INDIA

Cruise Report

ORV Sagar Kanya

Cruise # 304

Leg-1

From : Goa, March 03rd, 2013
To: Jakarta, April 12th, 2013

Theme: GEOTRACES

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Participating Institutes:

1) National Center for Antarctica & Ocean Research, Goa
2) National Institute of Oceanography, Regional Center, Vishakapatnam
3) Goa University, Goa
4) Cochin University of Science & Technology, Cochin
5) Mangalore University, Mangalore
6) Pondicherry University, Port Blair
7) Physical Research Laboratory, Ahmedabad

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INTRODUCTION

Indian Ocean

a) The Arabian Sea

Geographical setting of the Arabian Sea affects its circulation and biological productivity which causes its oxygen deficient conditions. During the southwest monsoon strong southwest winds produce intense coastal upwelling off Somalia, Yemen and Oman and these upwelled water are transported hundreds of kilometers offshore which enriches the euphotic zone with nutrients in these regions. These nutrients along with high aeolian dust flux results in high primary production. The northeast monsoon also causes convective mixing over a large area. The primary production during northeast monsoon is comparable with that during the southwest monsoon. High primary productivity is one major factor responsible for prevalence of sub-oxic conditions in the Arabian Sea. Denitrification process which is a perennial feature in the water column of the Arabian Sea is expected to have sufficient control on the distribution of redox sensitive elements. Various studies carried out till date have not fully addressed to this issue. We plan to take up detailed sampling in the water column for trace elements and their isotopes along with routine hydrographic parameters.

b) Bay of Bengal

A major forcing factor in the BoB is the combined flow of the Ganges and Brahmaputra Rivers. These rivers enter the northern BoB from India and Bangladesh to form a large plume of sediment and fresh water. The riverine outflow during the SW monsoon is so large that the BoB can effectively be considered an estuary of this giant river system. The Ganges and Brahmaputra Rivers influence ocean chemistry through their unique river water chemistry and large flux of immature sediment. The flux and isotopic ratio of strontium from the Ganges-Brahmaputra Rivers to the ocean has become a matter of controversy in terms of its lithologic source (silicate vs. carbonate) and its corresponding

isotopic ratio. Special attention has been focused on fluxes of Sr because the highly radiogenic composition of $^{87}Sr/^{86}Sr$ from this system plays a significant role in determining the present day oceanic ratio. Changes with time in Sr flux and isotopic ratio certainly affect the marine paleo record.

In addition to the huge fluxes of water and sediment from the rivers, additional fluxes from submarine groundwater discharge (SGD) have been recognized at the river mouth. These fluxes augment the already high riverine fluxes of alkaline elements Sr, Ba, and Ra. The source of these elements appears to be the weathering of aquifer protolith as well as adsorption-desorption reactions with aquifer solids. It is likely that other elements are also affected by SGD. Thus, SGD may serve as source and sink with respect to TEIs.

Atmospheric deposition is one of the most dominant and effective means of delivering trace element and their isotopes (TEIs) to surface waters of interest to GEOTRACES. This is particularly the case in the Indian Ocean, where enclosed sub-basins to the north are located in close proximity to large arid areas of dust and large human populations with related industrial emissions located on the Indo-Asian sub-continent. This includes the Bay of Bengal (BoB), which is impacted by dust and other aerosol emissions from both the Indian subcontinent to the west and East Asian regions to the east. The aerosol content is particularly prevalent during the inter-monsoon winter period.

OBJECTIVES

The present GEOTRACES Section Cruise is an attempt to understand various biogeochemical processes controlling the distribution of various Trace Elements and their Isotopes (TEIs) in the Bay of Bengal, the Andaman Sea and the GEOTRACES Section-03 up to Australia (Fig. 1). Broadly, the objectives of this study can be classified under the following themes:

Sources, sinks and internal cycling

1) To understand and quantify how the water masses are modified after the contact with the margins and the river mouths within the energetic continent/ocean interface surrounding the Bay of Bengal and in the Indian Ocean basin.
2) To trace the Himalayan weathering and its impact on the chemical composition of the neighbouring ocean,

3) To contribute to tracer studies of ocean circulation in association with physical oceanographers.
4) To understand the role of TEIs in primary productivity and their distribution within the water column.
5) Quantification of the sources and sinks of TEIs associated with the exchange process of the Indonesian Throughflow.
6) Atmospheric deposition of TEIs, their fluxes and processes.
7) To calibrate the behavior of paleo-circulation and paleo-weathering proxies.

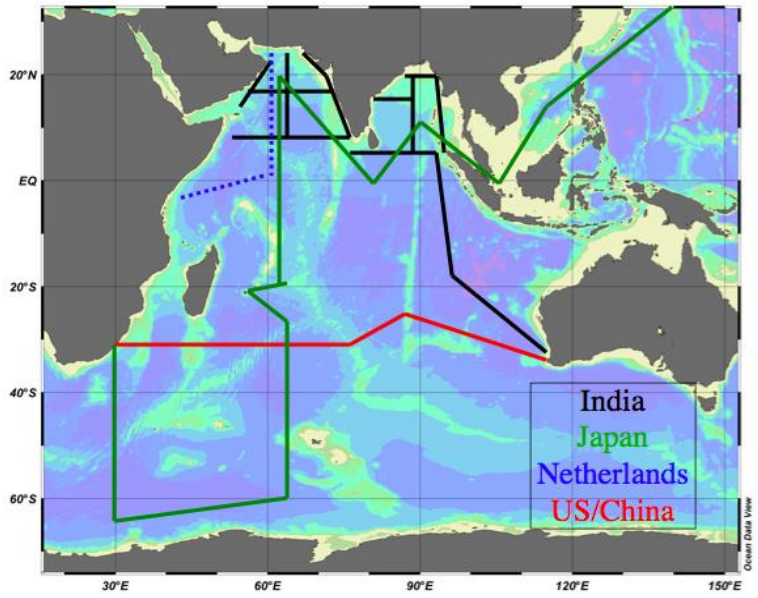

Fig. 1: Summary of tracks proposed for GEOTRACES cruises in the Indian Ocean during the GEOTRACES Indian Ocean Workshop, Oct 2007.

To understand the various physical processes governing ocean circulation, productivity being controlled by micronutrients, ecosystem and ocean anoxia, a coordinated global research programme named GEOTRACES has been initiated. This cruise is an attempt to address some of these issues in context of the Indian Ocean and would try to cover the GEOTRACES Section Cruise -03 as decided during the working group meeting during the GEOTRACES Indian Ocean Workshop (Fig. 1).

MATERIAL AND METHODS

This cruise was allocated to GEOTRACES for studies of water and sediments for the GEOTRACES Section – 03 for measurement of several trace elements and their isotopes

(TEIs) to understand various biogeochemical processes responsible for their distribution in the Indian Ocean region. One of the major requirements for the GEOTRACES cruise was requirement of clean sampling system which was procured for this programme. The clean sampling system was successfully tested and operated during the cruise for seawater sampling

a) Trace metal clean sampling systems

The first trace metal clean sampling system in the Indian Ocean region with a complete facility for trace-metal clean sampling at sea (e.g., non-contaminating rosette with GO-Flo or equivalent bottles; non-contaminating Kevlar wire; clean lab with HEPA filtered air for processing samples) was acquired for the GEOTRACES India project by Physical Research Laboratory, Ahmedabad with generous support of Ministry of Earth Sciences (MoES). This trace metal clean sampling system is a valuable asset to GEOTRACES. Clean sampling systems of somewhat different design have been constructed by scientists in Japan, the Netherlands and the U.S. Scientists

b) **Sediment sampling**: For paleoclimatic studies, long cores from various area were collected with gravity corer.

c) **Grab sampling**: For surface sediment, grab sampling was operated at various locations.

d) **Zoo**-Plankton Net

Additionally, various scientific equipment used for onboard analysis are:

1) CTD with rosette with 10 lit Niskin sampler
2) Autoanalyser for nutrient measurements
3) Autosal fo salinity measurements
4) Thermosalinometer
5) Water purification system (Milli-Q)
6) Deep freezers
7) Ovens
8) Refrigerators
9) Refrigerated storage room
10) Multibeam sounder
11) Laminar flow bench
12) Fumehoods
13) Deep sea Echosounder
14) UV Oxidation unit

SAMPLING DETAILS

The scientific operations carried out at the stations during the first leg (LEG-1) of the cruise SK-304 (Fig. 2) are described below:

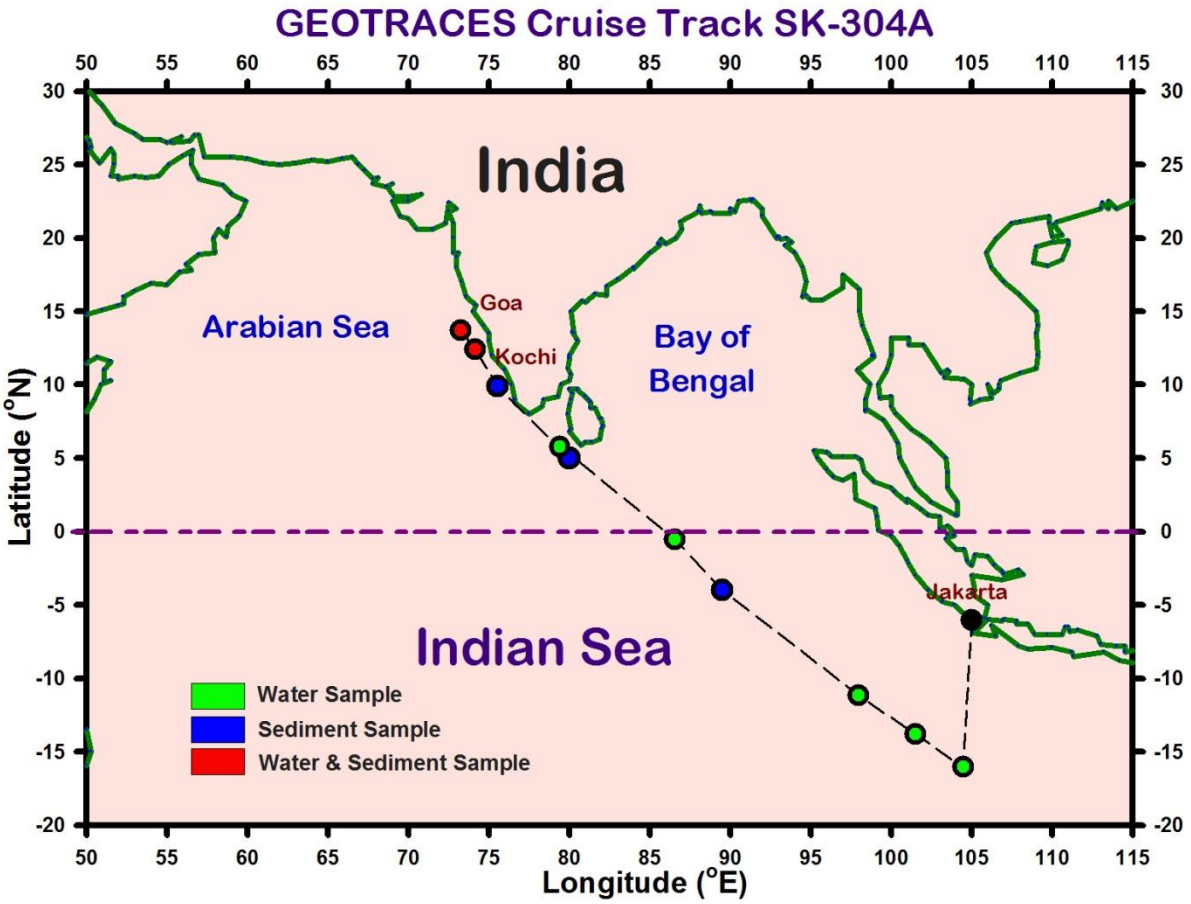

Fig. 2: Cruise track of the GEOTRACES cruise SK-304 during Leg-1 from Goa to Jakarta. The sampling stations have been indicated with different color coding.

