Marine Pollution Bulletin 66 (2013) 59–72

Contents lists available at SciVerse ScienceDirect

Marine Pollution Bulletin

journal homepage: www.elsevier.com/locate/marpolbul

Dinoflagellate cyst assemblages in recent sediments of Visakhapatnam harbour, east coast of India: Influence of environmental characteristics

Maria Shamina D'Silva, Arga Chandrashekar Anil *, Subhash Shivram Sawant

CSIR– National Institute of Oceanography, Dona Paula, Goa 403 004, India

ARTICLE INFO

Keywords:
Dinoflagellate cyst
Sediment
Environmental characteristics
Harmful species
Protoceratium reticulatum
Visakhapatnam harbour

ABSTRACT

The distribution and abundance of dinoflagellate cysts in recent sediments from Visakhapatnam harbour, east coast of India was investigated and compared with sediment characteristics and physico-chemical variables of the overlying water column. The cyst abundance varied from 11 to 1218 cysts g^{-1} dry sediment. Changes in the cyst assemblages from phototrophic to heterotrophic forms were observed from inner to outer harbour stations, and related to changes in environmental characteristics. Enhanced cyst production of potentially harmful dinoflagellate *Protoceratium reticulatum* was recorded in the inner harbour stations with higher nutrient concentrations. *Protoperidinium* cysts were the most diversified group, and were dominant in the outer harbour stations having improved water conditions and circulation. This study points out the potential use of dinoflagellate cyst populations in providing information on environmental conditions.

1. Introduction

Anthropogenic nutrient enrichment of coastal waters is considered as one of the reasons for the increased occurrence of Harmful Algal Blooms (HABs) (Smayda, 1990; Hallegraeff, 1993; Anderson et al., 2002; Glibert et al., 2005). Dinoflagellates are key components of phytoplankton community and contribute to formation of HABs. During their life-cycle, dinoflagellates produce resting cysts which are preserved in the sediment (Fensome et al., 1993). The population of dinoflagellates is influenced by environmental factors such as temperature, salinity, nutrients, turbidity and pollution (Taylor, 1987); and can also form cysts under adverse conditions. Dinoflagellate cysts (referred further in text as dinocysts) in the sediment encode information on the dinoflagellates present in the water column (Dale, 1976; Reid and Harland, 1978). The dinocyst assemblages, which comprise of phototrophic and heterotrophic forms, are important as the two trophic groups have different environmental requirements that are related to their nutrition (Harland et al., 2003) and can be used to characterise physico-chemical conditions in the overlying water column (Devillers and de Vernal, 2000; Godhe and McQuoid, 2003; Pospelova et al., 2004). Studies on dinocyst assemblages have highlighted the importance of cysts to serve as proxies for anthropogenic eutrophication (Thorsen and Dale, 1997; Dale, 1996, 2001; Dale et al., 1999; Matsuoka, 1999; Pospelova et al., 2002, 2004, 2005; Krepakevich and Pospelova, 2010; Shin et al., 2010, 2011).

In order to understand the status of dinocyst assemblages in relation to environmental characteristics, Visakhapatnam harbour, was selected for the present study since it is known to be highly polluted due to discharge of industrial effluents and domestic sewage (Ganapati and Raman, 1973; Raman, 1995). Eutrophication of the waters at this harbour has been investigated over the last 23 years (Raman, 1995). The land-locked situation of the harbour and the limitations of natural flushing processes have largely contributed to exposure of plant and animal communities to environmental pollution stress (Ganapati and Raman, 1973, 1979; Sarma et al., 1982; Raman and Ganapati, 1983, 1986; Raman and Prakash, 1989; Rathod et al., 1995; Kalavati et al., 1997; Tripathy et al., 2005). Impact of organic pollution in this harbour has resulted in periodic outbursts of phytoplankton blooms and fish mortality (Bharati et al., 2001; Raman, 1995). Therefore, observations on dinocyst assemblages from such a habitat can provide an overview of the changing scenario.

