Sci., 6 (1&2), 105-108.
- Chaghtai, F. and Qureshi R.M. (2001): Presence of Pyrodinium bahamense Cyst in top 2 cm Sediment Layer of Gwadar, North Arabian Sea.
- Hassan, D. & S.M. Saifullah (1973) Genus *Peridinium* Ehrenberg, from inshore waters of Karachi. Pak. J. Bot. 4 (2), 157-170.
- IAEA (1999): IAEA/RCA Review Meeting to Analyze the Regional Database on Marine Radioactivity, (Ed): Ross Jefferee (ANSTO, Sydney, Australia), Riffat M. Qureshi (PINSTECH/PAEC, Islamabad, Pakistan), Scott W. Fowler (IAEA-MEL, Monaco), (April, 1999), Unpublished Report No. C3-RAS-8.080-9003-01, ASPAMARD)
- Rabbani, M.M.; A. Rehman; C.E. Harms (1990). Mass mortality of fishes caused by dinoflagellates bloom in Gwadar Bay, Southwestern Pakistan. Proc. of Toxic Algal Bloom Cnf.
- Saifullah, S.M. and Durreshehwar H. (1973). Planktonic Dinoflagellates from Inshore waters of Karachi I. Goniaulax Diesing. Pak. J. Zool., 5 (2), 143-147.
- Saifullah, S.M. and M. Moazzam (1978). Species composition and seasonal occurrence of centric diatoms in a polluted marine environment. Pak. J. Bot., 10 (1), 53-64.

– Saifullah, S.M. and F. Chughtai (1990). Incidence of Noctiluca scintillans (Macartney)Ehrenb., blooms along Pakistan's shelf. Pak. J. Bot., 22 (2), 94-99.