Cast Details

Station-01

Date: 4th march, 2013
Station: SK-304A/GI03/01
Lat-Long**:** 13°42.343; 73°15.774
Water depth:
Arrival Time: 1210hrs

Cast-1

- No Archive to be collected from this station
- Started lowering the dead weight with clean winch upto 500m for testing
- Checked for making of the clean winch
- Lights are dripping, needs to be attended
- End Time: 1535hrs

Cast-2

- First Clean CTD operation
- CTD lowered till 25m. Noted suddenly disconnectivity of CTD cable with error message on desk unit
- CTD landed up and checking for the connectivity. There seems to be cable damage at the connecting wire.
- To be cut and reconnected
- **Date**: 5th march, 2013
- **Station**: SK-304A/GI03/01
- Lat-Long**:** 13°43.783; 73°16.760
- **Water depth:** 889m
- Time: 0010hrs
- Clean CTD started without DP
- **Sample collected at following depths:** 747, 650 , 550 , 450, 370 , 300, 200(4), 75(1), 25(1)

Cast-3: Regular CTD

- Lat-Long**:** 13°44.901; 73°18.673
- 25m all bottles tripped for ~100L.

Cast-4: Regular CTD

- 10m all bottles tripped

Cast-5: Regular CTD

- Winch cable exchanged
- 75m all bottles tripped

Cast-6: Clean CTD

Lat-Long**:** 13°42.893; 73°16.031

- Samples collected for 2, 10, 50,100, 300m
- Nd samples at 2 and 100m

Cast-7: Coring operation (gravity corer)

- Lat-Long**:** 13°50′26.546″; 73°17′31.7266″
- **Water depth**: 703m
- Time: 1430hrs
- Gravity corer operation begun
- **Water depth:** 666m
- **Core recovery:** ~2-2.5m

Cast-8: Grab operation

- Time**:** 1630hrs
- No samples, although grab touched the bottom but didn't close

Cast-9: Repeat Grab operation

- Time**:** 1930hrs
- Retrieve sediment grab sample
- Collected by: PRL, NIO, CUSAT, Manglore university, Goa university
- Time**:** 2300hrs
- Ship started sailing for next station

Station-02

Date: 6th march, 2013
Station: SK-304A/GI03/02
Lat-Long**:** 12°23′40.292; 74°09′32.48″
Water depth: 666m
Time: 1400hrs
File: sk304A_GI03_02a
Time: 1445hrs

Cast-1: Clean CTD operation

- While CTD surfaced, it was noticed that one of the bottle was closed.
- CTD was retrieved back. While retrieving back, it was noticed that Kevlar cable had got cut due to acute angle of the winch.
- Kevlar cable was cut ~25m and again reconnected

Cast-2: Clean CTD operation

- Lat-Long**:** 12°23′21″N; 74°09′15.42″E
- **Depth**: 704 m
- Time: 2130hrs
- Sample taken from 25, 75, 100,150, 200, 300, 400, 500, 625m
- **Date**: 6th march, 2013

Cast-3: Clean CTD Operation

- Time: 0130hrs
- Lat-Long**:** 12°22′27″N; 74°11′07″E
- **Water depth**: 514m
- Collected samples at 100, 75, 25 and 10m

Cast-4: Clean CTD Operation

- Time: 0235hrs
- Lat-Long**:** 12°22′07″N; 74°11′17″E
- **Water depth**: 510m
- Sample collected at 2, 10, 50, 75m

Cast-5: Sediment coring

- Time: 0334hrs
- Lat-Long**:** 12°22′073″N; 74°11′284″E
- Water depth: 535m
- Core length: ~3.6m (top ~10 cm mixed)

Cast-6: Grab Sampling

Station-03

Date: 11th march, 2013
Station: SK-304A/GI03/03
Lat-Long**:** 09°52′56N; 75°32′57″E
Water depth: 760m
Time: 0150hrs

Cast-1: Gravity Corer operation

- Lat-Long**:** 09°52′55.9N; 75°32′57″E
- **Depth**: 759.8m
- **Depth** (on hit):748.7m
- **Corer On deck**: 0330hrs
- **Core length**: 3.9m (top ~10 cm mixed)
- Core having sulphidic smell (H_2S)

Cast-2: Grab Sampling-1

- **Depth:** 751m
- **Depth** (on hit): 748.5m
- **Grab on deck**: 0420hrs
- Grab came on deck, but it was not closed.
- No grab sample was collected hence another grab sampling was done.

Cast-3: Grab Sampling-2

- **Depth:** 757.1m
- **Depth** (on hit): 752.3m
- **Grab** (on deck): 0515hrs
- Second Time also, grab didn't capture any sediment, but there were some sample on the top of the grab, which was taken in plastic bags.

Station-04

Date: 17th march, 2013
Station: SK-304A/GI03/04
Lat-Long**:** 05°0.056′N; 79°59.880′E
Water depth: 4327m
Arrival Time: 1145hrs

Cast-1: Regular CTD operation upto 100m

- Tripped all bottles (~90L) at 100m
- Samples for NIO & Po
- Bad Idronaut CTD has problem of tripping.
- No continuous data as well.

Cast-2: Regular CTD operation upto 50m

- Time: 1230hrs
- All bottles are tripped at 50m.
- Samples for NIO &Po

Cast-3: Clean CTD

- Lat-Long**:** 05°0.011'N; 79°55.620'E
- **Water depth:** 4317m
- **File name:** sk304A_4a
- Bottle tripped location
- Time**:** 1645hrs
- **Water depth:** 4311m
- Lat-Long**:** 04°59.796'N; 79°49.186'E
- Sample taken for trace elements: 2150(Nd), 1900(Nd,Th), 1600(Nd), 1300(Nd),1100, 900, 700**,** 600, 500, 400, 300, 200, 150, 100, 75, 50, 25, 10, 5
- **End** Time**: 2115hrs**
- Two niskin bottles (bottle no. 15 &16) were lost when the cast was retrieved due to opening of the lower bottle mount assembly while holder the bottle (part no. 50436).
- No sample for 300 and 400m

Cast-4: Regular CTD

- Time**:** 2200hrs
- Lat-Long**:** 05°0.809'N; 79°39.619'E
- Samples for NIO
- *Two new Niskin bottles with mantry assembly (2) and Teflon coated springs (2) connected to the CTD Rossette for the future use.

Cast 5: Regular CTD-25m

- Time: 2230hrs
- Samples for NIO

Cast-6: Regular CTD-10m

- Time 2300hrs
- Samples for NIO

Cast-7: Regular CTD-4m

- Time: 2315hrs
- Samples for NIO

Cast-8: Regular CTD-375m

- Time: 2335hrs
- Samples for Radium

Cast-9: Regular CTD-200m

- **Date**: 18th March, 2013
- Time: 0015hrs
- Samples for Radium

Cast-10: Regular CTD-110m

- Time: 1245hrs
- Samples for Ra

Cast-11: Clean CTD

- Time: 0250hrs
- Lat-Long: 05°3.467'N; 79°31.054'E
- **Water depth**: 4263m
- Samples taken for Trace element, Nd, Po: 1100(Nd*),900(Nd), 700(Nd), 600(Nd), 500(Nd, Po), 400(Nd, Trace), 300(Nd, Trace, Po), 200(Nd,Po, Th), 150(Po), 100(Nd), 50(Nd), 5(Nd*)

******duplicate samples***

- Cast finished at5:0530hrs on 18th March, 2013

Station-05

Date: 23rd march, 2013
Station: SK-304A/GI03/05
Lat-Long: 05°45.622"N; 79°24.763'E
Arrival Time: 0400hrs
Water depth: 3408m
Time: 0430hrs

Cast-1: Core operation (gravity corer)

- Deep sea winch is not working properly.
- Winch can lower the wire but the recoiling is not taking place (NORINCO and second engineer at work)
- Time**: 1215hrs**
- Winch repaired, problem with the hose pipe leakage. Relay contacts were loose.
- Control hydraulic line leakage
- Time**: 1230hrs**
- Coring operation started
- **Wire lowered:** 3900m
- Expected another 400-500m length of wire
- **Core on deck:** 1622hrs
- **Core length:** 4.1m (top ~ 15-20cm mixed up)

Bottom core catcher [--------1m--------][--------1m--------][--------1.3m--------][---0.8---] Top

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Station-06

Date: 27th March, 2013
Station: SK-304A/GI03/06
Lat-Long**:** 0°31.738"S; 86°33.570'E
Arrival Time**: 0700hrs**

Water depth: 4687m

Cast-1: Regular CTD -100m

- Time: 0800hrs
- 100m all bottles for NIO

Cast-2: Regular CTD-75m

- Time: 0845hrs
- All bottles tripped at 75m for NIO

Cast-3: Regular CTD-5m

- Time: 1000hrs
- All bottles tripped at 5m for Hf (PRL)

Cast-4: Clean CTD (for trace and Nd)

- Time: 1015hrs
- Lat-Long: 0°31.752″S; 86°33.536′E
- **Depth**: 4691m
- Wire jumped off after leaving 80m
- Stopped and wire put back in shear.

Cast-5, 6, 7: FRR and NIO CTD

- Time: 1230 to 1500 hrs

Cast-8: Regular CTD-100m

- Time: 1520 hrs
- Samples for Hf (PRL)
- All bottles tripped at 100 m

Cast-9: Regular CTD-50m

- Time: 1545 hrs
- All bottles tripped at 50 m

Cast-10: Regular CTD-25 m

- Time: 1615 hrs
- All bottles tripped at 25 m

Cast-11: Regular CTD-10m

- Time: 1630 hrs
- Samples collected for NIO
- All bottles tripped at 10 m

Cast-12: Regular CTD-2m

- Time: 1650 hrs
- All bottles tripped at 2 m

Cast-13: Clean CTD

- Time: 1700 hrs
- File: SK304A_06A1
- Lat-Long: 0°31.762″S; 86°33.536′E
- Sampled depth for Nd and Archive: 2,100,200,300,400

- TE: 2,25,50,75,100,150,200,300,400
- **Cast up**: 1745hrs
- Bottle no. 13(100m) didn't close

Cast-14: Regular CTD-100m

- Time: 1930 hrs
- All bottles tripped at 100 m for Ra.

Cast-15: Regular CTD-200m

- Time: 1955 hrs
- All bottles tripped at 200 m for Ra

Cast-16: Clean CTD: deep cast upto 2500m

- Time: 2030 hrs
- File: SK304A_06B
- Sampled depth for
  - Hf: 1500m, 2500m
  - Nd and Archive: 800,1000,1500,2000
  - TE: 700,800,1000,1500,2000
- **Cast up**: 2245 hrs
- Bottle no. 9(1500m) and 18(1000m) didn't close.

Cast-17: Regular CTD-25 m

- Time: 2315 hrs
- All bottles tripped at 25 m
- Sample collected for two depths 5m(Ra) and 25m(Th)

Cast-18: Regular CTD-300 m, 400, 500m

- Time: 2330 hrs
- Samples collected for Ra, Th, Po

Cast-19: Clean CTD

- 28th March, 2013
- Time: 0035 hrs
- **File**: SK304A_06C
- Lat-Long: 0°31.759"S; 86°33.566'E
- Water depth: 4692m
- Sampled depth
  - Hf: 4550m, 3500m
  - TE, Nd and Archive: 2500, 3000, 3500, 4000, 4600m
- At 4571m, CTD depth was not increasing, despite cable covering probably CTD touched the bottom a although water depth was 4692m
- Cast up: 0345hrs

Cast-20: Clean CTD: shallow cast upto 1000m

- Time: 0545 hrs
- **File**: SK304A_06D
- Lat-Long: 0°31.763"S; 86°33.534'E
- Water depth: 4692m

- Sampled depth:
  - Hf: 300,600,1000m
  - TE: 10,500,600m
  - Nd: 100,600,1000m
- Station closed: 0650hrs

Station-07

Date: 29th march, 2013
Station: SK-304A/GI03/07
Lat-Long**:** 03°59.100"S; 89°29.892'E
Time**:** 1945hrs
Water depth: 2905 m
Time**:** 2020hrs

Cast-1: Sediment coring

- **Depth:** 2908 m
- Wire let out 3200m
- While heaving, the winch doesn't heave beyond 10-15mps, it trips
- NO CORE RECOVERY
- Station ended: 0100hrs (30th march, 2013)

Station-08

Time **shifted from 1st April, 2013**
Date: 02nd April, 2013
Station: SK-304A/GI03/08
Lat-Long**:** 11°9.648"S; 97°59.165'E
Arrival Time**:** 1220hrs
Water depth: 5127m

Cast-1: FRR (NIO)

- Time: 1245hrs
- FRR operation, with and without light upto 100m

Cast-2: NIO CTD

- Time: 1315hrs
- Two operation of two NIO CTD upto 100m depth

Cast-3: Clean CTD (cast upto 500m)

- Time: 1415hrs
- Lat-Long: 11°9.648"S;97°59.162'E
- **File**: sk304A_08A
- Even with closed roller, wire slacked in the pulley and got cut.
- The cut wire part was tapper and there was no water leakage and cast was sent upto 500m only.
- After this cast, 15-20m (approx) of the wire to be cut.
- Cast upto 300m clean CTD
- Water mass observed at 50m, 300m and 400m

- Sample for trace & Nd: 500, 400, 300, 200, 100, 75, 50, 7m.
- 25-30m Kevlar wire was cut as it was damaged.