No previous survey on dinocysts has been undertaken in Visakhapatnam harbour. The field observations used in the present study was carried out as part of Ballast Water Control and Management Programme, India. The purpose of this study is (1) to evaluate spatio-temporal variation in dinocyst abundance and (2) to determine if the dinocysts preserved in the sediment reflect any environmental changes with respect to the water quality of the harbour.

* Corresponding author. Tel.: +91 832 2450404; fax: +91 832 2450615.
E-mail address: acanil@nio.org (A.C. Anil).

0025-326X/$ - see front matter © 2012 Elsevier Ltd. All rights reserved.
http://dx.doi.org/10.1016/j.marpolbul.2012.11.012

2. Materials and methods

2.1. Description of the study area

Visakhapatnam harbour is a semi-enclosed water body situated in north–east of Andhra Pradesh state, east coast of India (17°41′N; 83°18′E). The harbour area extends 4 km from north–western arm of inner to the outer area of the harbour. The inner harbour area is a land-locked area which consists of naturally protected entrance channel, turning basin and three navigable arms (northern, western and north–western arm). Whereas, the outer harbour area has access to the open sea (Bay of Bengal) through the entrance channel and has a protected basin with two breakwaters. There are 18 and 6 berths in the inner and outer harbour area with two moorings respectively. The climate in Visakhapatnam is governed by its location in the tropics and mainly affected by seasonal monsoons (south–west and north–east). There is inadequate tidal flushing and stagnant conditions prevailing in Visakhapatnam harbour (Sarma et al., 1982; Raman, 1995).

2.2. Sampling strategy

Sampling was carried out on four occasions in January 2007 (post-monsoon: PoM), November–December 2007 (north-east monsoon: NEM), April 2008 (pre-monsoon: PrM) and August 2008 (south-west monsoon: SWM) in Visakhapatnam harbour. Twenty-four stations were selected that included berths, wharf, dry docks, jetties and fishing harbour (Table 1). The sampling area was classified based on geographic location and environmental characteristics into two zones; the inner (Stations 1–13) and outer (Stations 14–24) harbour stations (Fig. 1).

2.3. Sediment sampling, processing and analysis for dinocysts

Sediment samples were collected in triplicates using a van Veen grab with a grabbing area of 0.04 m^2. Through the top windows of the grab, undisturbed sediment cores (20 cm long PVC corer with an inner diameter of 2.5 cm) were retrieved. Cores were sealed with airtight caps, stored in dark and kept in ice. After transportation to the laboratory, sediment cores were sectioned at 2 cm interval and stored in airtight plastic bags at 4 °C in the dark until further analysis.

For dinocyst analysis, top fraction (0–2 cm) which represents recent sediment was palynologically processed (Matsuoka and Fukuyo, 2000). Each sediment sample was acid-treated (10% HCl and 40% HF), sonicated and sieved through 100 and 10 μm mesh-sizes. The residue retained on the 10 μm mesh was transferred into a vial and suspended in 10 mL of distilled water. Aliquots of 0.5–1 mL of the processed samples were diluted to a total volume of 2.5 mL in a petridish (diameter 3.8 cm) and scanned under an inverted Olympus IX 71 microscope at 100–400 times magnification. Dinocysts were identified based on published descriptions (Bolch and Hallegraeff, 1990; Nehring, 1997; Sonneman and Hill, 1997; Godhe et al., 2000; Orlova et al., 2004). The cyst abundance was expressed as number of cysts g^{-1} dry sediment. The water content was calculated according to the formula given by Matsuoka and Fukuyo (2000).

For Scanning Electron Microscopy (SEM), the cyst samples were collected on Nucleopore polycarbonate filters (3 μm), dehydrated in increasing concentrations of ethanol series and freeze-dried. The filter was mounted on stubs, sputter-coated with gold and observed with JEOL, JSM 5800 LV Scanning Electron microscope.