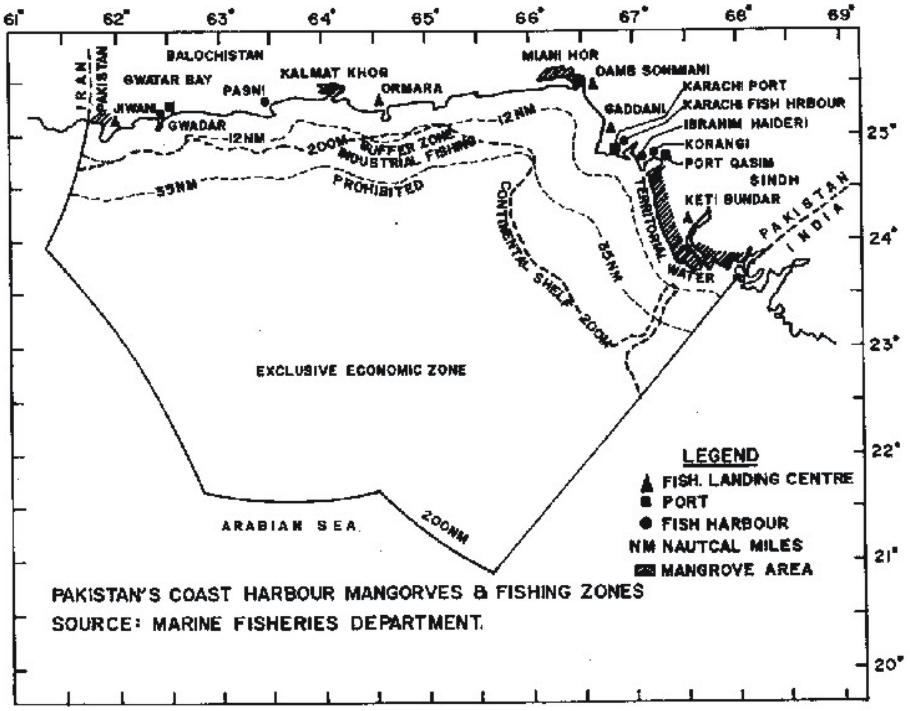

Figure – 1: Pakistan's Coast Harbour Mangorves & Fishing Zones

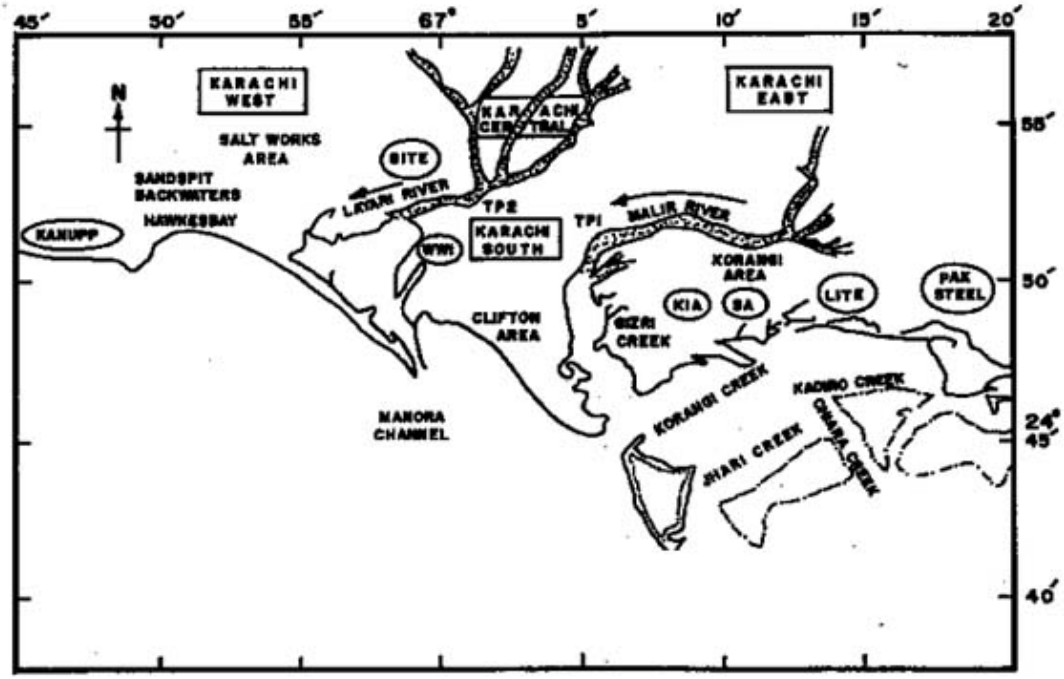

Figure – 2: Coastal Map of Karachi Showing Location of Industrial Sites and Drainage Course of Polluted Rivers into Karachi Sea

Table – 1: Details of Tentative Sampling (Types and Amount) Off Pakistan Coast

SAMPLE MATRIX	ANALYSIS TYPE	QUANTITY	SAMPLE PER Marine SITE
WATER	Isotopes:		
	O-18 and H-2 (water)	50 ml	5-15
	C-13 (TDIC)	1 Liter	5-15
	O-18 & S-34 (Sulfate)	100 ml	5-15
	H-3 (Tritium)	1 Liter	5-15
	C-14 (TDIC)	100 -250 Liters	3-5
	Low Level Radioactivity	100 -250 Liters	2-5
	Chemistry:		
	Major Ions	1 Liter	4-10
	Toxic Metals	500 ml	4-10
	Pesticides	100 -250 Liters	2-5
	PAHC	100 -250 Liters	2-5
	TDOC	100 -250 Liters	2-5
	Biological:		
	Coliform (Fecal & Total)	250 ml	5- 30 (in duplicate)
	HAB Species	100 ml	5-10
	Net Samples of Phytoplankton	Variable size	3-5
SEDIMENTS	Isotopes:		
	C-13 (TSIC)	100 gram	5-10
	C-13 (TSOC)	100 gram	5-10
	O-18 and S-34 (Sulfate)	100 gram	5-10
	N-15	100 gram	5-10
	Low Level Radioactivity	1 kg	2-5
	Chemistry:		
	Toxic Metals	250 - 500 gram	4-10
	Pesticides	500- 1000 gram	4-10
	PAHC	500 -1000 gram	4-10
	Biological:		
	HABs Cyst on Sediment Cores	50 – 75 cm long cores	5-10
Mollusks/ Shells	Isotopes		
	C-13	10 gram	3 -5 samples per specie
	O-18	10 gram	
FISH	Isotopes, Chemistry:		
	C-13 , N-15, Toxic Metals	1-2 kg Fish	3 -5
	Low Level Radioactivity	3-5 kg Fish	3-5
	Biological:		
	HABs Toxin	3-5 kg Fish	3-5
MUSSELS	Isotopes, Chemistry:		
	C-13 , N-15, Toxic Metals	500 grams	3-5
	Biological:		3-5
	HABs Toxin	2 kg Mussels	3-5
CRABS	Isotopes, Chemistry:		
	C-13 , N-15, Toxic Metals	1/2 kg	3-5
	Biological:		3-5
	HABs Toxin	3-5 kg Crabs	3-5
MANGROVES	Isotopes, Chemistry:		
	C-13 , N-15, Toxic Metals	1-2 Cores per tree	5-10 (2 samples per specie)
SEAWEEDS	Isotopes, Chemistry:		
	C-13 , N-15, Toxic Metals	200 grams per specie	3 – 5 species