Cast-4: Regular CTD: 100m (NIO)

- Time: 1600hrs
- All bottles are tripped At 100m.

Cast-5: Regular CTD: 75m (NIO)

- Time: 1645hrs
- All bottles tripped at 75m

Cast-6: Regular CTD: 50m (NIO)

- Time: 1710hrs
- All bottles tripped at 50m

Cast-7: Regular CTD: 25m (NIO)

- Time: 1730hrs
- All bottles tripped at 25m

Cast-8: Regular CTD: 10m (NIO)

- Time: 1740hrs
- All bottles tripped at 10m

Cast-9: Regular CTD: 2m (NIO)

- Time: 1800hrs
- All bottles tripped at 2m

Cast-10: Regular CTD: 100m (PRL)-Ra

- Time: 1815hrs
- All bottles tripped for Radium

Cast-11: Regular CTD: 5m (PRL)-Hf

- Time: 1830hrs
- All bottles tripped for Hf

Cast-12: Regular CTD: 5m (PRL)-Ra

- Time: 1845hrs
- All bottles tripped for Radium

Cast-13: Clean CTD (Deep Cast)

- Time: 1940hrs
- Lat-Long: 11°9.644”S; 97°59.160’E
- **File**: sk304A_08B
- **Depth**: 5126m
- Samples for Trace elements and Nd: 5000,4500,4000,3500,3000,2500,2000,1500
- Cast finished at 2300hrs

Cast-14: Regular CTD: 400m (PRL)-Ra

- Time: 2310hrs
- All bottles tripped for Radium at 400m

Cast-15: Regular CTD: 200m (PRL)-Ra

- Time: 2350hrs
- All bottles tripped for Radium at 200m

Cast-16: Regular CTD: 100m (PRL)-Ra

- Time: 0015hrs
- All bottles tripped for Radium at 100m

Cast-17: Regular CTD: 300m (PRL)-Hf

- Time: 0045hrs
- All bottles tripped for Hf at 300m

Cast-18: Clean CTD (up to 1200m)

- Time: 0115hrs
- Lat-Long: 11°9.644"S; 97°59.164'E
- **File**: sk304A_08c
- **Depth**: 5126m
- Samples for Trace elements, Nd and Hf : 1200m, 1000m,800m, 600m,500m,150m, 25m,2m

Cast-19: Regular CTD: 100m (PRL)-Hf

- Time: 0235hrs
- All bottles tripped for Hf

Cast-20: Regular CTD: 50m (PRL)-Hf

- Time: 0245hrs
- All bottles tripped for Hf at 50m
- Station ended at0315hrs, 03rd April, 2013.

Station-09

Date: 04th April, 2013
Station: SK-304A/GI03/09
Lat-Long**:** 13°49.056"S; 101°29.562'E
Arrival Time**: 1230hrs**
Water depth: 5072m

Cast-1: clean CTD (Deep Cast)

- Time: 1320hrs
- **File**: sk304A_09A
- **Depth**: 5126m
- Samples for Trace elements, Archive and Nd
- After 4949m CTD depth not increasing despite leaving of cable, possibly CTD rested on the seabed(100-120m offset in multibeam data)
- Samples at 4900,4500,4000,3500,3000,2500,2000m
- Cast ended at 1615hrs

Cast-2: FRR CTD:100m (NIO)

- Time: 1625 hrs

Cast-3: NIO CTD and FRR: 180 m

- Time: 1645hrs

Cast-4: Regular CTD: 100m (NIO)

- Time: 1710hrs
- All bottles tripped at 100m

Cast-5: Regular CTD: 75m (NIO)

- Time: 1725hrs
- All bottles tripped at 75m

Cast-6: Regular CTD: 50m (NIO)

- Time: 1750hrs
- All bottles tripped at 50m

Cast-7: Regular CTD: 25m (NIO)

- Time: 1810hrs
- All bottles tripped at 25m

Cast-8: Regular CTD: 5m (NIO)

- Time: 1835 hrs
- All bottles tripped at 5m

Cast-9: Clean CTD (Mid depth Cast)

- Time: 1910hrs
- **File**: sk304A_09B
- **Depth**: 5070m
- Lat-Long**:** 13°49.051″S; 101°29.562′E
- Samples for Trace elements, Archive and Nd at 2000, 1200,1000, 800, 600, 500, 400, 300, 200m
- **Cast Up**: 2040hrs

Cast-10: Regular CTD: 400m (Radium)

- Time: 2050hrs
- All bottles tripped at 400m

Cast-11: Regular CTD: 200m (Radium)

- Time: 2110hrs
- All bottles tripped at 200m

Cast-12: Regular CTD: 100m (Ra)

- Time: 2125hrs
- All bottles tripped at 100m

Cast-13: Regular CTD: surface Radium

- Time: 2150hrs
- All bottles tripped at surface.

Cast-14: Regular CTD: 100m (Hf)

- Time: 2210hrs

- All bottles tripped at 100m for Hf

Cast-15: Regular CTD: surface Hf

- Time: 2225hrs
- All bottles tripped for surface Hf.

Cast-16: Clean CTD (shallow cast)

- Time: 2310hrs
- Water Depth: 5068m
- Lat-Long: 13°49.048"S; 101°29.564'E
- Sample for trace, Nd, archive:5,10,25,50,75,100,150,200,300m
- **Cast ended**: 2345hrs
- Ship started at 0020hrs on 05th April, 2013.

Station-10

Date: 06th April, 2013
Station: SK-304A/GI03/10
Lat-Long**:** 16°1.544"S; 104°27.766'E
Arrival Time**:** 0600hrs
Water depth: 5860m

Cast-1: FRR+CTD (NIO) upto 100m

- Time: 0630hrs
- Operation up to 100m

Cast-2: PRL+NIO (CTD) upto 100m

- Time: 0650hrs
- Operation upto 100m

Cast-3: Clean CTD (Deep cast)

- Time: 0720hrs
- **File name**: SK304A_10A
- Salinity high at: 150m, 200-250, salinity maxi at 200-250
- Sample for trace, Hf: 5700, 5200, 4700, 4200, 3700, 3200,
- **Cast up**: 1315hrs

Cast-4: Regular CTD: 100m (NIO)

- Time: 1330hrs
- All bottles tripped at 100m

Cast-5: Regular CTD: 75m (NIO)

- Time: 1350 hrs
- All bottles tripped at 75m

Cast-6: Regular CTD: 50m (NIO)

- Time: 1420hrs
- All bottles tripped at 50m

Cast-7: Clean CTD (mid depth cast)

- Time: 1431hrs

- **Water Depth**: 5861m
- Lat-Long: 16°1.548″S; 104°27.769′E
- Sample for trace and Hf: 2700(Hf),2200, 1800(Hf),1400,1000(Hf),800,600
- **Cast up**: 1705hrs

Cast-8: Regular CTD: 25m (NIO)

- Time: 1715hrs
- All bottles tripped at 25m

Cast-9: Regular CTD: 10m (NIO)

- Time: 1740hrs
- All bottles tripped at 10m

Cast-10: Regular CTD: 2m (NIO)

- Time: 1800hrs
- All bottles tripped at 2m

Cast-11: Regular CTD: Surface-Hf (PRL)

- Time: 1820hrs
- All bottles tripped at surface

Cast-12: Regular CTD: 100m-Hf (PRL)

- Time: 1830hrs
- All bottles tripped at 100m

Cast-13: Clean CTD (shallow depth cast)

- Time: 1920hrs
- Sample for trace and Hf: 5, 10, 25, 50, 75, 100, 150, 200, 250 (Hf), 300, 400, 500(Hf), 600
- **Cast up**: 2000hrs
- **Station ended**: 2015hrs
- 07th April, 2013-04-07
- Time: 1100hrs
- Vessel stopped for southernmost station of the transect GI-03
- Lat-Long: 17°36.38″S; 104°37.14′E
- **Water Depth**: 5867m
- **Wind speed**: >26-30knots
- DP was unable to hold the ship in position in auto mode, while in manual mode it was holding and carring lot of power.
- However, swells were so high and windspeed >25knots, not favourable for any deep sea operation.
- Decision taken with consent of captain that operation shouldn't be carried out

Analytical Procedures

Samples collected during Leg 1 of cruise SK 304 cruise are given below:-

1) Trace Metal:Two liters of sea water samples collected after pressurized filtration of sea water filtered through 0.2 µm Acropack filters. A total of 117 numbers of trace metal samples were collected from different depths of 7 stations.

2) Neodymium:About 15-18 liters of sea water samples were collected after pressurized filtration of sea water filtered through 0.2 µm Acropack filters. A total of 80 samples of different depths from 6 different stations.

3) ΣCO_2: About 200 ml unfiltered sea water samples were collected for ΣCO_2 measurements. A total of 93 samples of different depths were collected from 7 different sampling stations.

4) TOC: About 300 ml seawater were collected for TOC (Total Organic Carbon) Measurements. A total of 85 samples of different depths were collected from 7 different sampling stations.

5) Stable Isotope:60 ml unfiltered seawater were collected for stable isotope measurements. A total of 62 samples of different depths were collected from 7 different sampling stations.

6) ^{14}C: 500 ml unfiltered seawater were collected for ^{14}C measurements. A total of 107 samples of different depths were collected from 7 different sampling stations.

7) pH & Alkalanity: 60 ml unfiltered samples were collected for pH and Alkalanity measurements onboard. A total of 110 samples of different depths were collected from 6 different sampling stations.

8) Salinity: About 300 ml unfiltered sea water samples were collected for salinity measurements onboard. A total of 52 samples of different depths were collected from 3 different sampling stations.

9) ^{234}Th: 4 liters of sea water samples were collected measurements of ^{234}Th isotopes. A total of 55 samples of different depths were collected from 6 different sampling stations.

10) $^{210}Po/^{210}Pb$:12 liters of sea water samples were collected for $^{210}Po/^{210}Pb$ measurements. A total of 40 samples of different depths were collected from 4 different sampling stations.

11) ^{228}Ra: About 100 liters of sea water sample were collected for ^{228}Ra isotope measurements. A total of 16 samples of different depths were collected from 4 different sampling stations.

12) Hf: About 60-100 liters of sea water samples were collected for Hafnium measurements depending on the depth. A total of 28 samples of different depths were collected from 4 different sampling stations.

13) Aerosol: pM 2.5 and pM 10 air samples were collected from High Volume Air Sampler in Quartz filter papers. Filters were collected in two days interval only in sailing conditions. A total 13 numbers of samples were collected from the date 05/03/13 to 08/04/13.

Air samples were also collected in Teflon filters through Staplex sampler with less frequency than pM 2.5 and pM 10. A total of three samples were collected from 15/03/13 to 04/04/13.

14) AIMS: AIMS is a continuous monitoring system for few water soluble major cations and anions. It collects and measures samples with a resolution time of one hour. It has been operating onboard since 03/03/13 till 10/04/13 and will continue upto end of the cruise.

15) PILS: PILS is a aerosol fraction collector. It is also a continuous system with a resolution time of 15 minutes. It has been operating since 03/03/13 till 10/04/13 and will continue till the end of the cruise.

16) Rain Water:Rain water samples were collected whenever available using a funnel system for stable isotope and other miscellaneous measurements. A total of 8 samples were collected during the period 08/03/13 to 08/04/13 in different raining events.

17) Sediment Core: Gravity Corer was used to get sediment cores from different locations. A total 4 numbers of cores were taken from different places in the first leg of SK 304 cruise.

Samples collected by NIO in Leg 1 of SK 304 cruise. Details are given below:-

1) Nutrients: 150 ml of unfiltered sea water samples were collected for nutrients (Ammonia, Nitrite, Phosphate, Silicate and Nitrate) measurements onboard. A total of 131 samples of different depths were collected and measured onboard from 7 different sampling locations.