2.4. Water and sediment parameters

Water samples were collected with a 5-L Niskin sampler. Temperature, pH and salinity were measured using multiparameter portable instrument (Merck 340i). Dissolved oxygen (DO), chlorophyll *a* (Chla), suspended particulate matter (SPM) and nutrient concentrations of nitrite (NO_2–N), nitrate (NO_3–N), ammonia (NH_4–N), phosphate (PO_4–P) and silicate (SiO_3–Si) were estimated by standard procedures (Parsons et al., 1984). Transparency was measured through secchi-disc at all stations sampled.

In addition, sediment samples were also collected using a van Veen grab for sediment texture, total carbon, inorganic carbon and total nitrogen analysis. The sediment texture was analysed by standard wet sieving and pipette analyses and expressed as percentage

Table 1
Details of station location, water depth, sediment texture, organic carbon (C_{org}), total nitrogen (%), organic carbon and nitrogen (C_{org}:N) molar ratio and nutrient index at 24 sampling stations (stations 1–13 are inner harbour stations and 14–24 are outer harbour stations) in Visakhapatnam harbour, east coast of India.

Station No.	Station name	Latitude (N)	Longitude (E)	Water depth (m)	Sediment texture	Corg (%)	TN (%)	C_{org}:N molar ratio	Nutrient index
1	West quay berth-1	17.695	83.284	10.8	Silt-sand	12.66	0.35	41.57	4.13
2	West quay berth-4	17.700	83.283	12.4	Sand-silt	47.60	0.64	40.94	5.74
3	East quay berth-9	17.707	83.285	11.9	Silt-sand	3.57	0.16	26.03	7.16
4	East quay berth-7	17.703	83.286	12.6	Silt	3.96	0.17	27.49	7.43
5	East quay berth-5	17.700	83.285	11.2	Sand-silt	11.18	0.49	35.16	4.76
6	East quay berth-1	17.693	83.285	11.7	Silt-sand	5.73	0.16	37.65	4.29
7	Turning basin	17.690	83.283	13.4	Sand-silt	1.72	0.05	37.81	4.24
8	Hindustan Shipyard-2	17.690	83.279	6.9	Silt-sand	10.34	0.56	20.13	3.95
9	Fertilizer wharf	17.692	83.274	11.2	Silt-sand	2.34	0.09	17.99	5.17
10	Oil refinery berth-2	17.692	83.277	12.1	–	1.60	0.06	23.20	3.82
11	Port dry dock	17.686	83.286	4.3	Sand-silt	7.52	0.22	39.88	3.74
12	Boat basin berth-3	17.686	83.289	10.2	Silt-sand	4.95	0.16	34.29	3.46
13	Deputy conservator jetty	17.686	83.292	6.9	Sand	1.78	0.04	52.50	3.82
14	Dredger berth	17.686	83.296	10.6	Sand	15.29	0.36	24.78	3.42
15	General cargo berth-south	17.687	83.298	15.4	Sand	1.93	0.05	45.03	3.15
16	General cargo berth-north	17.689	83.299	17.1	Sand	10.74	0.23	54.48	3.13
17	Ore berth-1	17.688	83.301	18.8	Sand	3.47	0.09	44.98	3.10
18	Ore berth-2	17.690	83.300	15.9	Sand-silt	1.42	0.04	39.34	3.07
19	Container berth-2	17.691	83.301	15.6	Silt-sand	3.86	0.15	30.02	3.01
20	Container berth-1	17.689	83.303	15.9	Silt	4.47	0.16	31.41	3.06
21	Turning circle	17.685	83.303	18.2	Sand	1.29	0.07	21.50	3.19
22	Oil berth	17.681	83.306	16.8	Sand-silt	2.07	0.12	20.25	3.00
23	Liquefied petroleum gas berth	17.684	83.298	17.2	Silt-sand	2.16	0.09	30.68	3.20
24	Fishery jetty	17.694	83.306	5.7	Sand-silt	1.49	0.10	17.94	3.17