Table-2: Average Radioactivity concentration in sediment (Bq kg^{-1}) & water (Bq l^{-1}) samples off Karachi Coast, Pakistan

[For sediments Limit of detection (LOD), for ^{226}Ra = 18.35, ^{228}Ra = 9.6 Bq/Kg, ^{137}Cs = 1.6], [for water Limit of detection (LOD), for ^{226}Ra = 1.62, ^{228}Ra = 1.4 Bq/Kg, ^{137}Cs = 0.32, ^{40}K = 10.96]

LOCATION	SEDIMENT				WATER
	Ra-226 (Bq/Kg)	**Ra-228** (Bq/Kg)	**K-40** (Bq/Kg)	**Gross Activity (Gamma)** Counts/Sec/Kg	**K-40** (Bq/l)
Layari River Outfall Area (Pre-Harbour outfall Zone)	*<18.35*	*14.28± 3.72*	*125.00± 28.60*	*59.39 ± 5.28*	<10.96
Layari River Outfall Area (Karachi Harbour Backwaters)	53.84 (n = 1)	20.46 ± 5.94	520.91± 112.96	74.65± 13.08	36.00 ± 17.23
Karachi Harbour Mains	<18.35	24.54 ± 4.94	522.65± 143.68	105.66± 11.88	65.34 ± 4.38
KPT Shipyard/ Kaemari Fish Harbour Channel	24.23 ± 5.97	22.37 ± 6.72	373.36± 11.05	105.66± 11.88	27.20 ± 16.97
Manora Channel Mains	29.18	21.8 ± 5.1	512.62± 188.06	72.46± 31.61	61.41 ± 2.54
Karachi Sea, South-East Coast	28.89	20.80 ± 5.77	780.36± 126.58	108.02± 25.26	61.41 ± 2.54
Karachi Sea, North-West Coast	45.91± 23.72	30.77 ± 6.88	384.99± 148.6	75.89± 18.49	16 ± 16.84

Table-3: Mixing Characteristics of Layari River water with Seawater in Layari River Outfall Zone across a mixing profile in Karachi Harbour using a two component chemical and isotope balance equation (Mixing Profile opposite Shipyard)

Sample Code	Profile Description	E.C. (mS/cm)	$\delta^{13}C$ per mill. (PDB)	$\delta^{18}O$ per mill. SMOW	EC Based % Contribution of Inorganic Pollution from		$\delta^{13}C$ Based Contribution of Carbon from Layari Outfall	$\delta^{18}O$ Based % Contribution of Water Layari River
					Pure Layari River	Layari Outfall Zone		
K5	Arabian Sea, Manora Channel Break Waters	55.6	-0.88	-0.08	-	-	-	-
K1	Layari River (At Gulistan Colony, Mirza Adam Khan Road, Near Tanga Stand, Middle of Layari Channel, 1230 hrs.)	2.6	-5.9	-6.67	-	-	-	-
K2	Layari River Outfall Zone	36	-10.22	-1.79	-	-	-	-
K25	Prior to apparent mixing boundary of Layari Channel in harbour near Shipyard	53	-4.42	0.13	4.9	13.3	37.9	1
K26	Prior to apparent mixing boundary of Layari Channel in harbour near Shipyard	52.8	-5.64	-0.22	5.3	14.3	24.2	2
K27	At apparent Mixing boundary of Layari Channel in harbour near Shipyard	53.8	-9.72	-1.24	3.4	9.18	94.7	17
K29	Extreme of Layari Channel in harbour near Butti in front of shipyard	45.6	-8.6	-1.76	18.9	49	82.7	25