2) Dissolved Oxtgen: 60 ml of unfiltered sea water samples were collected for dissolved Oxygen measurements. . A total of 131 samples of different depths were collected and measured onboard from 7 different sampling locations.

3) pH & Alkalanity: 60 ml of unfiltered sea water samples were collected for pH and Alkalanity measurements onboard. . A total of 130 samples of different depths were collected and measured onboard from 7 different sampling location

RESULTS

The following figures show results of the onboard measurements made on the various water profiles at each station.

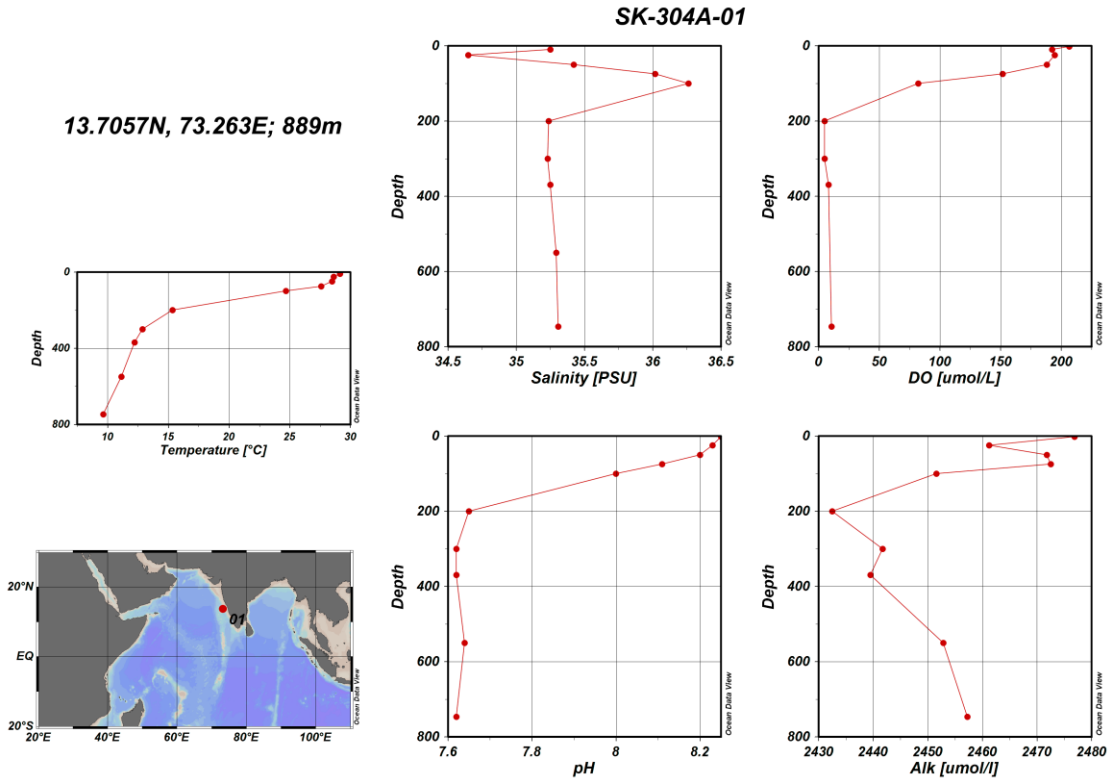


Fig. 3: Variation of temperature, salinity, dissolved oxygen, pH and alkalinity in the vertical profile of seawater column at the station SK-304-01.

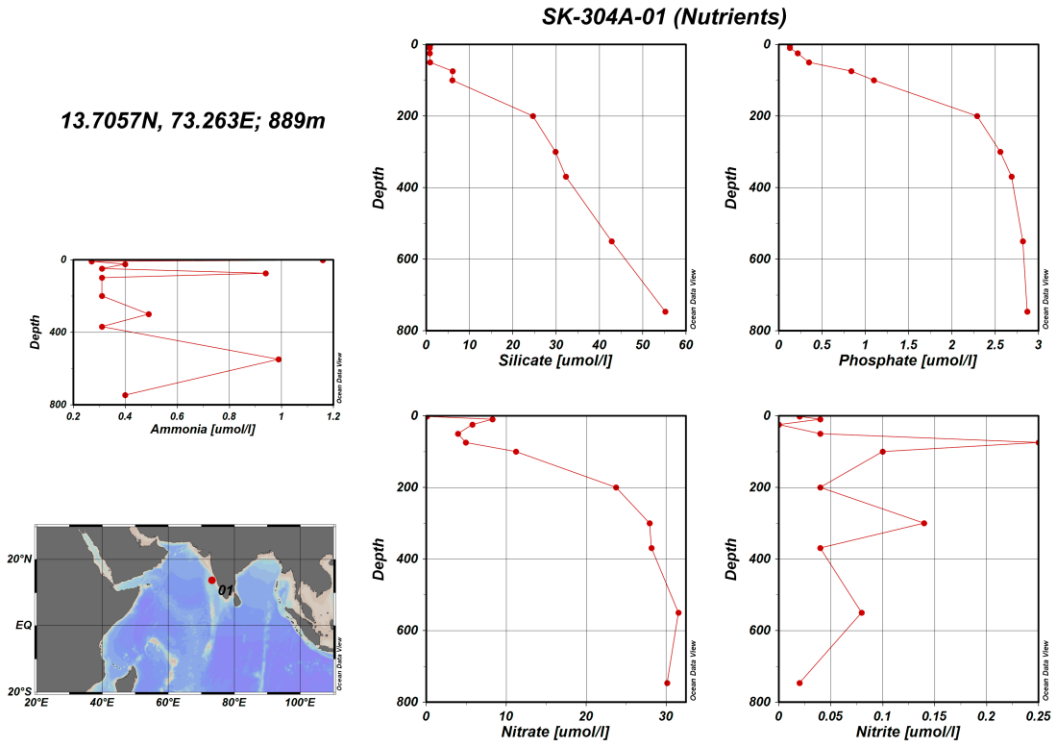


Fig. 4: Variation of nutrients in the vertical profile of seawater column at the station SK-304-01.

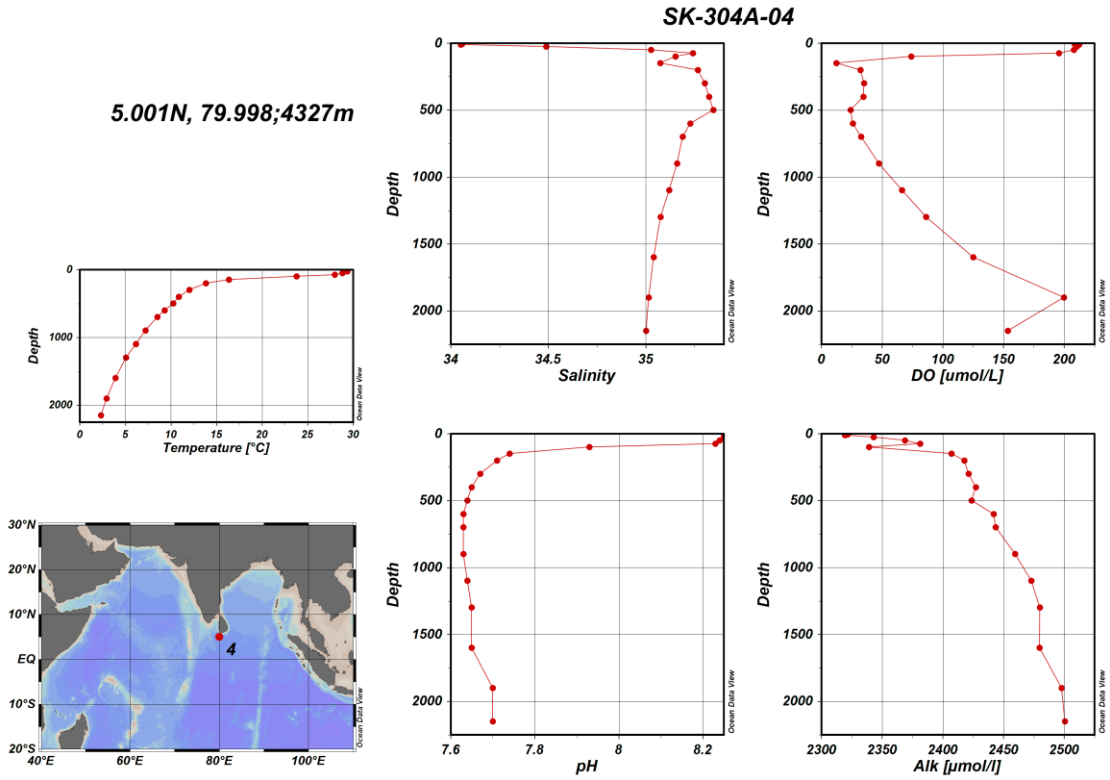


Fig.5: Variation of temperature, salinity, dissolved oxygen, pH and alkalinity in the vertical profile of seawater column at the station SK-304-04.

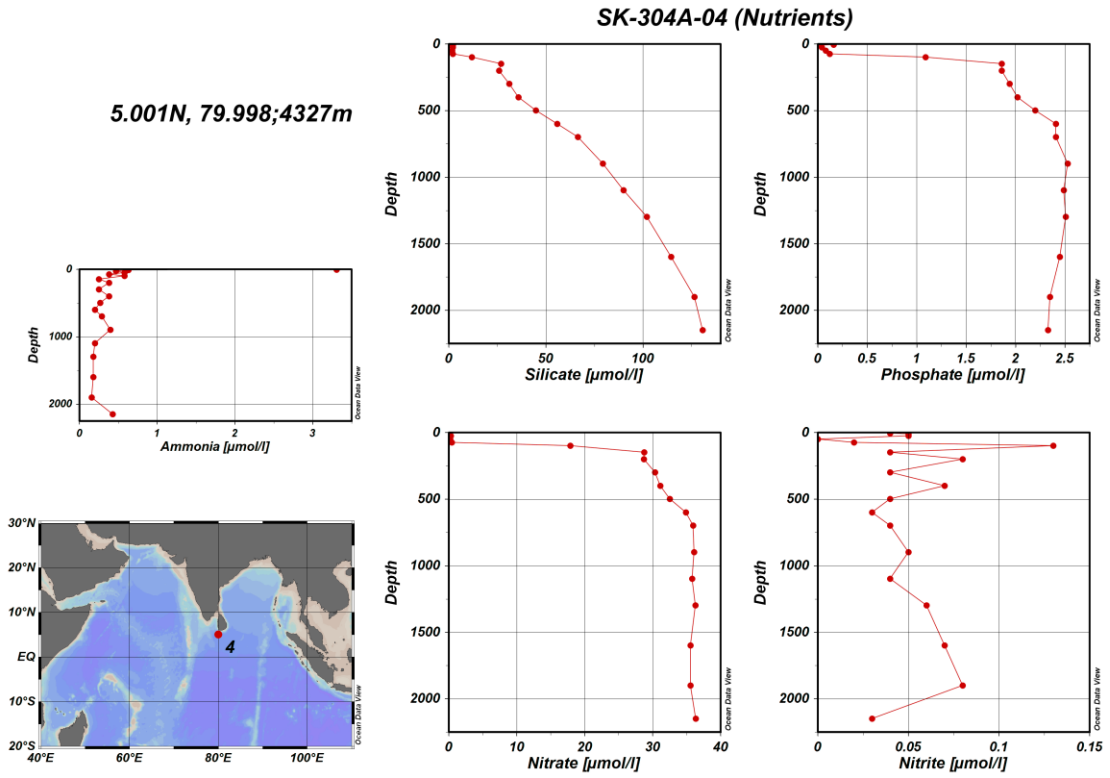


Fig. 6: Variation of nutrients in the vertical profile of seawater column at the station SK-304-04.

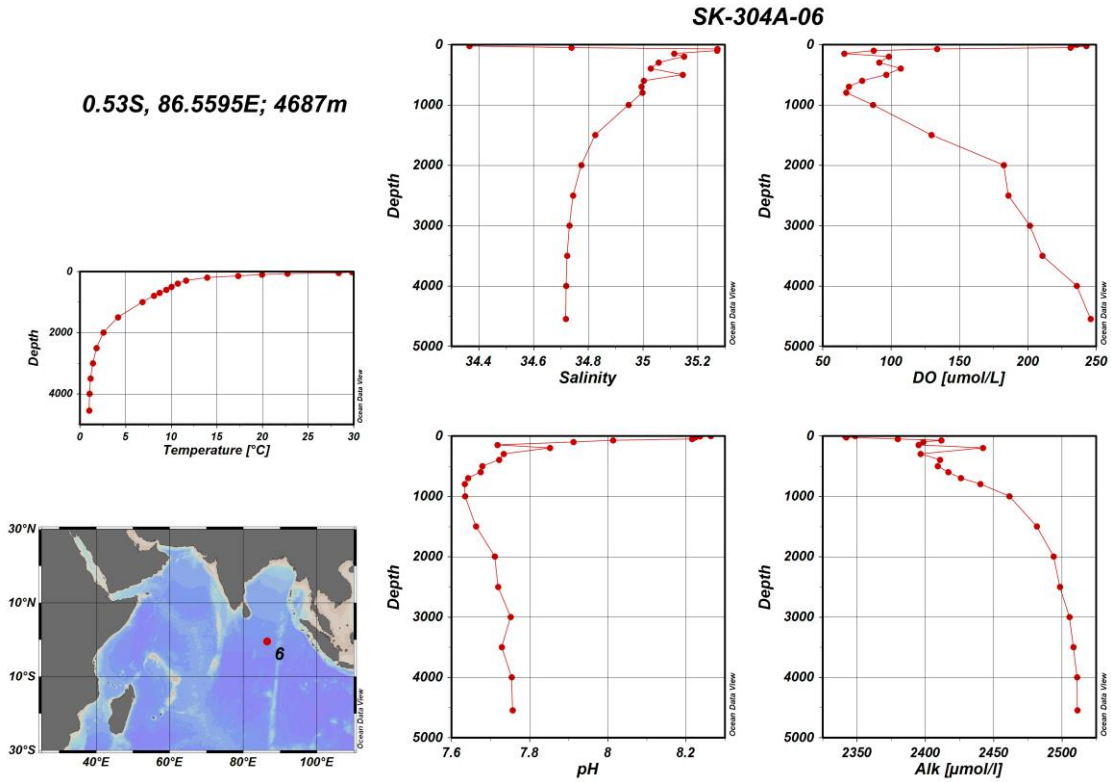


Fig.7: Variation of temperature, salinity, dissolved oxygen, pH and alkalinity in the vertical profile of seawater column at the station SK-304-06.

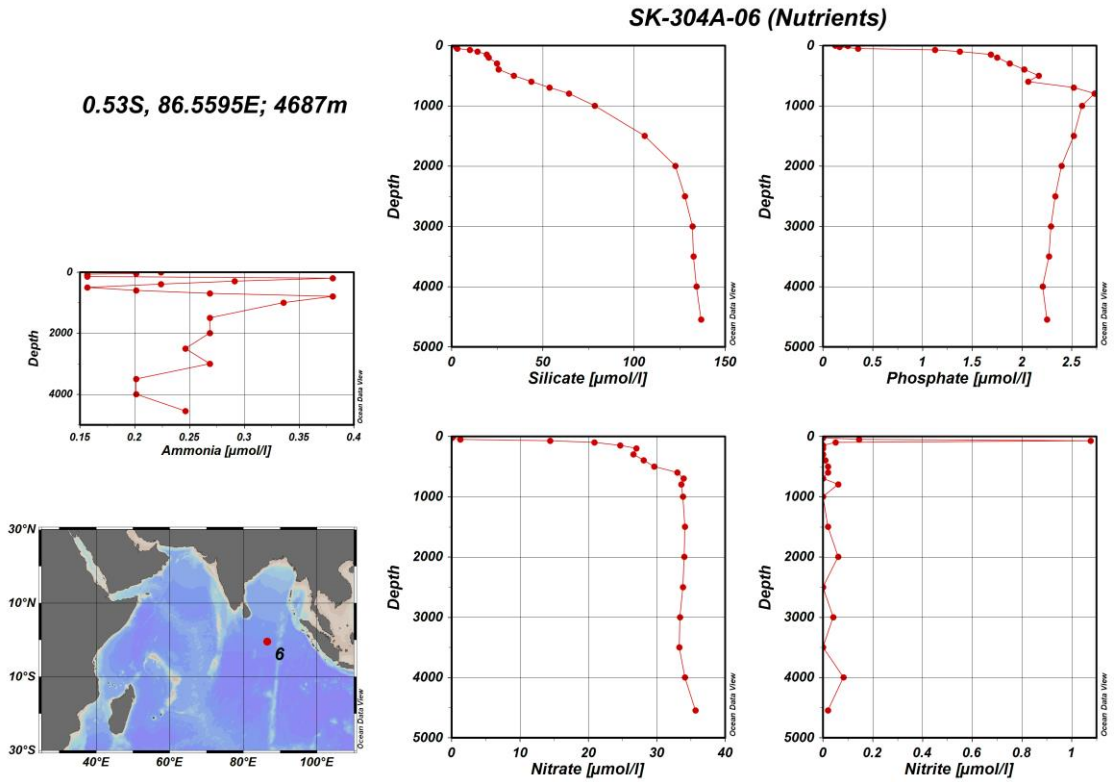


Fig. 8: Variation of temperature, salinity, dissolved oxygen, pH and alkalinity in the vertical profile of seawater column at the station SK-304-06.

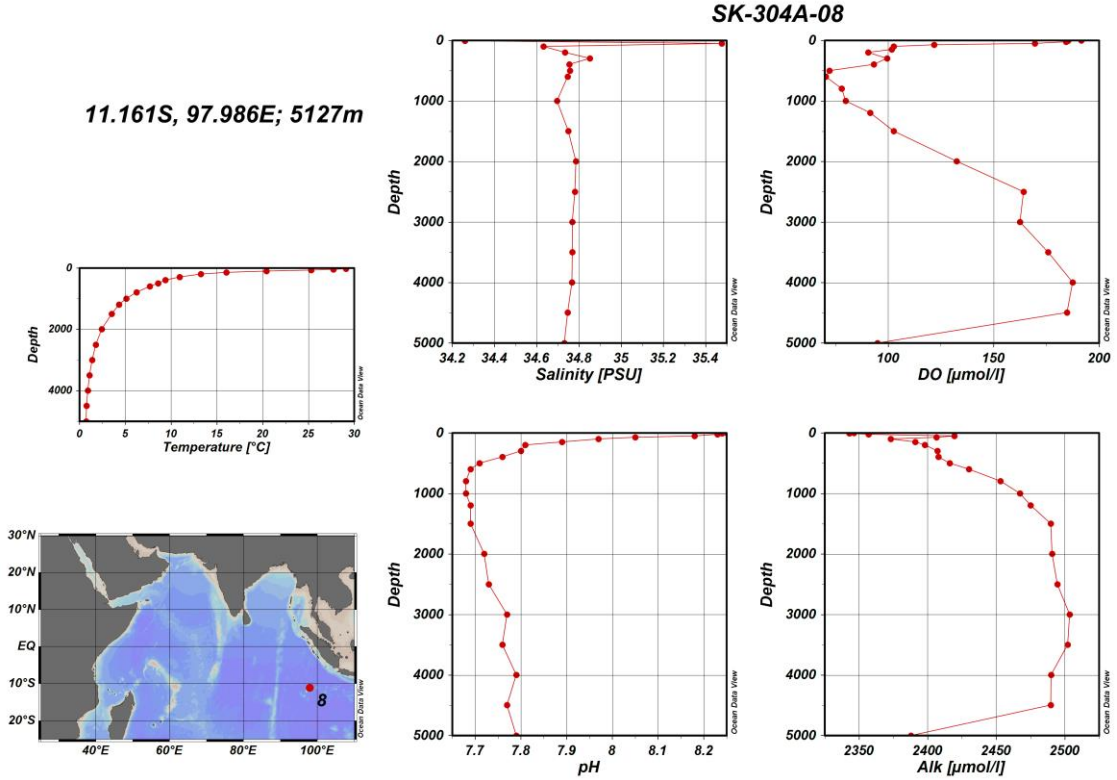


Fig.9: Variation of temperature, salinity, dissolved oxygen, pH and alkalinity in the vertical profile of seawater column at the station SK-304-08.

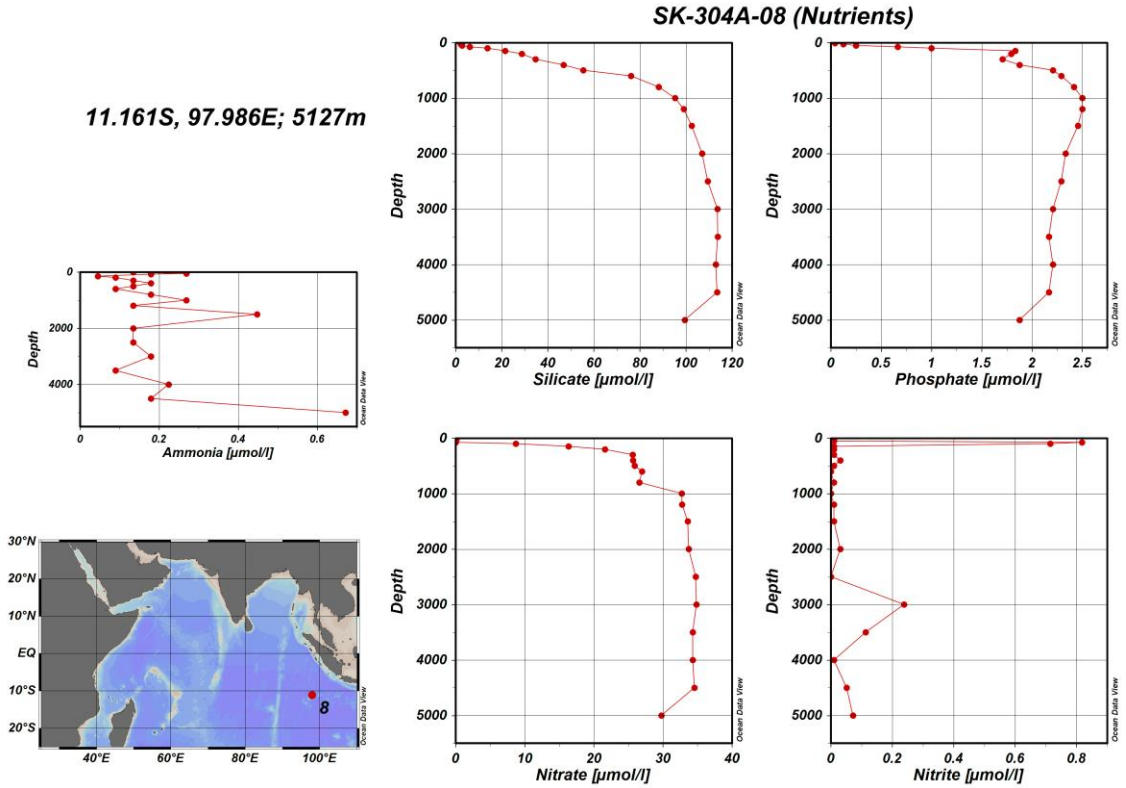


Fig. 10: Variation of temperature, salinity, dissolved oxygen, pH and alkalinity in the vertical profile of seawater column at the station SK-304-08.

SCIENTIFIC OBSERVATIONS

River fluxes: Fresh water influx is the most important external component in the BoB. In addition to the considerable buoyancy introduced to surface waters and to the dissolved load, the suspended sediments react with sea water to initiate desorption-adsorption reactions. Alkaline earths and REEs are also supply a source-specific signature. In this region, nutrients and their cycling, and the influence of metal-organic interactions on them, are important.

Atmospheric input: Perhaps the most important atmospheric input is rainfall that carries particles and aerosols and contributes buoyancy to surface waters. The region does not receive significant Saharan dust flux. However input of continental dust and of rainfall during the monsoon and under the influence of episodic events (cyclones, fires) requires further investigation. Anthropogenic inputs in the form of acid rain are significant.

Productivity controls: Productivity is limited in this region by nutrient supply from river water, SGD and vertical mixing, N_2 fixing and the ballast effect that removes live biomass

to the aphotic zone. In spite of the fact of low biological production and a less intense OMZ compared to the Arabian Sea, intense N_2O production occurs in the BoB shelf waters.

Indonesian throughflow: The Indonesian Throughflow (ITF) represents a major element of global meridional overturning circulation, as warm surface water from the Pacific moves into the Indian Ocean. Part of the ITF water is influenced by sediment-water exchange reactions as it passes over the shallow shelf regions surrounding Indonesia and Southeast Asia. Sources and sinks of TEIs associated with these exchange processes should be quantified. Exchange of water across the Indonesian archipelago between the old Pacific waters and younger Indian Ocean water of different biogeochemical signatures can be constrained by stable isotopes (C, N, O) and radioactive isotopes (^{14}C, Ra)

Residence time of surface water: The BoB is an integrating basin where concentrations are affected by external fluxes and internal recycling. A key parameter in evaluating these effects is the residence time of the surface water.

Deep sediment sources: The Bengal submarine fan extends to 12^{o}S. The deposition of its sediments is modulated by the glacial-interglacial changes over the geological time scale. Paleo depositional and diagenetic proxies of productivity, climate, continental weathering, hydrothermal and geothermal inputs are traceable by the analysis of different inorganic and organic proxies. Sediment cores collected from this region will help in understanding these processes.

ACKNOWLEDEMENTS

I am highly grateful and thankful to Dr. Shailesh Nayak, Secretary, MoES for his generous support and encouragement to the GEOTRACES scientific programme. On behalf of all scientific participants, Master and the ship staff of the cruise SK304 of ORV Sagar Kanya, I would like to profusely thank Dr. Shailesh Nayak for inaugurating the first GEOTRACES Cruise SK-304 from Goa. His presence boosted the spirit of all the cruise participants and would go long way in achieving scientific objectives as part of this national initiative GEOTRACES. I am grateful to Dr. S Rajan, Director NCAOR for his support and encouragement in providing ship time for this cruise. I am thankful to Master and the Ship Staff of cruise number 304 of ORV Sagar Kanya for their onboard help and support during the cruise. The Norinco engineers onboard were very kind and helpful in our various deck

operations, onboard measurements and scientific requirements. I would like to thank Mr. Subramaniam, NCAOR and its ship cell, who took special interest in our scientific requirements for this cruise and were very supportive with respect to our requirements for this maiden GEOTRACES cruise and made appropriate logistics arrangements. And finally, I would like to thank all scientific participants of this cruise from various institutions, who with their hard work and cooperation made this cruise a success.

Annexure - III

Technical Observation and Suggestions

ORV Sagar Kanya Cruise # 304

Observations:

1) Sagar Kanya being an oceanographic research vessel, scientific instruments onboard should be in the best of the working condition. With proper and routine maintenance, these equipments can be kept in best working condition.
2) For a good healthy scientific cruise, it is expected that ship should have a clean atmosphere. The ship is infected with cockroaches and bedbugs. Fumigation of the ship should be done at proper time to avoid inconvenience to participants.
3) The ship being a closed living unit, it is important that air-conditioning should be functioning properly and efficiently, The cooling of AC both in the living area and labs was bad and it needs immediate attention.
4) For oceanographic measurements, seawater line in one of the important component. We could get only one seawater line instead of two with desired pressure. Due to this in the Leg-1 of this cruise, pCO_2 system couldn't be operated. This vessel had seawater line in every lab earlier, but they are all missing.
5) CTD system is one of the basic requirement for any oceanographer. There should be one good working CTD system onboard. Idronaut CTD system presently onboard is not working properly. Except for the bottle tripping mechanism (which was basically from Seabird), no reliable CTD data could be retrieved from it. Sampling done with Idronaut CTD does not have any data. Although, Norinco engineers tried hard to make it working but it was a futile exercise. Immediate requirement for its repair/replacement.
6) Deep Sea winch has serious problem while heaving and it cannot be used in present circumstances, needs immediate repair.
7) Most of the monitoring cameras of CTD/Deep Sea Winch are not functional, they should be made operational for efficient monitoring and operation.
8) There should be strict warning for all cruise participants to clear all the lab spaces, storage areas, fridges, freezers, fumehoods, racks etc soon after they finish their

cruise. Except some specialised samples or equipments which are planned to be used in immediate next cruise. It is noted that many such things are lying in labs used by earlier participants. Ship is not a junk yard where things can be dumped indefinitely causing inconvenience to other cruise participants.

9) Autoanalyser is major tool for any chemical oceanography cruise and if it is not functioning, it should have been mentioned clearly. Could not perform any nutrient measurement onboard.
10) Autosal is not working. We had to use a portable Autosal with low precision (0.02).
11) With scientific participants onboard, there were three blackouts in mid-sea for ship repair work almost extending to 8-10 hours each causing severe inconvenience to all. Such blackouts once in a while may be required for some urgent repairs, but frequent blackouts should be good enough an indicator of the ship problems and its necessity for repair.
12) Chief Scientist cabin networking computer is very slow. No attachments can be downloaded or attached, needs immediate repair.
13) DP was one of the major requirements for this maiden GEOTRACES cruise and it failed within first 2-3 days due to Azimuth Thruster (AT) failure. However, with due attention and efforts of Master and his team, SCI and NACOR, it was repaired within reasonable time for us to use in later part of the cruise. I am thankful to all of them for attending this problem on priority basis during the cruise.
14) Lastly and most important, I have always noticed that most of the major repairs are indefinitely delayed leading to severe damage to the respective equipments. All requirements for repairs/spares etc must be taken care well in advance and routine maintenance be done in time.

Suggestions:

1) Email facility: Since scientists on ship spend significant part of their time on ship, it is important that email connection port (through ship server) be provided in all scientist rooms for sending and receiving emails. Direct email connectivity should be provided to scientists.

2) Internet Facility: For the cruise duration (30-45 days), scientists onboard are totally cut off from any scientific update (new publications), scientific correspondence, paper submission and reviewing, devoid of access to official scientific mails and downloading any scientific data and information. Internet facility for scientists onboard should be provided. In the world of high connectivity, such alienation from connectivity discourages many a good scientist to participate in cruise. Cost of such facility for internet should be negligible compared to that spent for maintenance of ship.
3) Maintenance of scientific equipments is a major concern. The various scientific equipments onboard need routine maintenance to prevent major mishaps.
4) After every cruise, chief scientist's report should be followed up for further repairs, maintenance and replacement required as per his scientific operations. This should be attended immediately after every cruise to avoid inconvenience to future scientific participants.
5) All scientific equipments onboard should be providing quality data and functioning at their best. This could only be possible if routine monitoring (every 4-6 months) by a team of technical experts from leading oceanographic institutes is done routinely.
6) Although, this vessel is 30 year old, with proper maintenance it can serve another 5-10 years. We have sailed on research vessels from other countries RV Hakuho Maru (Japanese, 5 years younger than this) and RV Polarstern (German, 3 years younger than this) are presently in as good as condition as we were 20 year ago with ORV Sagar Kanya.

Annexure – I

SK-304 Participants

Physical Research Laboratory, Ahmedabad

1.	Dr. Ravi Bhushan	Chief Scientist
2.	Dr. R. Rengarjan	Scientist-SE
3.	Dr. Vineet Goswami	Post-Doctoral Fellow
4.	Sh. D Balaji	Project Associate
5.	Sh. J P Bhavsar	Sr. Technical Asst.
6.	Sh. K. Damodar Rao	Research Fellow
7.	Ms. Upasana Banerji	Project Associate
8.	Ms. Sneha Sawant	Project Associate
9.	Sh. Dipjyoti Deka	Project Associate

National Center for Antarctica and Ocean Research, Goa

10.	Ms. Lathika N.	Scientist-B
11.	Mr. Rupesh Sawant	Shipboard Asst.

National Institute of Oceanography, Regional Center, Vishakapatnam

12.	Ms. K.R. Mangala	JRF-Inspire
13.	Sh. R. Viswanatham	PA-II
14.	Sh. G. Srikanth	PA-II
15.	Sh. N. Anil Kumar	PA-II
16.	Sh. D.H. Bardhan	PA-II
17.	Ms. T. Priyadarshini	PA-II

Cochin University of Science & technology, Cochin

18.	Mr. Akhil P.S.	Research Scholar
19.	Ms. Arsha K	M.Sc. Student
20.	Mr. Mrudulag S.S.	Research Fellow

Pondicherry University, Port Blair

21.	Mr. Muruganantham M.	Research Student

Goa University, Goa

22.	Ms. Kalpana Dhiman	Project Fellow

Mangalore University, Mangalore

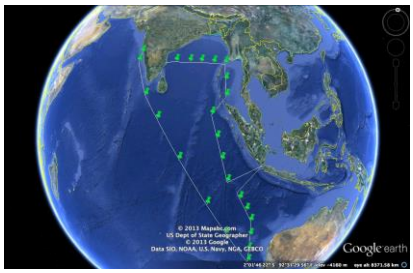
23.	Mr. Naveen Kumar	Project Fellow

Engineers - M/s Norinco Pvt. Ltd

24.	Sh. Biju V. Nair	Service Engineer
25.	Sh. B. Viwanathan	Service Engineer
26.	Sh. Shreejith P. B.	Service Engineer
27.	Sh. I. Vasanthraja	Service Engineer

Annexure-II

NATIONAL INSTITUTE OF OCEANOGRAPHY
REGIONAL CENTRE - VISAKHAPATNAM



GEOTRACES INDIA SECTION-2

CRUISE REPORT

ORV SAGAR KANYA – 304 (Leg 1)

(3rd March to 9th April, 2013)

Biogeochemical observations in the North Western, Central and Southern Indian Ocean

Chief Scientist: *Dr. Ravi Bhushan (PRL)*

Participants:

S.No.	Name	Designation & Place of working
1.	Ms. K.R. Mangalaa	JRF(INSPIRE); NIO-RC, Waltair
2.	Mr. R.Viswanath	PA II; NIO-RC, Waltair
3.	Mr. N.AnilKumar	PA II; NIO-RC, Waltair
4.	Mr. G.Srikanth	PAII; NIO-RC, Waltair
5.	Ms. T.Priyadharsini	PA II; NIO-RC, Waltair
6.	Mr. Harsa Bardhan Dalabehera	PA II; NIO-RC, Waltair

Ships Complement

S. No.	Name	Designation
1	Mr. P.K. Chanan	Captain
2	Mr. Laxman Singh	Chief Officer
3	Mr. Singh Jasbeer	Second Officer
4	Mr. Karunakaran	Catering Officer
5	Mr. Varma Devendra Nath	Chief Engineer
6.	Mr. Rupesh R Sawant	Ship Management

Itenary of the cruise program:

Name of vessel	ORV SAGAR KANYA
Cruise No.	304; Leg 1
Port of Embarkation	Goa
Date & time of Embarkation	3rd March 2013; 16.00 Hrs.
No. of Scientists participated	23
Region	North Western, Central and Sothern Indian Ocean
Operations performed	CTD (Rosette system), Peterson Grab, Zoo Plankton net
Sample type	Water and sediment
Parameters studied	DO, pH, Alkalinity, Carbohydrates, Amino acids and Proteins (CAP), Nutrients, N_2O, CH_4, DIC, DMS, $^{13}C_{DIC,}$ ^{15}N, Particulate Organic Carbon (POC), Total Chlorophyll, HPLC pigments, Primary Productivity, Phytoplankton, Zooplankton, Total Bacterial Count (TBC), Total Viable Count (TVC), Macro Benthos
No. of Stations	7
Name of Chief Scientist	Dr. Ravi Bhushan
Name of Dy. Chief Scientist	Dr. Vineet Goswami

Equipment brought from the NIO, Regional Centre, Visakhapatnam

S. No.	Name (No.)	Made
2.	Potentiometer (2)	Metrohm
3.	Spectrophotometer (2)	Shimadzu
4.	Underway pCO_2 system (1)	General Oceanics
5.	Aspirators (1)	Cole Parmer
6.	C.T.D (2)	Sea Bird
7.	Filteration pumps	Millipore
8.	Vacuum line	

GEOTRACES MISSION:

"To identify processes and quantify fluxes that control the distributions of key trace elements and isotopes in the ocean and to establish the sensitivity of these distributions to changing environmental conditions."

The three main overriding goals in GEOTRACES mission includes,

- Fluxes and processes at the Ocean air interface
- Internal cycling
- Development of proxies for the past change.

STUDY OBJECTIVE:

To fulfil the objective of flux and processes at Ocean interface and internal cycling of nutrients & its isotopes, uptake and regeneration in the surface and subsurface waters, we carried out biogeochemical observations in the water column.

In order to study the biogeochemical cycles in the water column, we collected the water samples for,

- Dissolved Gases (Dissolved Oxygen, Nitrous oxide, Methane, Dissolved Inorganic Carbon, Dimethyl sulphide)
- Inorganic carbon Components (pH, Total Alkalinity, ^{13}C Dissolved Inorganic carbon)
- Nutrients (Nitrate, Nitrite, Phosphate, Silicate, Ammonia and ^{15}N isotopic composition)
- Primary production (^{13}C based primary productivity, Light and Dark bottle method, Triple Oxygen Isotopes)

- Particulate Organic Carbon, Chlorophyll and other pigment analysis, CAP (carbohydrate, Amino acid and Protein)
- Phytoplankton, Total Bacterial Count, Total Viable Count, Bacterio-chlorophyll and Zooplankton.
- Sediment samples also collected for macro benthic study.

Sampling strategy:

Samples for biogeochemical study were collected on board ORV Sagar Kanya (SK 304) from March 3 to April 9, 2013 in the North Western, Central and Southern Indian Ocean. Leg 1 covered 7 transects, two in the Arabian Sea (13^0 44' N and 12^0 23' N), two in the Central Indian Ocean (05^0 00' N and 0^0 31' S) and three in the Southern Indian Ocean (11^0 09' S, 13^0 49' S and 16^0 1' S). Water samples (All Basic parameters) were collected from ~ 24 predetermined depths (near surface, 10 m, 25 m, 50 m, 75 m, 100 m, 150 m, 200 m and thereafter 100 m intervals up to 1000 m and 500 m intervals' up to 5500m depth). Temperature and salinity data were collected using a clean CTD system. Bulk water samples (For all filtration purpose) were collected using general CTD rosette system. In addition to that every one degree samples were collected from surface sea water for limited parameters (Dissolved oxygen, pH, and Alkalinity, DIC, Nutrients, Triple O_2 Isotopes and Particulate Organic Carbon)

Parameters measured on board:

Physical Parameters (CTD Rosette)

1. CTD (Salinity, Temperature, Depth, Density, PAR, Fluorescence, Turbidity Sensor)

Basic chemical Parameters:

1. DO – Metrohm Titrator (Grasshoff et al., 1983)
2. Dissolved Inorganic Nutrients (Nitrate, Nitrite, Ammonia, Phosphate, Silicate) – Manual (Spectrophotometric) (Grasshoff et al., 1983).
3. pH – Titrator (Potentiometric method)
4. Total Alkalinity – Titrator (open cell titration method, SCOR protocols)
5. Real time surface Nitrate from Satlantic Nitrate sensor.

Biological Parameters:

1. Fast repetition rate flourometry (FRRF Sensor) to measure real time Photosynthetic activity.
2. Chlorophyll (Filtration by GF/F, 45mm filter paper)
3. Phaeopigments – HPLC (Filtration by GF/F, 45mm filter paper)
4. Particulate Organic Carbon (Filtration by GF/F pre combusted, 45mm filter paper)
5. Primary Productivity:

a) ^{13}C primary productivity: Samples collected, spiked with known ^{13} C and incubated for 24h. Filtration by using pre-combusted GF/F 45mm filter paper and it was preserved in -20^{0}C.

b) Δ^{17} Anamoly (Triple O_2 Isotopes): Surface samples was collected in pre evacuated glass bottle and equilibrated and samples were extracted in 1ml pyrex tubes. Samples carried to the laboratory for further processes.

c) Light and Dark Bottle: Samples were collected from surface to 100 m depth in 125 ml light and dark glass bottle and incubated for 24 hours in continuous sea water flow. Changes in dissolved oxygen are measured by Winkler's method.

Geological Parameters:

1. Sediment samples were collected and preserved for macro benthic study and texture analysis.

Parameters to be measured off board:

Chemical Parameters:

1. Dissolved Inorganic carbon (DIC)
2. Nitrous oxide
3. Methane
4. Dimethyl Sulfide (DMS)
5. ^{15}N (NO_3 &NH_4)
6. ^{13}C DIC
7. Carbohydrates, Amino acids, Proteins (CAP)

Biological Parameters:

1. Phytoplankton
2. Zooplankton
3. Bacteriochlorophyll
4. Total Viable Count (TVC)
5. Total Bacterial Count (TBC)
6. Depth integrated primary production
7. Particulate Organic Carbon
8. Benthos.

Expected Outcome:

- Understanding the cycles of nutrients is still rudimentary and this study really provides the information regarding the distribution, concentration, isotopic composition and its influence over the primary production and flow of Carbon in the

Ocean. Cycling of these nutrients is the key aspect of Ocean systems, controlling not only the amount of oceanic productivity but also its type and the functions that it performs.

- Fluxes of green house gases and its effects on the biological parameters can be picturized.
- Estimation of CO_2 fluxes provides information regarding the source/ sink of CO_2 and its effects on climate change. The distribution of CO_2 parameters in the Ocean provides better understanding the fate of anthropogenic carbon emission and its effects on increasing global temperature.
- Planktonic production in the ocean is a primary mechanism of global oxygen formation and carbon fixation. For this reason, much attention has been given to estimating the marine primary production. In order to alleviate the problems in traditional methods, a robust method was developed based natural oxygen triple isotopes and ratio of oxygen to argon dissolved in the water. This method gives integrated oceanic productivity in the mixed layer over residence time of oxygen in the water. The value of $^{17}\Delta$ anomaly depends on the ratio of the rates of GOP and the influx of O_2 from the atmosphere. Thus, GOP can be estimated from $^{17}\Delta$ of DO, and influx of O_2. O_2 /Ar ratio provides the information regarding the Net community production.
- The amount of Carbon exported is preciously calculated from Net to Gross production ratio, also gives the metabolic balance of the ecosystem.
- The formation of trace gases and the processes involved in its formation could be revealed, this could be helpful for understanding the quantity of these gases contributed to the atmosphere.
- The fate of Organic carbon is better studied for the first time in this study region, to predict the carbon cycle regionally.

Annexure – III

GEOTRACES CRUISE SK-304 (Leg-1) REPORT SUBMITTED BY CUSAT

Project Title:"Biogeochemistry of Selected Trace Element and their Isotopes (Fe, Zn, Mn and Cu) in the realm of Arabian sea with special reference to Kerala Coast"

Reference No: No.36/OOIS/Siber/07 Dated 09/09/2011

Principal Investigator: Dr.Sujatha C H

Department of Chemical Oceanography,

School of Marine Sciences,

Cochin University of Science and Technology (CUSAT),

Cochin, Kerala,India.

Details of Participants: 1. Akhil P. S, Research Scholar, CUSAT

2. Mrudul Rag S.K, Research Fellow, CUSAT

3. Arsha Krishnan ,M.Sc Student, CUSAT

Objectives

- To examine the sediment-trace metal distribution (Fe, Zn, Mn and Cu) along the cruise track.
- To compare and correlate the data with textural characteristics of the sediment and the Total Organic Carbon.
- To understand the biogeochemistry and quantify the organic content in the study area.

Sampling Details

As part of GEOTRACES cruise we got three surface sediment samples from Arabian Sea.

Sampling locations: 1. $13^0$50' 26.5464''N; 73^0 17' 31.7226''E

2. 12^0 22' 13.2294'' N; 74^0 11' 13.2036''E

3. 9^0 52' 55.9'' N; 75^0 32' 57''E

Participant Activities at onboard

- **Participant Name**: Akhil P S

- ✓ Acquired to deal with clean lab facilities at onboard.
- ✓ Learned about isotopes of Thorium, Polonium and Radium and its application to oceanography and was involved in seawtater sample processing procedure onboard.
- ✓ Had hands on experience on analysis of nutrients using Autoanalyzer onboard.

Present GEOTRACES programme would promote and encourage research and investigations for the study of the sea, particularly the trace elements and their isotopes.

Scientific comprehensions learned from present cruise which will help us to apply our study area (Kerala Coast & Cochin Estuary), and are summarized below:

- ✓ The four commonly used isotopes of thorium (^{234}Th, ^{232}Th, ^{230}Th and ^{228}Th) are produced from the decay of uranium series. Thorium is present in highly insoluble forms and can be rapidly removed via scavenging by particulate organic matter. Therefore, it has been used widely as a tracer of removal rate of particulate from the water column, their fluxes and to calculate POC exported in Upper Ocean.
- ✓ Polonium-210 is a decay product of ^{210}Pb and is produced mainly in the water column, with some atmospheric inputs. High variability in both ^{210}Pb and ^{210}Po in estuaries is generally attributed to remobilization from sediments and formation of organic complexes.
- ✓ Radium makes an excellent tracer in coastal systems because it has a highly particle reactive thorium parent. It can be used to measure ground water inputs to coastal waters and to model residence times in estuary.

❖ **Participants Name**: ***Mrudul Rag S.K*** and ***Arsha Krishnan***

We got a good opportunity to study different scientific instruments onboard, learnt approach for a scientific topic and various experimental work carried out onboard, which includes physiochemical parameters, DO, alkalinity, chlorophyll, POC etc. Acquired knowledge about CTD and its functioning.

- ✓ Had experience of handling Autoanalyzer and Micro Salinometer.
- ✓ Learned about various isotopes of Nd, Hf and Os and sample processing procedure in sea water.

Our purpose of participation was to learn and apply state-of-the-art analytical methods in environmental investigations, which would also provide a forum in which an international community of marine scientists, professionals and students gather to share their work in theme-based series of discussions. The training acquired during the GEOTRACES cruise will encourage and motivate to widen the horizon of knowledge in our future endeavor of science.

Acknowledgements

We are grateful to Dr. Ravi Bhushan and Dr. Sunil Kumar Singh (Chief Scientist, PRL, Ahmadabad), for giving an opportunity to participate in the GEOTRACES Cruise Expedition 2013 organized by Ministry of Earth Science (MoES), Government of India. We specially thank our supervisor and PI GEOTRACES project Dr. Sujatha C.H. for her encouragement and motivation for participation in this first GEOTRACES cruise, which would be very helpful to us in our future scientific research. Our special thanks to Dr. Ramabadran Rengarajan (Scientist-F,PRL). We would like to express sincere thanks to Captain (O.R.V Sagar Kanya), all Cruise members and NORINCO team during the voyage.

Annexure-IV

GEOTRACES CRUISE PROGRAMME ON INDIAN OCEAN – 2013

Chief Scientist: Dr. Ravi Bhushan

1st LEG REPORT

March 3 -April 12, 2013

by

M. MURUGANANTHAM

PONDICHERRY UNIVERSITY

ANDAMAN. 744 112

INTRODUCTION:

The GEOTRACES, an international research program is initiated to study the distribution of trace elements and their isotopes as well as using them as new proxies of paleoenvironment in world oceans. The GEOTRACES program on Indian ocean led by Physical Research Laboratory and sponsored by MoES, New Delhi. Three research institutes PRL, NCAOR and NIO, four universities those are Pondicherry, Mangalore, Goa and Cochin Universities are participating in this program. The oceanographic research vessel ORV Sagar Kanya allocated by MoES for GEOTRACES program, a total of 22 scientists are participating under the guidance of chief scientist Dr. Ravi Bhushan. Sailing started at 3rd march, 2013 from the Goa port.

OBJECTIVE:

In this research program our aim is to study the distribution of living benthic foraminifera in different marine environmental settings, their taxonomy and paleoclimatic study of Andaman and Nicobar Islands by the investigation of stable isotopes from the fossil foraminiferal carbonates. In addition to this, learning the new methodologies for isotope and trace metal analysis, clean sampling and processing in clean lab and general oceanographic techniques are initiated by me.

SUMMARY:

During this GEOTRACES cruise I have collected surface sediments samples by the Pietersen Grab at the depth of 600-700 m, and core samples to study the Foraminifera. I learned the analysis of Thorium-234 isotope from the seawater samples to understand the carbon export flux, under the guidance of Dr. R. Rengarajan (PRL). I have carried out the PILS aerosol sampling for measuring atmospheric soluble Fe and other trace elements. I have observed the CTD operation and sediment coring and I could understand the different distribution of general parameters such as temperature,

salinity, dissolved oxygen and nutrients in ocean water column by the CTD data. I attended all presentations and group discussions and also I gave a talk about the foraminifera and their role in marine environments. The seminars and group discussions helped me to learn various scientific techniques from the other participants.

OBSERVATION:

From surface sediment collected from the Arabian sea at the location near cochin harbour, we observed abnormal growth of a benthic foraminifera Elphidium species, an interesting observation without any microscopic observation. It would provide some interesting results on the foraminifera and the ambient environment. Further study of this species will be carried out in laboratory.

SCIENTIFIC TECHNIQUES LEARNT ONBOARD:

I have learned the beta counting technique for the thorium isotope analysis for carbon flux export study and also I learned the technique of PILS instrument for collecting aerosol samples from the marine atmosphere.

AKNOWLEDGEMENTS:

I would like to thank my research guide Prof. Dr. P M Mohan, Head of the Department of Ocean studies and marine biology, Pondicherry University, Andaman.

I really want to show my gratitude to chief scientist Dr. Ravi Bhushan, first leg of the cruise, for providing me the chance to attend this cruise program and his great advices.

Also I would like to thankful to Dr. R. Rengarajan (PRL) for his guidance to learn about the isotopes and their analysis. As well as I like to thank Dr. Vineet Goswami for his useful advices.

I am happy to share my thanks to all the participants and crew members.

Yours sincerely,

(M. MURUGANANTHAM)

Annexure – V

GOA UNIVERSITY
TALLEGIO, GOA

GEOTRACES INDIA SECTION-2

Cruise Report
By
Ms. Kalpana Dhiman
SK 304 (Leg 1) (3rd March-9th April)

Geochemical study of trace metals in the Coastal Arabian Sea

Chief Scientist

Dr. Ravi Bhushan

Objective of geotraces:

"To identify processes and quantify fluxes that controls the distributions of key trace elements and isotopes in the ocean, and to establish the sensitivity of these distributions to changing environmental conditions".

Objective of my study:

1. To identify and understand the process control the speciation of trace metals in the Coastal Arabian Sea surface sediments.

2. To learn the key parameters involved in the formations of these speciation of metals like nutrients, primary productivity.

3. To investigate influence of external processes, such as river discharge and tides, and internal processes on cycling of trace metals

4. To learn and understand the different methods to estimate the basic parameters of water column like Dissolved Oxygen, pH, total Alkalinity and Dissolved nutrients.

Sampling:

Sediments samples were collected from two location (13^0 44' N and 12^0 23' N) in the Coastal Arabian Sea. These samples are stored in ice and carried to the laboratory for further analysis.

Learned Methods and Parameters on board:

1. Sediment sampling process by gravity corer
2. Water samples collecting from clean CTD
3. Dissolved Oxygen by using Titrator
4. pH and Alkalinity by using Potentiometeric method
5. Dissolved Inorganic Nutrients (Nitrate, Nitrite, Ammonia, Phosphate, and Silicate) by using Spectrophotometric method.

How will use this training programme:

1. This program involves multiple disciplines which are very essential for me to understand the key processes controlling the speciation of trace metals in the study region.

2. Hence, my participation in this program will definitely help me to understand how to link variation in several properties in the coastal area, physical, chemical and biological processes and their relation to the trace metals cycle.

3. After returning from the cruise, I would conduct a systematic and continuous study on from the Arabian coastal sediments with high spatial and temporal resolution.

Annexure-VI

GEOTRACES SK-304 (Leg-1_ CRUISE REPORT

Participant Name: Lathika N
NCAOR, Goa

Objective:

- Assess the relationships between the environmental variables in the water column and the trace metal records in different sediment phases, within Indian Ocean including the major oceanic gateways in Indian Ocean (Indonesian Throughflow & Agulhas Leakage).
- Evaluation of trace metals as proxies of productivity & oceanic processes and constrain new proxies for palaeoceanographic reconstruction.

Work carried out by me during Geotraces Cruise SK304A/GI03

1. **Sampling:**

I was part of the clean sampling team. The sampling was carried out in the clean container van where samples for different trace and isotopic analysis were collected and acidified. These samples were packed for detailed analysis.

2. **Post Sampling:**

- **Basic parameters:**

Nutrients**:**

Different nutrients like phosphate, silicate, nitrate and nitrite were measured using autoanalyser.

Salinity:

Salinity was measured on-board using the instrument salinometer.

- **Neodymium Precipitation:**

Fe-carrier was added in the acidified water samples (around 12 litres). It is kept for 24 hrs and ammonia is added to precipitate Neodymium. After 24 hrs it is filtered and precipitate is collected for detailed analysis.

3. **Rain water collection:**

Rain water is collected along the cruise track. Total 20 samples were collected in the first leg.

Annexure-VII

GEOTRACES CRUISE REPORT-2013

Submitted by Mangalore University

Principle investigator: Dr.BR.Manjunatha, Associate Professor.
Participant: Naveen Kumar A, Junior Research Fellow.

OBJECTIVE:

In this program our aim is to do the mineralogical studies in atmospheric aerosol samples from the Arabian Sea and the Indian Ocean.

As part of GEOTRACES cruise program, I collected 8 numbers of dust sample from the Arabian Sea and the Indian Ocean along the cruise track for the mineralogical studies, which will compliment scientific studies of the GEOTRACES mission.

SCIENTIFIC TECHNIQUES LEARNT ONBOARD**:**

- I had hands-on experience with the micro salinometer and also learned the technique of PILS instrument for collecting aerosol samples from the marine atmosphere.
- I have learnt the sampling techniques employed with the clean lab facility onboard.
- To collect samples for their different chemical and biological studies onboard.
- Learnt sample collection technique and onboard processing for various radioisotopes studies in sea water.

As a beginner in the field of oceanography, this kind of cruise program will help me to improve my knowledge and skills to future research.

AKNOWLEDGEMENTS:

I would like to thank my guide associate Prof. Dr BR Manjunatha, Department of marine geology, Mangalore university. I really want to show my gratitude to chief scientist Dr. Ravi Bhushan, first leg of the cruise, for providing me the chance to attend this cruise program and his great advices. Also I would like to thankful to Dr. R. Rengarajan (PRL) for his guidance to learn about the PILS instrument for collecting aerosol samples from the marine atmosphere. I would like to thank specially Ministry of Earth Science (MoES) for supporting this programme..

Annexure-VIII

THE NAVHIND TIMES
SUNDAY, MARCH 3, 2013

Setting up of world-class GEOTRACES lab at Sada would be major achievement: Nayak

The secretary of Ministry of Earth Sciences, Dr Shailesh Nayak and NCAOR director, Dr S Rajan seen along with the team of other scientists onboard 'ORV Sagar Kanya' before leaving Goa for Indonesia on Saturday.
Sudesh Bhosle | NT

NT NETWORK

VASCO: Claiming that the Ministry of Earth Sciences

Dr Nayak also disclosed that the strength of NCAOR and GEOTRACES has increased four-fold during

J Baig, Mr P K Gangopadhyay, Capt P Chanan and other scientists.

As many as 23 scientists

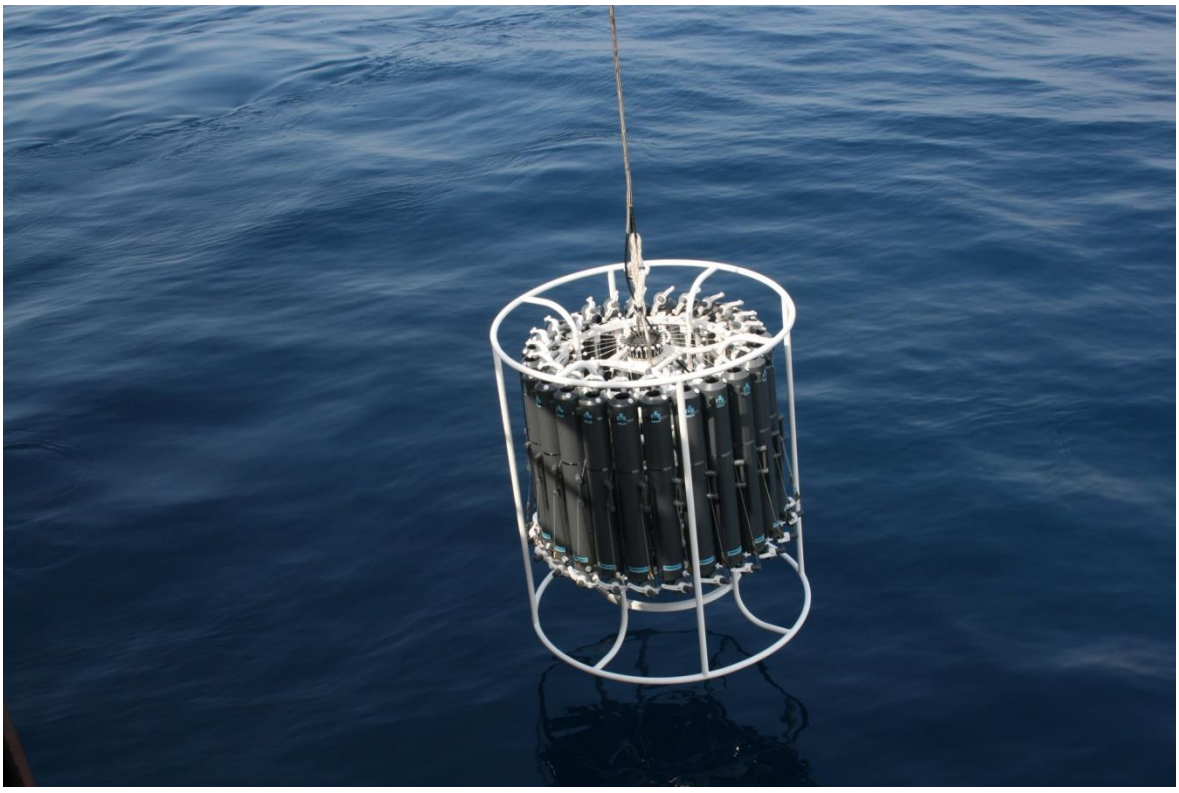
GEOTRACES would boost India's productivity.

Encouraging the scientists' team of NCAOR and GE-

GEOTRACES SK304 cruise participants with Dr. Shailesh Nayak, seceratory, MoES (press report).

Dr. Shailesh Nayak inaugurating the clean van onboard ORV Sagar Kanya (Cruise SK-304).

Clean CTD system with Niskin samplers onboard ORV Sagar Kanya



Clean CTD being deployed for collection of seawater samples

Operating the clean winch system for deployment of clean CTD

Filtration and sub-sampling of seawater samples inside clean van during cruise SK-304 onboard ORV Sagar Kanya.

Annexure-IX

List of Seminars presented in SK-304A

Speaker	Institute	Date	Topic
Dr. Ravi Bhushan	PRL	24/03/13	*GEOTRACES: Study of Trace Elements and their isotopes in Ocean*
Dr. Vineet Goswami	PRL	25/03/13	*Studying the water mass circulation in the Arabian Sea using isotopic tracers*
Ms. Arsha Krishnan	CUSAT	30/03/2013	*Assessment of Heavy Metals Pollution in Cochin Estuarine system*
Ms. Mangala & Mr.ViswanadhamRongali	NIO	30/03/2013	*Biogeochemical Observations in GEOTRACES Cruise program*
Mr.Balaji D	PRL	31/03/2013	*Paleoclimatic Records from the Arabian Sea*
Mr.Muruganantham	Pondicherry University	31/03/13	*Foraminifera And Their Role In Marine Environments*
Ms.UpasanaBanerji	PRL	01/04/2013	*Mid- Late Holocene Sea Level Changes along the Southern Saurashtra coast, Diu: A Preliminary Results*
Dr.R. Rengarajan	PRL	01/04/2013	*Particle Export*
Ms.Lathika Nambiyathodi	NCAOR	10/04/2013	*Glacial Interglacial changes in deep water mass circulation in the Indian sector of Southern Ocean: Investigation through geochemical and sedimentological proxy records*
Mr. Naveen Kumar	Mangalore University	10/04/2013	*An Introduction to Aerosols*
Ms.Kalpana Dhiman	Goa University	11/04/2013	*Coastal issues and management*
Mr.Akhil Pattathu	CUSAT	11/04/2013	*Core sediment Geochemistry in specific zones of Cochin Estuarine System (CES)*